Initiative for Climate Action Transparency - ICAT -

Evaluation of historical sectoral emissions and possible trends of the pilot states

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Deliverable #4

AUTHORS
Emilio Lèbre La Rovere
Carolina Burle Schmidt Dubeux
Bruna Silveira Guimarães
Erika Carvalho Nogueira
Centro Clima/COPPE/UFRJ

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Acronyms

AFOLU	Agriculture Forests and Other Land Use
ANEEL	National Electric Energy Agency
CBC	Centro Brasil no Clima
CDM	Clean Development Mechanism
COPAM	Environmental Policy Council in Minas Gerais
FBMC	Brazilian Forum on Climate Change
FRMC	Rio Forum on Climate Change
FTP	Force Prevention Task
GDP	Gross domestic product
GHG	Greenhouse Gas
GWP	Global warming potential
IBGE	Brazilian statistic agency
INEA	Environment state agency in Rio de Janeiro
IPCC	Intergovernmental Panel on Climate Change
IPPU	industrial processes and product use
LULUCF	Land Use, Land-Use Change, and Forestry
MCTIC	Ministry of Science, Technology, Innovations and Communications
MME	Ministry of Mines and Energy
MRV	Measuring/monitoring, reporting and verification
NDC	Nationally Determined Contribution
PEMC	Rio de Janeiro State Plan for Climate Change
PEMC	Minas Gerais Energy and Climate Change Plan
SEAS	Rio de Janeiro State Secretariat for the Environment and Sustainability
SEEG	Greenhouse Gas Emissions Estimation System

Introduction

Centro Brasil no Clima (CBC), with technical support from Centro Clima/COPPE/UFRJ, and institutional support from the Brazilian Forum on Climate Change (FBMC), has already completed the first phase of a project establishing indicators to monitor the implementation of Brazilian NDC[1]. This second phase focuses on the MRV (measuring/monitoring, reporting and verification) process of Brazilian NDC at the subnational level. It will be based on the key achievements and lessons learned, from a technical point of view, in the first phase of the ICAT project.

In the first phase, the ICAT Brazil Project had the objective to develop a methodology to estimate the effect of different sets of mitigation actions (grouped in mitigation scenarios) in terms of avoided GHG emissions to help MRV of the progress achieved in the implementation of quantified commitments of the Brazilian NDC. To do so, the project elaborated three types of indicators: absolute emission indicators, emission driver indicators and intensity indicators.

To broaden national efforts toward the achievement of the NDC targets, the ICAT Brazil phase 2 project will help subnational governments to understand how they can contribute to achieving the NDC commitments, prioritizing the development of actions and capacities at the state level. This new phase will build on the first phase of the ICAT Brazil project and will provide sets of state-level MRV indicators, promoting a sectoral mitigation approach to be implemented across the country. At the same time, the project will support stakeholders, such as the Ministry of Science, Technology, Innovations and Communications (MCTIC), local governments and civil society, in the task of monitoring and reporting Brazilian emissions and mitigation efforts.

For this purpose, the project will engage with three states as pilot cases. Following a kick-off workshop involving stakeholders from many states, Rio de Janeiro, Minas Gerais, and Amazonas were those selected as pilot case studies. The aim of the pilot cases is to develop a process for estimating their potential contribution to the NDC and to develop emissions indicators to monitor their emissions trajectories.

This report presents an assessment of historical sectoral emissions and possible trends in the states of Rio de Janeiro, Minas Gerais, and Amazonas (Output 4 of the project). This assessment is based on information provided by the state administrations in the case of Rio de Janeiro and Minas Gerais. For the Amazonas State, the values used come from the SEEG (Greenhouse Gas Emissions Estimation System) database. Therefore, although there was an attempt of standardization of information, the approach used in each state was adapted to the specificities of the available information.

It is important to highlight that the indicators were elicited from data obtained in the inventory reports carried out by the states themselves in the case of Rio de Janeiro and Minas Gerais. In some exceptions, we used data from public databases, like the Brazilian Statistic Agency (IBGE) or the SEEG (Greenhouse Gas Emissions Estimation System), which provide GHG emissions for states. In the case of Amazonas, all data are from SEEG.

[1] Indicators for Progress Monitoring in the Achievement of NDC Targets in Brazil, ICAT/Centro Clima/CBC (2019).

1 State of Rio de Janeiro

This section focuses on the state of Rio de Janeiro, describing its historical emissions and assessing its emissions trends.

1.1 Commitments assumed by the State of Rio de Janeiro

Due to growing concerns about climate change, different sectors of society are adopting measures that can reduce its environmental, social and economic impacts. Several actors, including state governments, have begun to quantify and monitor their greenhouse gas (GHG) emissions. In addition, some of them have adopted climate policies aimed at reducing emissions, such as the state of Rio de Janeiro.

The Law no. 5690, of 14 April 2010, institutes the State Policy on Global Climate Change and Sustainable Development in the state of Rio de Janeiro and takes other measures. This law establishes principles, objectives, guidelines and instruments applicable to prevent, reduce and adapt the state to climate change, for the benefit of current and future generations, as well as to facilitate the implementation of a low carbon economy through measures to mitigate GHG emissions.

The Decree no. 43216, of September 30, 2011, regulates the State Policy on Global Climate Change and Sustainable Development and establishes targets for the reduction of greenhouse gas (GHG) emissions for the 2030 horizon. The mitigation goals as originally published in the Decree are as follows:

- General mitigation target: carbon intensity of GDP in 2030 below 2005 level;
- Sectoral mitigation goals[2]:
    - Sewage: reduction of 65% in 2030 compared to 2005 (kg CO_2e/inhab./year);
    - Solid waste treatment: reduction of 65% in 2030 compared to 2005 (kg CO_2e/inhab./year);
    - Transport: 30% reduction in 2030 compared to 2010 (kg CO2e/year); and
    - Public sector energy consumption: 30% reduction in 2030 compared to 2005
    - (kg CO_2e/year).

The State Decree no. 45892, of January 18, 2017, instituted the management group for the elaboration of the State Plan for Mitigation and Adaptation to Climate Change for the consolidation of a low carbon economy in agriculture in the state of Rio de Janeiro, the ABC-RJ Plan.

The Decree no. 46912, of January 24, 2020, institutes the Rio Forum on Climate Change (FRMC), which will function with material and administrative support from the State Secretariat for the Environment and Sustainability (SEAS), as a consultative entity, having the objective of monitoring the State Plan for Climate Change (PEMC, 2012), and engaging society and the State Government of Rio de Janeiro in the discussion and support for the phenomenon of global climate change.

As mentioned above, the State Policy on Global Climate Change and Sustainable Development was launched in 2010, thus prior to the Brazilian NDC pledges (2015). After that, some policies have been introduced with other main objectives, but they also contribute to the mitigation of GHG emissions. These policies are:

[2] With units as in the decree.

- The Environment State Agency (Inea/RJ) resolution no. 43 (2011) – disposes on the presentation of a greenhouse gas declaratory questionnaire for environmental licensing purposes in the state of Rio de Janeiro
- INEA resolution no. 64 (2012) – disposes on the presentation of a verified by third party greenhouse gas emissions inventory for environmental licensing purposes in the state of Rio de Janeiro.
- INEA resolution no. 65 (2012) – requires a plan for mitigating greenhouse gas emissions for environmental licensing purposes in the state of Rio de Janeiro.
- Law no. 7122 (2015) – institutes the state policy to foster solar power use.
- Law no. 7307 (2016) – disposes on the use of solar energy and rainwater, in sports arenas and stadiums, in the state of Rio de Janeiro.
- Law no. 8151 (2018) – institutes the Reverse Logistics System for Packaging in the State of Rio de Janeiro, in accordance with the federal law no. 12305 (2010).
- Law no. 8538 (2019) – institutes the State Policy for Ecological Restoration and authorizes the Government to create the State Plan for Ecological Restoration.
- Resolution SEAS (State Secretariat for the Environment and Sustainability) no. 13 (2019) – regulates the Declaratory Packaging Act and the Goals and Investment Plan established by the Reverse Logistics System for packaging. It is an instrument provided for in Article 11 of State Law no. 8151 (2018).

1.2 GHG emissions inventory – methodology and structure

The Rio de Janeiro State GHG Emissions Inventory used the methodology described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and the GWP of the Fifth Assessment Report – AR5 (IPCC, 2013). To better reflect the concept of “responsibility for emissions” the concept of “scopes” of the GHG Protocol was adopted. It was also the opportunity to standardize the approach of the state inventory to that adopted by INEA (State Environment Agency – Resolution no. 64 of December 12, 2012), which provides for the presentation of a GHG inventory by sources requesting environmental licenses, using the GHG Protocol Standard.

The inventory is divided into sectors, according to the IPCC methodology (2006), as follows:

1. Energy – emissions due to the burning of fuels in the energy transformation, residential, commercial, public, agricultural, transportation and industrial sectors, and fugitive emissions from the oil, gas and coal industry. Emissions from the reduction process in steel mills with mineral coke and the use of fuels as a raw material in the chemical industry were considered in the sector of industrial processes and product use (IPPU);

2. Industrial Processes and Use of Products (IPPU) – emissions resulting from productive processes in industries that are not the result of the energy use of fuels. The segments considered are mineral, chemical and metallurgical industries, in addition to the use of products;

3. Agriculture, Forests and Other Land Use (AFOLU) – emissions and removals resulting from variations in the amount of carbon in biomass from areas with vegetation. Emissions due to enteric fermentation of cattle, manure management, agricultural soils, rice cultivation, sugar cane burning, use of nitrogen fertilizer, application of lime and dolomite and use of urea; and

4. Waste – emissions from the disposal of solid urban, industrial and health waste and from the treatment of urban and industrial sewage/wastewater.

The sectoral structure for estimating GHG emissions and removals, as well as the subsectors and categories are shown in Figure 1. It is noteworthy that the report used the 2006 IPCC guidelines structure to estimate the emissions, as above. However, the structure of the report is rearranged into the economic sectors shown in the legend of Figure 1.

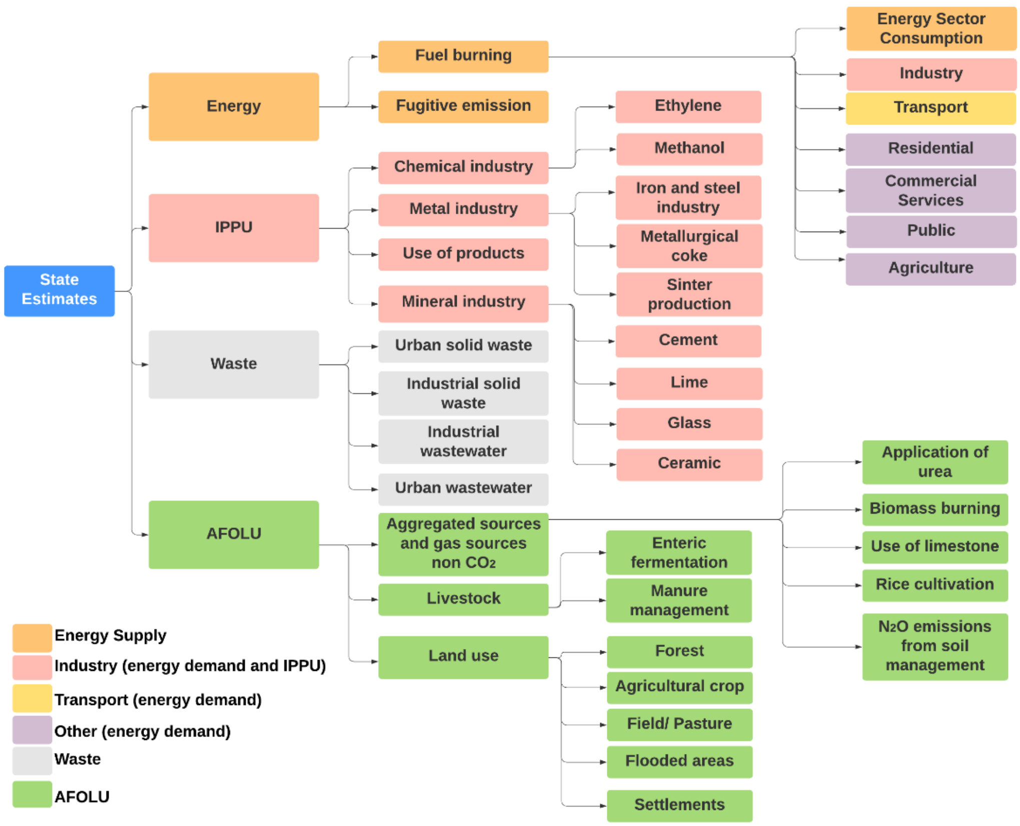

Figure 1. Structure of the Inventory of the State of Rio de Janeiro
Source: Authors

With respect to scopes, emissions were accounted for in scope 1 (emissions that occurred in the state territory), in scope 2 (generation emissions from electricity imported from the national grid) and in scope 3 (emissions from some traceable sources that occurred outside the state territory due to the state's activities in its territory). Scope 3 emissions were not added to the total and are only informative.

Emissions reported using the structure of the economy sectors attributed Scope 1, 2 and 3 emissions to the sectors responsible for them. Therefore, emissions from electricity generated in scope 1 were attributed to the energy supply sector and emissions in scope 2 were distributed among the sectors that consumed the electricity from the grid. Scope 3 emissions, like Scope 2, were informed in the sectors responsible for them. For example, emissions from the production of imported clinker were informed in the cement sector.

The inventory accounts for emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), in 2015. In addition, a review of the 2005 and 2010 inventories was carried out for the purpose of standardization and comparison (Table 1).

Table 1. Greenhouse gases accounted for in the Inventory of the State of Rio de Janeiro, by sector

Sector	Energy	Industrial	AFOLU	Waste
Gases	CO_2	CO_2	CO_2	CO_2
	CH_4	CH_4	CH_4	CH_4
	N_2O	N_2O	N_2O	N_2O
		SF_6		
		C_2F_6		
		CF_4		
		HFCs		

Source: RJ State GHG Inventory

1.3 GHG emissions from the State of Rio de Janeiro (2005-2015)

1.3.1 Evolution of total emissions

Total emissions reached 92.690 Mt CO_2e[3] in 2015, a growth of more than 40% between 2005 and 2015. The share of the energy sector continued to increase during the period and reached 75.7% of the total emissions in 2015, as shown in Table 2 and Figure 2. They present the estimates in the same structure provided by the 2006 IPCC Guidelines for GHG National Inventories (IPCC, 2006).

Table 2. Emissions of the State of Rio de Janeiro, by the IPCC sectors, in the period 2005-2015 (Mt CO_2e and %)

Sector	2005		2010		2015		2005-2010 variation	2010-2015 variation	2005-2015 variation
	Mt CO_2e						%		
Energy*	38.919	58.90%	51.082	67.60%	70.203	75.70%	31.30%	37.40%	80.40%
IPPU	9.381	14.20%	11.579	15.30%	12.476	13.50%	23.40%	7.70%	33.00%
AFOLU	11.189	16.90%	4.823	6.40%	4.556	4.90%	-56.90%	-5.50%	-59.30%
Waste	6.638	10.00%	8.093	10.70%	5.456	5.90%	21.90%	-32.60%	-17.80%
Total	**66.126**	**100,0%**	**75.578**	**100.00%**	**92.69**	**100.00%**	**14.30%**	**22.60%**	**40.20%**

* includes scope 2 emissions (from the use of the national electricity grid)
Source: RJ State GHG Inventory

[3] 92.8% of total emissions are scope 1 and 7,2% scope 2. Scope 3 emissions are considered only for information purposes but not included in the total.

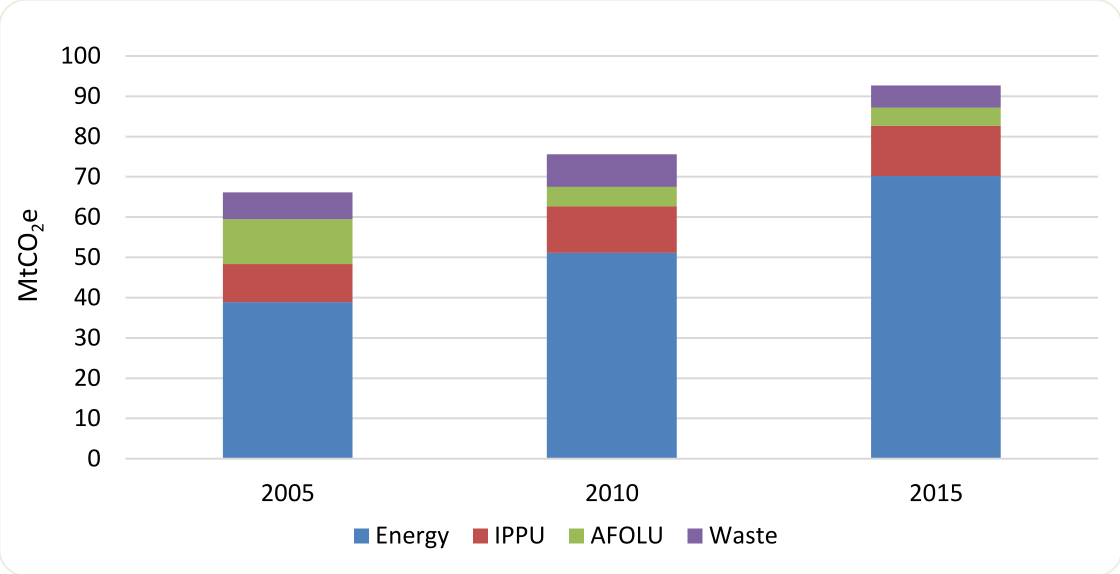

Figure 2. Emissions of the State of Rio de Janeiro, by the IPCC sectors, in the period 2005-2015 (Mt CO_2e)
Source: RJ State GHG Inventory

1.3.2 Evolution of sectoral emissions

This section presents the results of the inventory using a different structure from that provided by the IPCC. 2006 (see Figure 1). This is due to the fact that detailed emissions (by subsectors) in the original inventory report are presented using the structure of the IPCC (2006) only for the year 2015. The section in the report where 2005 and 2010 emissions are also detailed uses the economic sectors instead. Therefore, it presents emissions on the energy supply side and on the energy demand side, such as transportation, industry (also including process emissions) and other energy demand sectors, such as residential, agriculture and services (commercial and public). The other sectors (AFOLU and waste) follow the original structure of the IPCC (2006).

a. Energy Supply

The energy sector as presented in the state inventory comprises the transformation centers – public service power plants, self-produced electricity, coke plants, coal plants, natural gas processing units and oil refineries – and the activities of production, exploitation and transportation of oil and gas. Emissions from fuel consumption and fugitive emissions are also considered. There is a substantial increase in emissions from thermoelectric generation and in the consumption of the energy sector itself in all the years analyzed, as can be seen in Table 3.

Table 3. Emissions from the Energy Supply Sector of the State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources		2005	2010	2015	2005-2010 Variation	2010-2015 Variation	2005-2015 Variation
		Mt CO_2e			%		
Transformation Centers	Electricity Generation	5.9	10.5	20.6	78.0%	96.2%	249.2%
	Charcoal	0.002	0.001	0.004	-50.0%	300.0%	100.0%
	Coke	1.64	1.61	1.39	-1.8%	-13.7%	-15.2%
Fugitive	Oil and gas E&P	5.58	6.62	6.45	18.6%	-2.6%	15.6%
	Oil and gas transportations	0.563	0.62	0.614	10.1%	-1.0%	9.1%
	Oil and gas refining and processing	0.039	0.036	0.034	-7.7%	-5.6%	-12.8%
Final consumption	Energy sector consumption	4.99	6.42	10.7	28.7%	66.7%	114.4%
Total		18.7	25.8	39.8	37.9%	54.2%	112.6%

Source: RJ State GHG Inventory

Emissions from power generation and the from the energy sector consumption are presented by energy sources, whether transformed or consumed, in Figures 3 and 4. In both cases and in all the years analysed, natural gas is the most responsible for emissions.

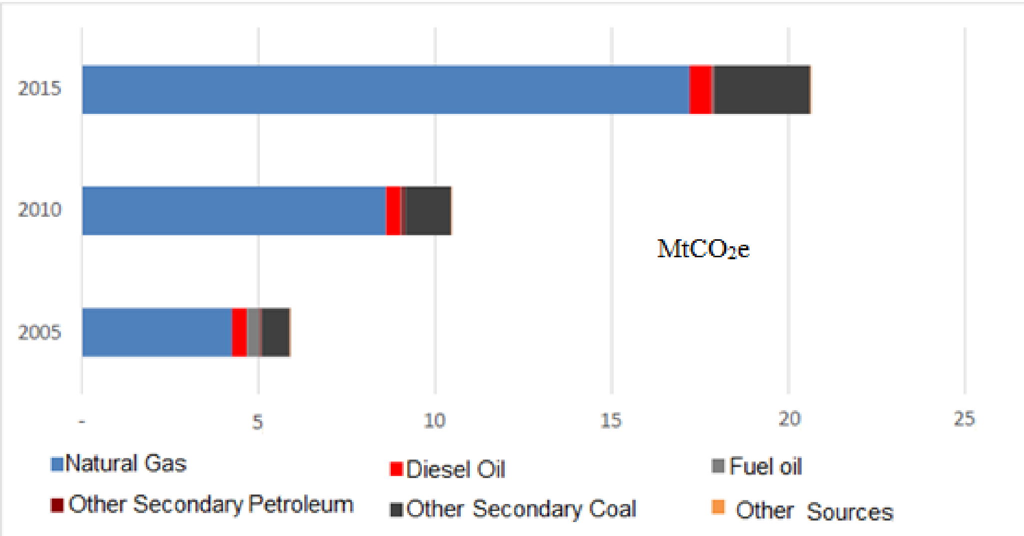

Figure 3. Emissions from the thermopower generation in the State of Rio de Janeiro (Mt CO_2e)
Source: RJ State GHG Inventory

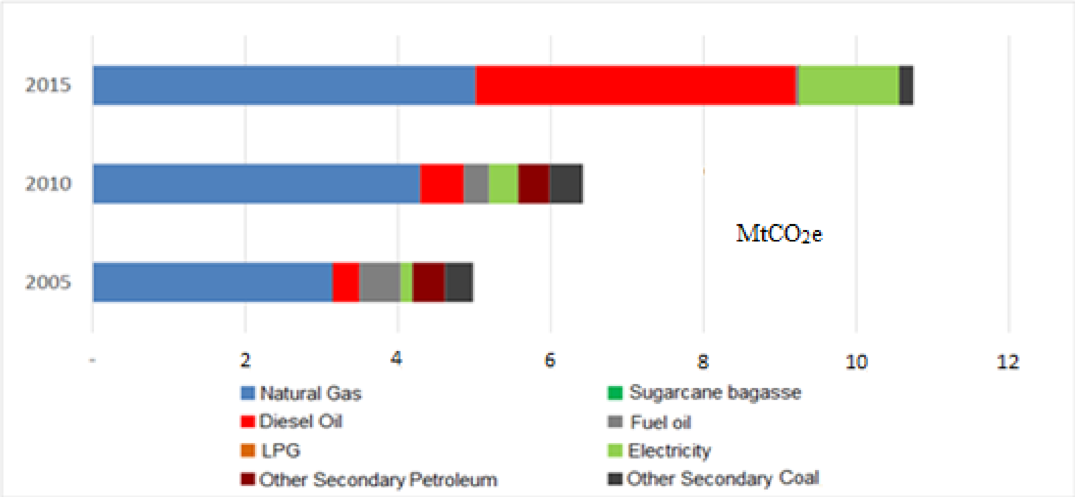

Figure 4. Emissions from the Energy Sector consumption in the State of Rio de Janeiro (Mt CO_2e)
Source: RJ State GHG Inventory

Brazil is characterized by highly centralized energy planning. The installation of power and transmission projects is controlled by federal authorities, through auctions held by the National Electric Energy Agency (ANEEL) and the Ministry of Mines and Energy (MME). These auctions result in competition between power plants from different Brazilian states and between different energy sources. For illustrative purposes, we present in Figure 5 the data referring to renewables installed in the state of Rio de Janeiro which already have 28 MW of *wind* energy and 4.29 MW of *solar* energy (photovoltaic).

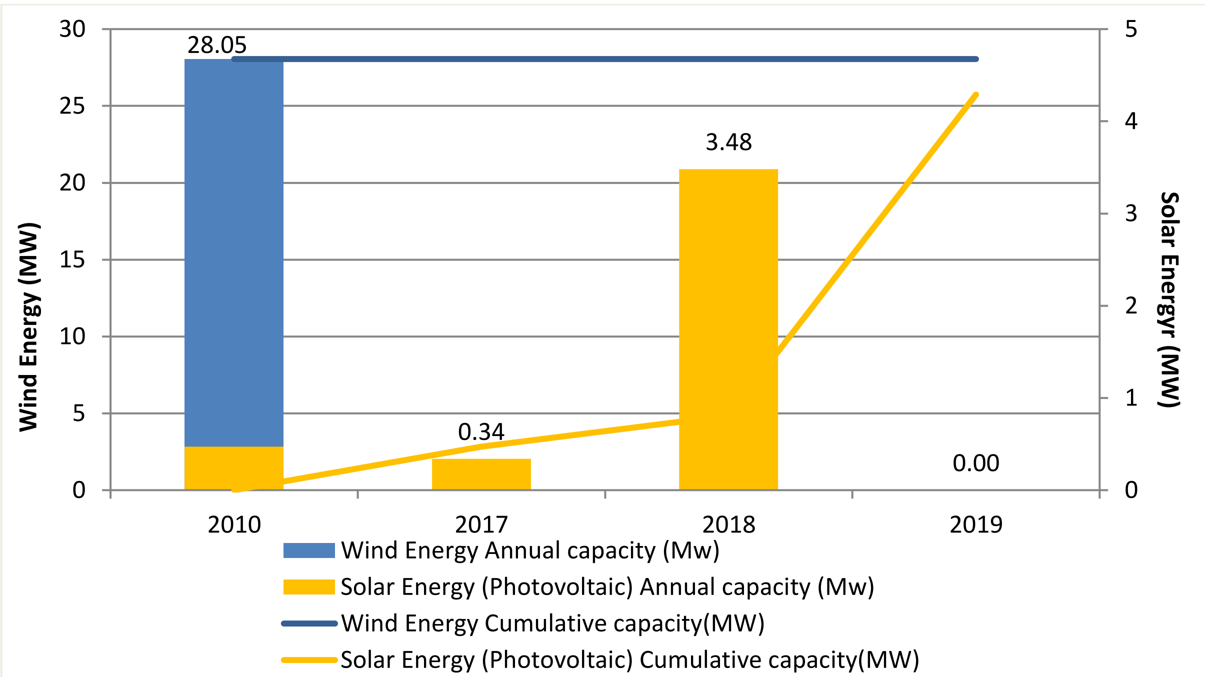

Figure 5. Annual and cumulative wind and solar energy installed capacity in the State of Rio de Janeiro (MW)
Source: ANEEL, 2020

Transport (energy demand)

In the transport sector, the emissions increased 32.7% between 2005 and 2015, as shown in Table 4. Then, in Table 5 are the emissions by fuel used in this sector where it is observed that diesel oil is the largest emission source.

Table 4. Emissions from the Transport sector in the State of Rio de Janeiro (Mt CO2e)

Source	2005	2010	2015	2010 - 2005	2015 - 2010	2015 - 2005
Road	8.7	11.2	11.7	28.7%	4.5%	34.5%
Railway	0.32	0.41	0.29	28.1%	-29.3%	-9.4%
Air	1.6	2.4	2.6	50.0%	8.3%	62.5%
Waterway	1.1	1.5	1.1	36.4%	-26.7%	0.0%
Total	11.8	15.6	15.7	32.2%	0.4%	32.7%

Source: RJ State GHG Inventory

Table 5. Emissions from fuels used in the transport sector in the State of Rio de Janeiro in 2015(Mt CO_{2e})

Mode	Diesel Oil	Fuel oil	Gasoline	Kerosene	Natural Gas	Electricity	Ethanol	Total	Modal share
Road	5.5	0.00	4.1	0.00	2.1	0.00	0.02	11.7	**74,7%**
Railway	0.28	0.00	0.00	0.00	0.00	0.01	0.00	0.29	**1,8%**
Air	0.00	0.00	0.00	2.59	0.00	0.00	0.00	2.6	**16,5%**
Waterway	0.54	0.54	0.00	0.00	0.00	0.00	0.00	1.08	**6,9%**
Total	6.3	0.54	4.1	2.59	2.1	0.01	0.02	15.6	**100,0%**
Fuel Share	**40,4%**	**3,5%**	**26,2%**	**16,5%**	**13,3%**	**0,1%**	**0,1%**	**100,0%**	-

Note: disaggregated
Source: RJ State GHG Inventory

Emissions from road transport were responsible for 74.1%, 72.0% and 74.7% of the total transport sector, respectively in 2005, 2010 and 2015, therefore remaining with a constant share. In this modal, it is observed that the greatest emission comes from diesel oil, mostly used by cargo and mass transportation. Emissions by energy source for this modal are shown in Table 6.

Table 6. Emissions from road transport in the State of Rio de Janeiro (Mt CO_2e and %)

Year	Unit	Diesel Oil	Gasoline	Natural Gas	Ethanol	Total
2005	Mt CO_2e	4.02	3.03	1.67	0.007	8.74
	%	46.1%	34.7%	19.1%	0.1%	100.0%
2010	Mt CO_2e	5.81	3.31	2.09	0.013	11.23
	%	51.8%	29.5%	18.6%	0.1%	100.0%
2015	Mt CO_2e	5.50	4.10	2.08	0.015	11.69
	%	47.1%	35.0%	17.8%	0.1%	100.0%

Source: RJ State GHG Inventory

Energy consumption in the transport sector increased by 36.5% in 2010 compared to 2005 and only 2% in 2015 compared to 2010. Total consumption was 5954.7 thousand toe (tons of oil equivalent) in 2015, highlighting the importance of diesel and of gasoline. Figure 6 shows the share of energy sources in the transport sector in the years of the analysis.

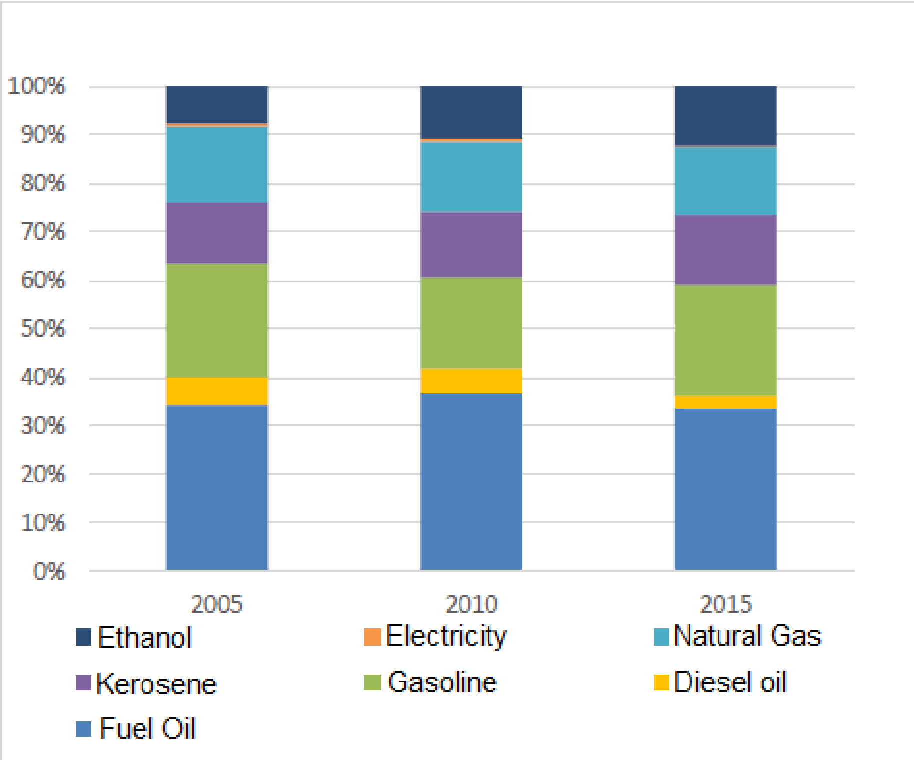

Figure 6. Share of the energy consumption in the transport sector in the State of Rio de Janeiro (%)
Note: Bunker emissions not included
Source: RJ State GHG Inventory

Figure 7 compares the energy consumption between modes of transportation. Road mode accounts for almost 80% of consumption in the three years of the analysis.

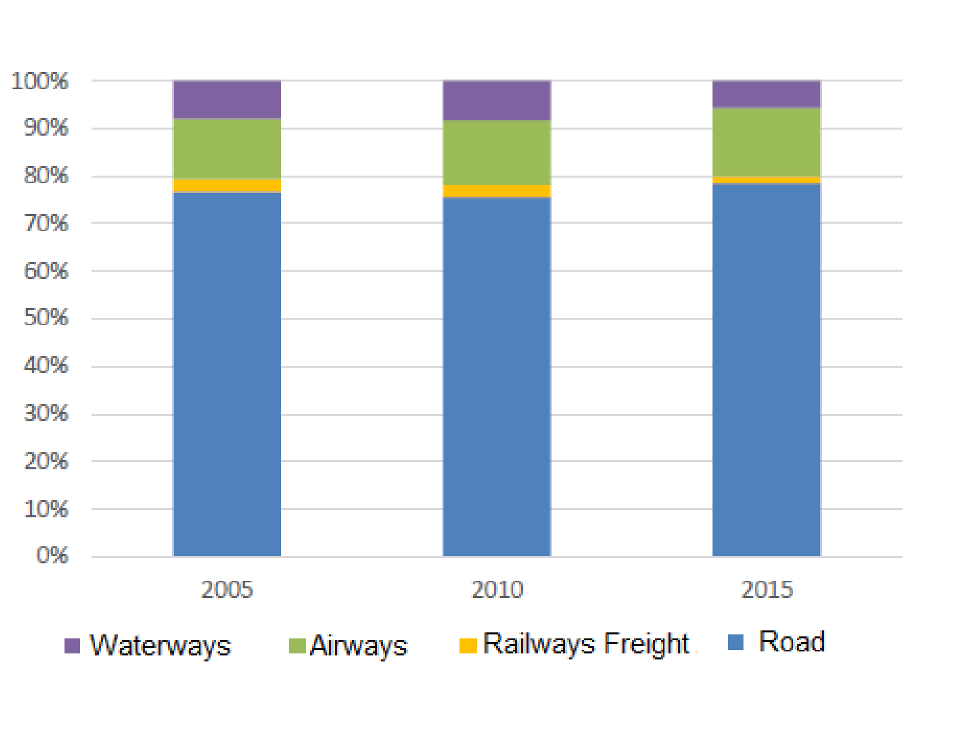

Figure 7. Share of energy consumption by the transport mode in the State of Rio de Janeiro (%)
Source: RJ State GHG Inventory

b. Industry (energy demand, industrial processes and product use)

The emissions in the industrial sector in the Rio de Janeiro inventory report combines emissions from both energy use and from industrial processes and product use (IPPU). The sector had an increase of 13.5% in annual physical production in 2010 compared to 2005, and a reduction of 15.8% in 2015 compared to 2010 (IBGE, 2017d). Comparing 2015 with 2005, the reduction was 5.4%.

The main industrial branch in terms of GHG emissions in the State of Rio de Janeiro is metallurgical. Then there are non-metallic minerals (with cement being the most important) and chemicals, but with much less importance. Of the total emissions from industry, these categories accounted for approximately 87% in 2015. Table 7 presents the share in terms of emissions from different industrial subsectors, in the years analyzed.

Table 7. Emissions from the Industry Sector of the State of Rio de Janeiro (Mt CO2e and %)

Emission Sources	2005		2010		2015		2005-2010 variation	2010-2015 variation	2005-2015 variation
	Mt CO_2e	%	Mt CO_2e	%	Mt CO_2e	%	%	%	%
Industry – Total	14.8	100.0%	17.7	100.0%	21.3	100.0%	19.3%	20.7%	44.0%
Mining	0.05	0.4%	0.07	0.4%	0.40	1.9%	21.6%	512.1%	644.2%
Non-metallic minerals	1.90	12.8%	2.54	14.4%	1.72	8.1%	33.9%	-32.4%	-9.5%
Cement	1.13	7.6%	1.84	10.4%	1.21	5.7%	63.1%	-34.5%	6.9%
Ceramics	0.07	0.5%	0.05	0.3%	0.08	0.4%	-36.9%	68.8%	6.5%
Glass	0.31	2.1%	0.30	1.7%	0.27	1.2%	-2.5%	-12.0%	-14.2%
Others	0.39	2.6%	0.35	2.0%	0.17	0.8%	-9.6%	-52.1%	-56.7%
Metallurgical	9.62	65.0%	11.98	67.9%	15.99	75.0%	24.6%	33.4%	66.2%
Iron and steel	9.09	61.4%	11.88	67.3%	15.88	74.5%	30.7%	33.7%	74.8%
Non-ferrous and other metals*	0.53	3.6%	0.11	0.6%	0.11	0.5%	-80.0%	-0.2%	-80.0%
Pulp and Paper	0.10	0.7%	0.11	0.6%	0.10	0.5%	11.3%	-9.4%	0.8%
Chemical	1.96	13.3%	1.52	8.6%	0.91	4.3%	-22.7%	-40.3%	-53.9%
Textile	0.04	0.3%	0.03	0.2%	0.03	0.1%	-18.9%	-22.5%	-37.1%
Food products	0.23	1.6%	0.18	1.0%	0.15	0.7%	-22.0%	-20.2%	-37.8%
Beverage	0.18	1.2%	0.22	1.3%	0.21	1.0%	25.0%	-6.8%	16.5%
Others Industries	0.37	2.5%	0.45	2.5%	0.87	4.1%	21.1%	96.0%	137.3%
Product Use	0.34	2.3%	0.56	3.1%	0.95	4.5%	61.5%	70.7%	175.6%

*includes the production of aluminum in 2005, which did not occur in 2010 and in 2015.

Note: Emissions from electricity generation from the national grid consumed in the industrial sector are considered.

Source: RJ State GHG Inventory

As can be seen in Table 8, the most-emitting energy sources are mineral coal and its products, used as fuel and also as reductant. The second largest portion is natural gas, also considering its use as energy and raw material. The generation of consumed electricity starts to have a great participation in the State's emissions in 2015, as there was a strong increase in the carbon content of electricity in the national interconnected system through the dispatch of fossil fuel plants, due to the water crisis that affected the country and, consequently, reduced the supply of hydroelectricity.

Table 8. Emissions of energy use from the Industry Sector of the State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources	2005		2010		2015		2005-2010 variation	2010-2015 variation	2005-2015 variation
	Mt CO_2e	%	Mt CO_2e	%	Mt CO_2e	%	%	%	%
Total	12.2	100.0%	14.7	100.0%	18.7	100.0%	20.3%	27.3%	53.2%
Coal, coke e coal products	8.04	65.9%	10.1	68.7%	13.8	74.0%	25.4%	37.1%	72.0%
Natural Gas	3.04	24.9%	3.08	21.0%	2.31	12.3%	1.6%	-25.2%	-24.0%
Electricity	0.37	3.0%	0.601	4.1%	1.56	8.3%	63.9%	158.6%	324.0%
Bagasse	0.02	0.2%	0.013	0.1%	-	0.0%	-33.4%	-100.0%	-100.0%
Wood and charcoal	0.007	0.1%	0.006	0.0%	0.008	0.0%	-11.0%	36.1%	21.1%
Other petroleum secondaries	0.242	2.0%	0.459	3.1%	0.142	0.8%	90.2%	-69.1%	-41.3%
Fuel Oil	0.231	1.9%	0.122	0.8%	0.032	0.2%	-47.1%	-73.5%	-86.0%
Diesel Oil	0.216	1.8%	0.266	1.8%	0.728	3.9%	23.0%	173.7%	236.7%
Other primary sources	0.001	0.0%	-	0.0%	-	0.0%	-100.0%	0.0%	-100.0%
LPG	0.039	0.3%	0.043	0.3%	0.087	0.5%	8.8%	105.0%	123.0%

Source: RJ State GHG Inventory

Either for energy purposes or as reductant in industry (accounted in IPPU), total energy consumption varied little in the years analysed. There was a growth of 14.3% in 2010 compared to 2005 and 12.6% in 2015 compared to 2010, when the 5958 thousand toe (tons of oil equivalent) were consumed in the last year. Comparing 2005 and 2015, the growth was 28.8%. As shown in Figure 8, the energy source with the greatest participation in the industrial sector is mineral coal and its products such as coke and other coal products, followed by natural gas, which in 2015 loses share compared to the other years analysed.

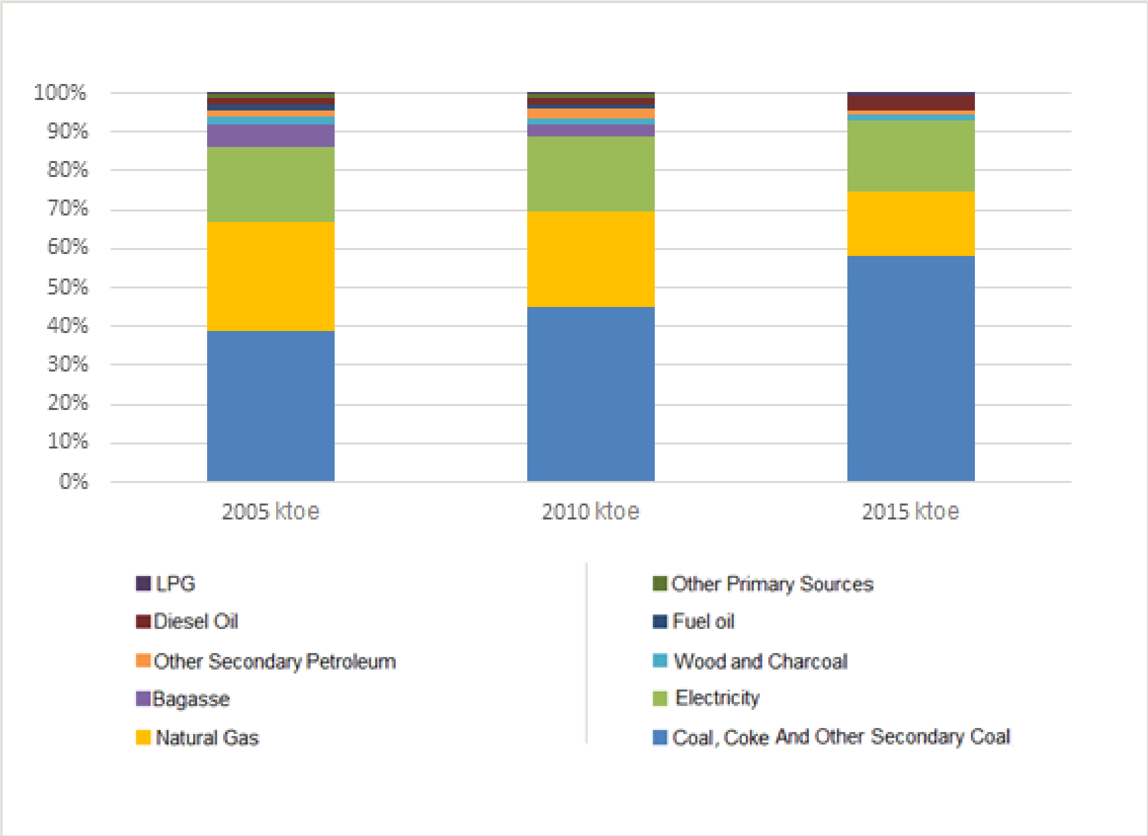

Figure 8. Share of the energy sources in the industrial sector of the State of Rio de Janeiro (%)
Source: RJ State GHG Inventory

The two most-relevant industrial branches with respect to the share of emissions are detailed below.

Metallurgical Sector

The iron and steel is the most important industry in the metallurgical sector, responsible for more than 99% of the 2015 emissions. It had a drop in physical production, according to IBGE (2017d), of -2.4%, in the period comparing the values of the years 2015 and 2005, though noting that it grew in 2010 compared to 2005 but a decrease occurred between the years 2010 and 2015 (Table 9). However, fuel consumption (as energy source and reductant) did not fall; on the contrary, it grew steadily, with 26.8% in 2010 compared to 2005 and 29.7% in 2015 compared to 2010. In the period, growth was 64.4% in 2015 compared to 2005, totalling 4619.8 thousand toe (tons of oil equivalent) in the last year. Coal and its products are the most consumed fuels in this sector (Figure 9).

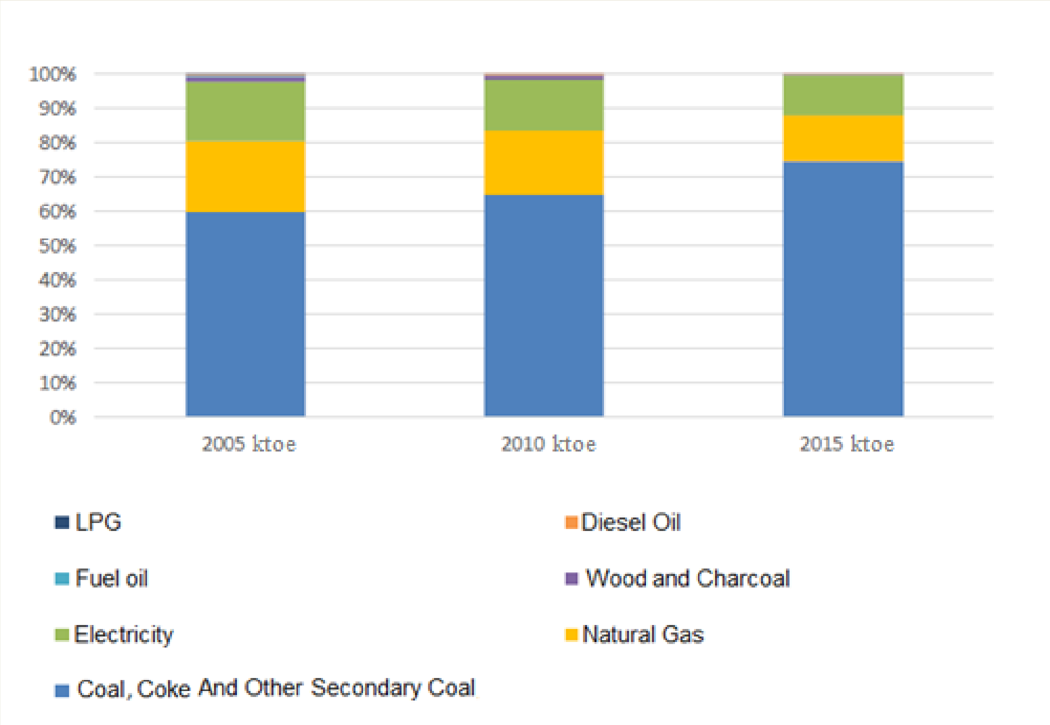

Figure 9. Share of the energy sources in the metallurgical industry of the State of Rio de Janeiro (%)

Source: RJ State GHG Inventory

The performance indicators reveal that the carbon intensity of the products has been increasing over time, following the specific consumption indicator, as can be seen in Table 9.

Table 9. Emissions from the iron and steel industry of the State of Rio de Janeiro (Mt CO2e and %)

Emission sources and indicators	2005	2010	2015	2005-2010 variation	2010-2015 variation	2005-2015 variation
	Mt CO_2e	Mt CO_2e	Mt CO_2e	%	%	%
Natural Gas	1.39	1.51	1.44	9.1%	-5.1%	3.6%
Coal and mineral coke (IPPU)	6.34	8.61	9.86	35.7%	14.5%	55.4%
Oil products	0.06	0.05	0.04	-17.5%	-16.1%	-30.8%
Biomass and other primary sources	0.004	0.003	-	-8.6%	NA	NA
Electricity	0.16	0.30	0.79	93.4%	160.8%	404.4%
Other secondary coal	1.14	1.40	3.87	23.2%	175.3%	239.2%
TOTAL (Mt CO_2e**)**	9.09	11.9	16.0	30.7%	34.6%	75.9%
Production (1000 t)	6,834.0	7,093.0	6,670.0	3.8%	-6.0%	-2.4%
Intensity (t CO_2/t)	1.3	1.7	2.4	25.9%	43.2%	80.3%
Energy consumption (1000 toe)	2,810.10	3,562.40	4,619.77	26.8%	29.7%	64.4%
Specific consumption (toe/t)	0.4	0.5	0.7	22.1%	37.9%	68.4%

Source: RJ State GHG Inventory

Cement Subsector

The cement industry had a production peak in 2010 compared to 2005 and a sharp drop in 2015 compared to 2010, reflecting the positive period of growth in construction works and the subsequent strong retraction due to the national economic crisis.

Regarding energy consumption, the total rose 31.5% in 2010 compared to 2005 and subsequently dropped 59.1% in 2015 compared to 2010, totalling 116.6 thousand toe (tons of oil equivalent) in the last year. With regard to energy sources, following the sector performance country-wide, there was a gradual replacement of some fuels for petroleum coke (represented on Figure 11 as “other petroleum secondaries”), whose consumption practically doubled in the period 2005-2010 and then fell sharply in the subsequent period (2010-2015). In this second period, there was an increase in “Coal, coke e coal products” and electricity, as shown in Figure 10 and in Table 11.

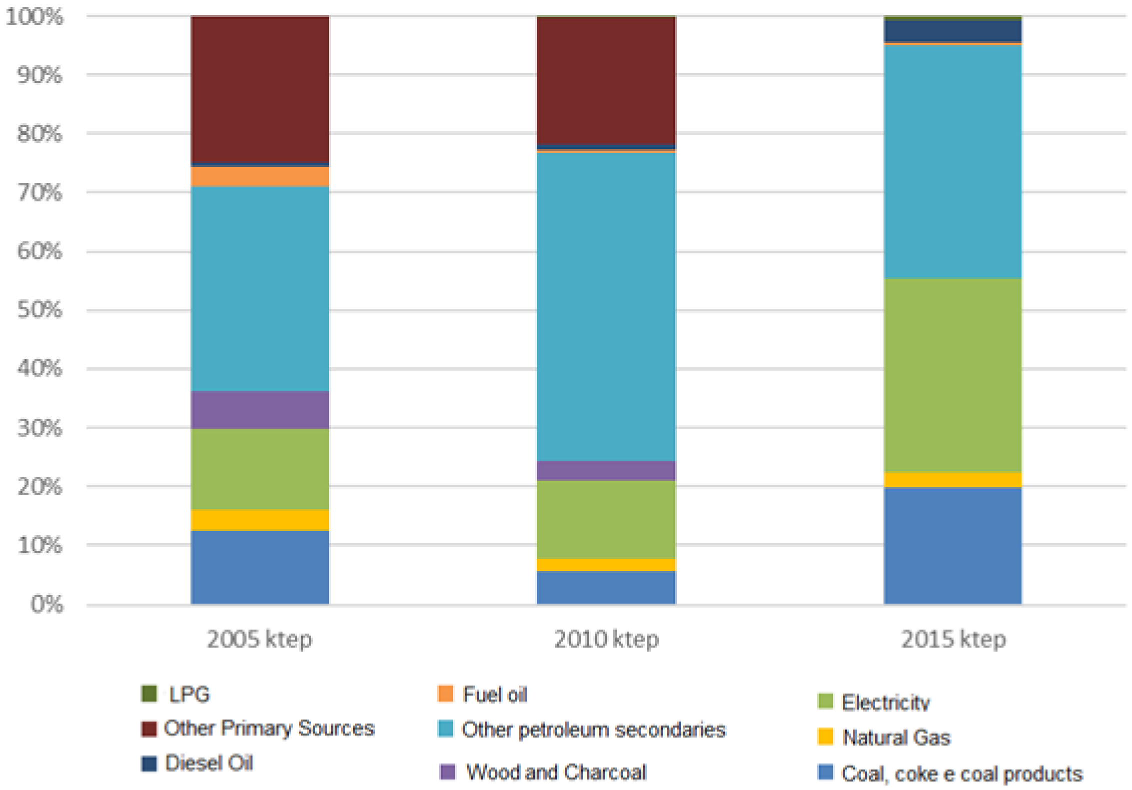

Figure 10. Share of the energy sources in the cement industry in the State of Rio de Janeiro (%)
Source: RJ State GHG Inventory

In terms of emissions, it is noteworthy that even with a reduction in total energy consumption, there was an increase in emissions from this source in 2015 compared to 2010, due to the higher dispatch of fossil fuel thermoelectric plants. The increase in energy use efficiency is notable, with a 58% reduction in specific consumption in the period 2005-2015. This led to a reduction in the intensity of total emissions of 17% in the same period.

Table 10. Emissions from the cement industry of the State of Rio de Janeiro (Mt CO_2e and %)

Emission sources and indicators	2005	2010	2015	2005-2010 variation	2010-2015 variation	2005-2015 variation
	Mt CO_2 e	Mt CO_2 e	Mt CO_2 e	%	%	%
Emissions from clinker production (IPPU) (Mt CO_2e)	0.721	1.26	0.879	74.7%	-30.2%	21.9%
Emissions from energy consumption (Mt CO2e)	0.405	0.582	0.326	43.7%	-43.9%	-19.4%
Coal coke / energy coal (Mt CO_2e)	0.115	0.072	0.104	-37.2%	44.9%	-9.0%
Oil products (Mt CO_2e)	0.26	0.473	0.159	81.5%	-66.3%	-38.9%
Natural Gas (Mt CO_2e)	0.018	0.014	0.007	-19.7%	-51.1%	-60.7%
Electricity (Mt CO_2e)	0.012	0.022	0.056	86.6%	150.4%	367.1%
Others (Mt CO_2e)	0	0.0008	0	NA	-100.0%	NA
TOTAL (Mt CO_2e)	**1.13**	**1.84**	**1.21**	**63.6%**	**-34.5%**	**7.1%**
Cement with clinker production (Scope 1) (1000 t)	1,861.7	3,252.0	2,281.9	74.7%	-29.8%	22.6%
Cement without local clinker production (Scope 3) (1000 t)	2,267.7	3,961.1	3,018.1	74.7%	-23.8%	33.1%
Total cement production (1000 t)	4,129.5	7,213.1	5,300.0	74.7%	-26.5%	28.3%
Intensity (t CO_2/t)	0.27	0.26	0.23	-6.4%	-10.9%	-16.6%
Total energy consumption (1000 tep)	216.2	284.3	116.4	31.5%	-59.1%	-46.2%
Specific consumption (tep/1000 t)	52.4	39.4	22.0	-24.7%	-44.3%	-58.1%

Source: RJ State GHG Inventory

c. Other (energy demand)

The values in Table 11 account for emissions from energy use in residential, commercial, public and agriculture sectors. The residential sector is the largest emitter, followed by the commercial and public sectors. There is a big increase in emissions from the commercial and public sectors in the period. The only sector that has reduced its emissions is agriculture, although the sector's GDP has grown in the period.

Table 11. Emissions from the Residential, Commercial, Public and Agriculture sectors of the State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2005-2010	2010-2015	2005-2015 variation
	Mt CO_2e			%		
Residential	2.01	2.31	3.38	15.2%	46.0%	68.2%
Commercial	0.44	0.65	1.66	48.7%	154.6%	278.7%
Public	0.29	0.39	0.69	34.1%	77.4%	137.9%
Agriculture	0.27	0.29	0.13	8.1%	-55.1%	-51.5%
Total	3.01	3.65	5.85	21.3%	60.6%	94.7%

Source: RJ State GHG Inventory

d. Waste

In 2015, the GHG emissions from the waste sector were reduced by 17.8% compared to 2005 emissions, because of the implementation of the State Policy on Solid Waste that aimed at implementing a program to create new managed landfills in the state. Table 12 shows the figures.

Table 12. Emissions from the Waste Sector of the State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2005-2010	2010-2015	2005-2015 variation
	Mt CO_2e			%		
Urban Solid Wastes	4.95	6.06	3.09	22.4%	-48.9%	-37.5%
Industrial Solid Wastes	0.278	0.381	0.513	37.4%	34.4%	84.7%
Urban Wastewater	1.04	1.08	1.31	3.6%	21.1%	25.4%
Industrial Wastewater	0.365	0.571	0.539	56.5%	-5.5%	47.8%
Total	**6.64**	**8.09**	**5.46**	**21.9%**	**-32.6%**	**-17.8%**

Source: RJ State GHG Inventory

Solid Waste

The quantities of solid municipal waste sent to different final destinations indicate, between 2010 and 2015, that although there was an increase in open dumps, the state could finally eliminate unmanaged deep deposit sites (or controlled dumping) and increased sharply dumping in managed landfills with methane recovery and flaring. In relation to 2005, open-air dumps decreased in 2015. Table 13 shows the destination of the waste and Table 14 shows the participation of these sources in the sectoral GHG emissions throughout the period of analysis.

Table 13. Disposal of solid urban waste in the State of Rio de Janeiro (ton/year)

Destination	2005	2010	2015	2005-2010	2010-2015	2005-2015 variation
	ton/year			%		
Open dumps/not categorized	1,190,133	828,508	918,401	-30.3%	10.8%	-22.8%
Unmanaged deep site	3,683,744	4,260,900	0	15.6%	-100.0%	-100.0%
Landfill	793,422	828,508	5,900,000	4.4%	612.1%	643.6%
Total	**5,667,299**	**5,917,916**	**6,818,401**	**4.4%**	**15.2%**	**20.3%**

Source: RJ State GHG Inventory

Table 14. Emissions from solid waste sources of the State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources (treatment system)	2005	2010	2015	2005-2010	2010-2015	2005-2015 variation
	Mt CO_2e			%		
Open dump	0.561	0.346	0.178	-38.3%	-48.5%	-68.2%
Unmanaged deep site	3.46	4.69	-	35.6%	-100.0%	-100.0%
Landfill	0.932	0.897	2.353	-3.8%	162.3%	152.4%
Not categorized	-	0.128	0.561	-	339.3%	-
Industrial waste*	0.252	0.356	0.487	41.0%	36.7%	92.7%
Composting	-	0.0001	0.001	-	832.8%	-
Thermal treatment	0.025	0.026	0.026	1.5%	1.7%	3.2%
Total	**5.23**	**6.44**	**3.61**	**23.2%**	**-44.0%**	**-31.0%**

*waste sent to landfills
Source: RJ State GHG Inventory

Domestic, commercial and industrial wastewater

The quantities of urban sewage sent to different final destinations indicate that in the period 2010-2015, there was a large increase in sewage collection with a corresponding reduction in the use of septic tanks and direct discharge in water bodies. Table 15 shows the final sewage destinations.

Table 15. Emissions from domestic sewage and effluents of State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources (treatment system)	2005	2010	2015	2005-2010	2010-2015	2005-2015 variation
	Mt CO_2e			%		
Domestic Wastewater Treatment Plant	0.606	0.636	1.159	4.9%	82.2%	91.3%
Industrial Wastewater Treatment Plant	0.365	0.571	0.539	56.5%	-5.5%	47.8%
Septic tank	0.149	0.105	0.112	-29.5%	6.7%	-24.8%
Untreated	0.291	0.342	0.041	17.7%	-88.1%	-86.0%
Total	**1.41**	**1.65**	**1.85**	**17.2%**	**11.9%**	**31.2%**

Source: RJ State GHG Inventory

e. Agriculture, Forestry and Other Land Use – AFOLU sector

GHG emissions from the AFOLU sector in 2015 showed a significant drop of 59.3% when compared to 2005 emissions (Table 16 and Figure 11). This is mainly due to the contribution of land use (LULUCF) emissions that became negative as of 2010. This is due to the reduction of deforestation rates and the increase of protected areas.

GHG emissions in agriculture are mainly the result of: (i) biotic processes inherent to the use and management of soil; (ii) processes inherent to the specific physiology of herd animals (enteric fermentation of ruminant cattle); (iii) anaerobic decomposition processes related to deep-water cropping systems (such as flooded rice cultivation); (iv) treatment and disposal of vegetation and animal waste; and (v) management of native areas for their use as agricultural ecosystems.

GHG emissions from agricultural activities remained relatively constant over the years as in Table 16.

Table 16. Emissions from the Agriculture, Forestry and Land Use Change (AFOLU) Sector of the State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2005-2010	2010-2015	2005-2015 variation
	Mt CO_2e			%		
Land use	6.26	-0.196	-0.395	-103.1%	-101.4%	-106.3%
Agriculture	4.93	5.02	4.95	1.9%	-1.4%	0.5%
Livestock	3.94	3.80	3.98	-3.5%	4.6%	1.0%
Enteric Fermentation	3.697	3.556	3.746	-3.8%	5.3%	1.3%
Manure Management	0.243	0.246	0.232	1.3%	-5.8%	-4.5%
Crops	0.986	1.217	0.973	23.4%	-20.0%	-1.3%
Liming	0.207	0.161	0.105	-21.9%	-35.3%	-49.5%
Rice cultivation	0.039	0.014	0.001	-65.4%	-95.2%	-98.3%
Burning of forest residues	0.088	0.062	0.045	-29.9%	-26.6%	-48.6%
Agricultural Soils	0.648	0.976	0.819	50.5%	-16.1%	26.3%
Urea use	0.004	0.004	0.004	10.9%	-5.3%	5.1%
Total	**11.2**	**4.82**	**4.56**	**-56.9%**	**-5.5%**	**-59.3%**

Source: RJ State GHG Inventory

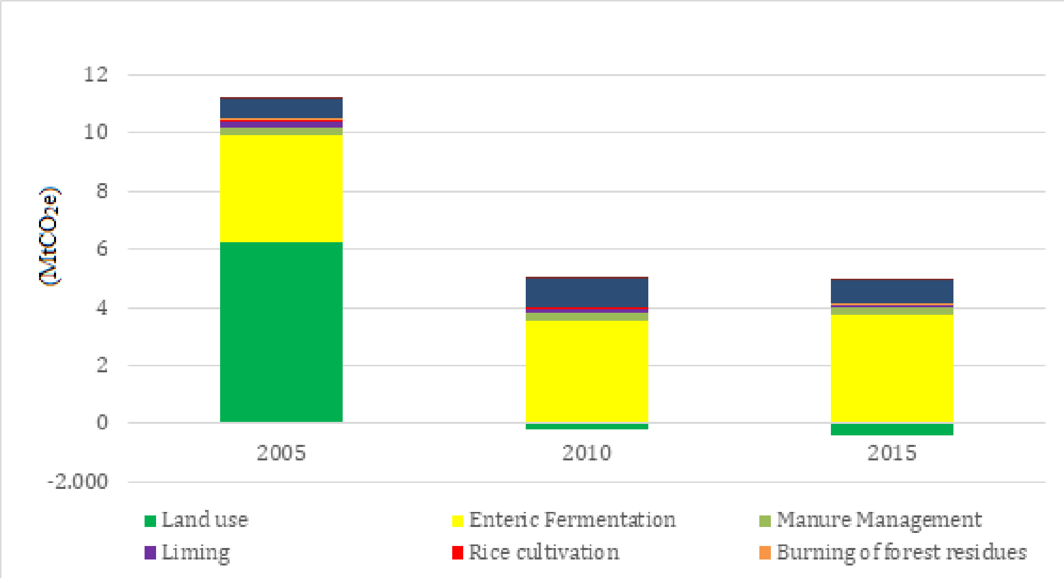

Figure 11. Emissions from the AFOLU sector by subsectors of the State of Rio de Janeiro (Mt CO_2e)

Source: RJ State GHG Inventory

Land Use, Land-Use Change, and Forestry (LULUCF) subsector

The variation in vegetation cover is shown in Table 17. It is worth mentioning that areas with secondary forest increased by 9.4% and reforestation by 9.6% between 2005 and 2015, while the other classes remained almost constant. These parameters, together with an increase in conservation units, as in Table 18, explain the main factors responsible for the reduction of emissions in LULUCF.

Table 17. Total area by land use and land cover classes in the State of Rio de Janeiro (hectare)

Classes of Land Use (ha)	2005*	2007	2010*	2013	2015	2005-2015 variation
Natural						
Rocky outcrop	24,429.9	24,371.1	24,258.5	24,116.8	24,116.4	-1.3%
Water	78,763.3	79,001.8	79,459.5	80,037.1	80,035.9	1.6%
Wet areas	38,209.5	38,102.9	37,902.2	37,652.5	37,643.9	-1.5%
Relic Community	5,340.2	5,339.9	5,339.5	5,338.9	5,338.9	0.0%
Sandy strands	64,187.2	63,669.5	62,698.2	61,493.4	61,442.9	-4.3%
Dunes	358.7	358.6	358.3	357.9	357.9	-0.2%
Beach vegetation	41,290.5	41,148.3	40,875.7	40,531.8	40,532.3	-1.8%
Mangrove	19,220.6	19,209.9	19,184.5	19,147.7	19,159.8	-0.3%
Secondary vegetation early stage	216,307.3	220,053.7	227,667.7	237,675.0	236,634.9	9.4%
Secondary vegetation medium / high stage	1,069,373.7	1,069,748.2	1,070,550.0	1,071,640.0	1,071,438.2	0.2%
Anthropic						
Agriculture	217,516.1	216,872.7	215,924.9	214,998.0	214,312.8	-1.5%
Grass / Pasture	2,370,025.6	2,357,020.6	2,332,736.3	2,302,720.0	2,301,179.2	-2.9%
Reforestation (economic)	23,013.5	23,482.0	24,027.6	24,384.6	25,230.4	9.6%

Classes of Land Use (ha)	2005*	2007	2010*	2013	2015	2005-2015 variation
Saline	3,676.2	3,670.2	3,658.8	3,644.3	3,644.5	-0.9%
Exposed soil	1,486.2	2,609.7	4,738.2	7,398.5	7,458.3	401.8%
Urban area	234,068.7	242,445.4	257,354.4	275,076.0	277,827.5	18.7%
Others						
Cloud	367.6	365.3	360.7	355.0	355.0	-3.4%
Shadow	1,209.4	1,473.2	1,978.8	2,616.4	2,616.4	116.3%
Total	**4,408,843.9**	**4,408,943.1**	**4,409,074.1**	**4,409,183.9**	**4,409,325.4**	**0.0%**

* projected values (as in the original document)
Source: RJ State GHG Inventory

Table 18. Area of the conservation units in the State of Rio de Janeiro (hectare)

Conservation Units	Total Area per period	Increase per period
	ha	%
Until 2005	265,726	
2006 – 2010	378,051	42%
2011 – 2015	441,745	17%

Source: RJ State Inventory

Agriculture Subsector

Livestock (enteric fermentation and manure management)

The variation of the emission factor between the years is evident through the emission indicators per capita, for each emission source of the livestock, which are higher for the bovine herd in 2005 for enteric fermentation and the same for all years in management of manure (Table 19).

Table 19. Herd emission indicators in 2005, 2010 and 2015 in the State of Rio de Janeiro (kgCH_4 and N_2O/head)

Herd	2005	2010 e 2015	2005, 2010 e 2015	2005, 2010 e 2015
	Enteric Fermentation (kgCH4/cap.)		Manure (kgCH4/cap.)	Manure (kgN2O/cap.)
Bovine	60.24	56.6	1.40	0.12
Buffalo	55.00	55.00	1.00	0.03
Sheep	5.00	5.00	0.15	0.03
Goat	5.00	5.00	0.17	0.02
Horses	18.00	18.00	1.64	0.00
Mules and asses	10.00	10.00	0.90	0.08
Swine	1.00	1.00	5.90	0.15
Poultry	-	-	0.02	0.01

Source: RJ State GHG Inventory

The variation in emissions per animal followed a similar pattern to the variation in herds, as shown in Table 20.

Table 20. Variation in the number of animal heads in the State of Rio de Janeiro in the periods 2015-2010 and 2010-2005 (%)

Period	Bovine	Buffalo	Sheep	Goat	Horse	Mules and asses	Swine	Poultry
2010-2015	5.9%	25.3%	-8.2%	-44.1%	-5.7%	0.8%	-49.5%	-3.7%
2005-2010	2%	13%	17%	-2%	2%	-11%	-6%	6%

Source: RJ State G|HG Inventory

Agricultural soils

The data on synthetic and organic nitrogen fertilizers applied in 2015, as well as data on the quantity produced by crops and the nitrogen contained in animal waste on pastures, underwent significant variations in relation to 2005 and 2010, thus explaining the increase in absolute emissions as the quantity of fertilizers/ha remained constant over time.

There was a 350% increase in the amount of synthetic and organic nitrogen fertilizer applied in 2010, compared to 2005, and a 46.3% reduction in 2015 compared to 2010. The amount of N present in manure of animal on pasture varied by 3.0% and 5.8% in 2010 compared to 2005 and in 2015 compared to 2010, respectively. Agriculture yield suffered two successive falls, reaching a reduction of 14.7% in 2010 in relation to 2005 and 61.1% in 2015 in relation to 2010.

Burning of agricultural residues (sugarcane)

The harvest area with sugarcane in 2005 and 2010 was higher than in 2015. This reduction was 26% in 2010 compared to 2005, and 43% in 2015 compared to 2010. Although there was a reduction in area, an increase in productivity was observed, going from 44.8 t / ha in 2005 to 70.03 t / ha in 2010 and 2015. Therefore, the emission indicators per area burned in 2005 were lower than in 2010 and 2015 (17.55 kg CH4 / ha burned and 0.46 kg N2O / ha burned, and in 2010 and 2015 of 27.37 kg CH4 / ha burned and 0.70 kg N2O / ha burned). This indicates that the variation in absolute emissions between the years considered is due to both the variation in the burned area and the emission factor, which account for the crop yield. The emissions varied accordingly with a reduction of 30% in 2010, in relation to 2005, and of 27% in 2015, in relation to 2010.

Liming of soils and application of urea in crops

The amount of lime applied to the soil in the years 2005, 2010 and 2015 varied, showing a reduction of 22%, and 35% respectively, in the period 2010-2005 and 2015-2010. The amount of urea used in the crops, on the other hand, increased by 10.9% in 2010, in relation to the values of 2005, but decreased 5.3% in 2015, in relation to 2010. Emissions from both the use of limestone and urea application reflects the amount used of these products.

Rice cultivation

The observed variation in emissions is a function only of different levels of activity considering that the emission indicators are constant (300 kg CH4 / ha harvested). The reduction in emissions was 65.4% in 2010, compared to 2005, and 95.1% in 2015, compared to 2010.

1.4 Evaluation of aggregated values and intensity indicators

Table 21 shows the emission sources in decreasing order of magnitude, considering the year 2015. Table 22 shows the indicators used to assess the evolution of emissions. It shows that the total emissions that grew 40.2% in the period 2005-2015 were mitigated by LULUCF by absorbing carbon from the atmosphere in 2010 and 2015. Without this carbon uptake, emissions would have grown 55.5%. During this period, GDP grew only 37.8%, resulting in an increase in the indicator of carbon content of GDP. The same is observed in relation to total per capita emissions and sectoral per capita emissions except for the per capita emissions in the waste sector.

Table 21. Total emissions of the State of Rio de Janeiro, by sector, in decreasing order of magnitude (Mt CO_2e and %)

Emission Sources	2005	2010	2015	Emissions share in 2015
	Mt CO_2e			%
Energy supply emissions (scopes 1 and 2)	18.7	25.8	39.9	43.0%
Industry emissions (Energy and IPPU)	14.8	17.7	21.3	23.0%
Transport emissions	11.8	15.6	15.7	16.9%
Total agriculture emissions (Crops, Livestock and energy emissions)	5.20	5.31	5.08	5.5%
Households emission	2.01	2.31	3.38	3.6%
Urban solid Waste emissions	4.95	6.06	3.09	3.3%
Commercial emissions	0.44	0.65	1.66	1.8%
Urban wastewater emissions	1.05	1.08	1.31	1.4%
Industry emissions from waste (Solid and wastewater)	0.64	0.95	1.05	1.1%
Public Sector emissions	0.29	0.39	0.69	0.7%
LULUCF net emissions	6.26	-0.20	-0.40	-0.4%
Total	66.1	75.6	92.7	100.0%

Source: based on RJ State GHG Inventory

Table 22. Emission and economic indicators of the State of Rio de Janeiro in 2005, 2010 and 2015 and 2030 targets.

Annual indicators		2005	2010	2015	2005-2010	2010-2015	2005-2015	2030 Targets
Economy Wide	Total emissions (Mt CO_2e)	66.1	75.6	92.7	14.3%	22.6%	40.2%	
	Total emissions without LULUCF (Mt CO_2e)	59.9	75.8	93.1	26.6%	22.9%	55.5%	
	GDP (Million R$ 2015)	432,071	571,472	595,573	32.3%	4.2%	37.8%	
	Carbon intensity of GDP (t CO_2e/Million R$ 2015)	153	132	156	-13.6%	17.7%	1.7%	< 2005
	Carbon intensity of GDP without LULUCF (t CO_2e without LULUCF emissions/Million R$)	139	133	156	-4.3%	17.9%	12.8%	
	Population (Million people)	15.6	16.3	16.8	4.8%	3.3%	8.2%	
	Per capita emissions (total t CO_2e/inhab.)	4.25	4.64	5.50	9.2%	18.5%	29.4%	
	Per capita emissions without LULUCF (t CO_2e without LULUCF emissions/inhab.)	3.85	4.65	5.53	20.8%	18.9%	43.6%	
Energy Supply and Other Energy Indicators	Total energy supply (M toe)	14.2	17.0	20.5	19.7%	20.5%	44.2%	
	Total energy supply (Mt CO_2e)	18.7	25.8	39.9	37.8%	53.6%	111.6%	
	TPES / capita (toe/capita)	0.92	1.05	1.22	14.1%	16.2%	32.6%	
	Total electricity demand (TWh)	37.0	45.4	55.6	22.9%	22.4%	50.4%	
	Electricity demand over GDP (GWh/Million R$ 2015)	85.6	79.5	93.3	-7.1%	17.4%	9.1%	
	Share of electricity in total energy demand (%)	0.22	0.23	0.23	4.5%	0.0%	4.5%	
	Carbon intensity of eletrictricy consumed (Kg CO_2e/MWh)	160	230	371	44.4%	61.1%	132.5%	

Annual indicators		2005	2010	2015	2005-2010	2010-2015	2005-2015	2030 Targets
	Emissions from total energy supply over GDP ($t\ CO_2$-eq/Million R$ 2015)	43.3	45.1	66.5	4.2%	47.4%	53.5%	
Transport Sector	Transport emissions ($Mt\ CO_2e$)	11.8	15.6	15.7	32.2%	0.4%	32.7%	-30% compared to 2010
	Transport emissions/GDP ($t\ CO_2e$/Million R$ 2015)	27.3	27.3	26.3	0.0%	-3.7%	-3.7%	
	Share of ethanol in the road mode (%)	8.12 %	11.5 %	12.9 %	41.5%	12.5%	59.2%	
Industry	Industry emissions – energy and IPPU ($Mt\ CO_2e$)	14.8	17.7	21.3	19.3%	20.7%	44.1%	
	Industry Value Added (Million R$ 2015)	119,300	143,794	118,618	20.5%	-17.5%	-0.6%	
	Industry emissions/GDP ($t\ CO_2e$/Million R$ 2015)	34.2	30.9	35.8	-9.8%	15.9%	4.5%	
	Industry emissions/VA of Industry ($t\ CO_2e$/Million R$ 2015)	124	123	180	-1.0%	46.4%	44.9%	
Other energy demand sectors	Commercial emissions ($Mt\ CO_2e$)	0.44	0.65	1.66	47.7%	155.4%	277.3%	
	Commercial emissions/GDP ($t\ CO_2e$/Million R$ 2015)	1.02	1.14	2.79	11.7%	145.0%	173.7%	
	Households emission ($Mt\ CO_2e$)	2.01	2.31	3.38	14.9%	46.3%	68.2%	
	Households per capita emissions ($t\ CO_2e$/inhab.)	0.13	0.14	0.20	9.7%	41.6%	55.4%	
	Public Sector emissions ($Mt\ CO_2e$)	0.29	0.39	0.69	34.5%	76.9%	137.9%	- 30% compared to 2005
	Agriculture energy emissions	0.27	0.29	0.13	8.1%	-55.1%	-51.5%	

Annual indicators		2005	2010	2015	2005-2010	2010-2015	2005-2015	2030 Targets
	(Mt CO_2e)							
AFOLU	AFOLU net emissions (Mt CO_2e)	11.2	4.82	4.56	-56.9%	-5.5%	-59.3%	
	AFOLU net emissions/VA of Agriculture (kt CO_2e/Million R$ 2015)	5.70	2.47	1.67	-56.6%	-32.4%	-70.7%	
LULUCF	Deforestation (km^2/year)	1.26	0.51	0.27	-59.5%	-47.1%	-78.6%	
	Protected Areas and Indigenous Lands (M ha/year)	716	830	894	16.0%	7.7%	24.9%	
	LULUCF net emissions (Mt CO_2e)	6.26	-0.20	-0.40	-103.1%	-101.4%	-106.3%	
	LULUCF net emissions/Annual deforestation area (Mt CO_2-eq/km^2)	4.97	-0.38	-1.46	-107.7%	-280.5%	-129.4%	
	LULUCF net emissions/GDP (t CO_2e/Million R$ 2015)	14.50	-0.34	-0.66	-102.4%	-93.3%	-104.6%	
	LULUCF net emissions/VA of Agriculture (kt CO_2e/Million R$ 2015)	3.19	-0.10	-0.15	-103.2%	-44.2%	-104.5%	
Agriculture	Number of cattle (cattle heads (Million)	2.09	2.16	2.31	3.3%	6.9%	10.5%	
	Agriculture Emissions (crops & livestock) Mt CO_2e	4.93	5.02	4.95	1.9%	-1.4%	0.5%	
	Total agriculture emissions (Crops, Livestock and energy emissions – Mt CO_2e)	5.20	5.31	5.08	2.2%	-4.3%	-2.2%	
	Value Added of Agriculture (Million R$ 2015)	1,96	1,95	2,72	-0.6%	39.7%	38.8%	
	Total agriculture emissions/VA of Agriculture (kt CO_2e/Million R$ 2015)	2.65	2.73	1.87	2.9%	-31.5%	-29.5%	
	Livestock Emission/ Meat production (Mt CO_2-eq/Mt)	184	80.0	87.0	-56.4%	8.8%	-52.6%	
	Meat production / VA of Agriculture (t/Million R$ 2015)	10.9	24.4	16.8	123.0%	-31.2%	53.4%	

Annual indicators		2005	2010	2015	2005-2010	2010-2015	2005-2015	2030 Targets
	Livestock Emissions / VA of Agriculture (kt CO_2-eq/ Million R$ 2015)	2.01	1.95	1.46	-2.9%	-25.1%	-27.3%	
	Meat production / Pastureland Area (kt/Mha)	16.3	34.2	30.2	109.9%	-11.7%	85.2%	
	Livestock / Pastureland Area (cattle head /ha)	1.59	1.56	1.53	-2.2%	-1.7%	-3.8%	
	Pastureland area / VA of Agriculture (M ha/Billion R$ 2015)	1.21	1.20	0.85	-0.9%	-29.4%	-30.0%	
	Agricultural area /VA of Agriculture (M ha/Billion R$ 2015)	0.11	0.11	0.08	-0.1%	-28.9%	-29.0%	
Waste	Total Waste Emissions (Mt CO_2e)	6.64	8.09	5.46	21.9%	-32.6%	-17.8%	
	Solid Waste Deposited in Managed Landfills (Mt)	0.79	0.83	5.90	5.1%	610.8%	646.8%	
	Urban Solid Waste emissions (Mt CO_2e)	4.95	6.06	3.09	22.4%	-48.9%	-37.5%	
	Total waste Per capita emissions (t CO_2e/inhab.)	0.43	0.50	0.32	16.4%	-34.7%	-24.1%	
	Urban Solid Waste per capita emissions (t CO_2e/inhab.)	0.32	0.37	0.18	16.8%	-50.6%	-42.3%	- 65% compared to 2005
	Urban wastewater emissions (Mt CO_2e)	1.05	1.08	1.31	3.6%	21.1%	25.4%	
	Urban wastewater per capita emissions (t CO_2e/inhab.)	0.07	0.07	0.08	-1.1%	17.2%	15.9%	- 65% compared to 2005
	Industry emissions – solid waste and wastewater (Mt CO_2e)	0.64	0.95	1.05	48.3%	10.4%	63.8%	

Source: Authors, based on the RJ state inventory and IBGE (2020)

Analysing the indicators in face of the state targets, we can conclude that:

- The general target of reducing the carbon intensity of GDP, which by 2030 should be lower than 2005, grew 1.69% in the period 2005-2015, requiring an increase in mitigation measures. It is worth mentioning that, if we disregard the negative LULUCF emission values, the carbon intensity of the GDP would have increased by 12.81% in the period.

- The sectoral mitigation targets may be partially achieved. For example, the solid waste treatment sector that should reduce emissions in 65% by 2030 compared to 2005 (in kg CO_2e / inhab. / year) so far achieved a reduction of 42,3%. On the other hand, the wastewater sector with the same mitigation goal as the solid waste sector (reduction of 65% in 2030 in relation to 2005, in kg CO_2eper capita / year), shows an inverse trend, since it grew 15,9% in the same period. The same occurs with the transport and the public sectors. The first should reduce 30% by 2030 compared to 2010 (in kg CO_2e / year) but grew 0.4% from 2010 to 2015. The second should reduce 30% in 2030 compared to 2005 (in kg CO_2e / year) but also increased by 138%.

1.5 Conclusion

Rio de Janeiro's GHG historical data allowed a detailed assessment of the evolution of the emissions profile and the identification of priority areas for mitigation in the state. Over the analysis period, there was an increase of 40.2% in state emissions in 2015 (92.69 Mt CO_2e) in relation to 2005 (66.13 Mt CO_2e).

Regarding the evolution of sectoral emissions, it is worth mentioning that only three sectors were responsible for 80.5% of emissions in 2015: energy supply, industry and transport

In the energy supply sector, emissions have grown mainly due to the substantial increase in thermo-power generation and the consumption of the energy sector itself over the years. In 2015 it emitted 42.9% of the total emissions from the state. The industry sector is the second largest emitter with a share of 23.1%, followed by the transport sector with 17.0%.

Ranking the emissions rate of increase in the period 2005-2015, the commercial sector stands out with an increase of 277%, followed by the public sector (138%) and the energy supply sector (112%) although these sectors have a small share in the overall calculation. The only sector where emissions have reduced is agriculture and livestock if we disregard the emissions from the energy consumption of the sector. Otherwise, emissions increased 5.4% in the period.

The decrease in the LULUCF sector emissions is justified by the reduction of deforestation and the increase in protected areas. In the transport sector, diesel oil is the largest emitting source and there is a large participation of the road mode. In the case of the waste sector, in total, there was a decrease in emissions in the period, but emissions from the urban wastewater subsector increased sharply.

2 State of Minas Gerais

This section focuses on the state of Minas Gerais, describing its historical emissions and assessing its emissions trends.

2.1 Commitments assumed by the State of Minas Gerais

At the state level, Minas Gerais stands out for its commitment to climate issues. In 2005, the creation of the Minas Gerais Forum on Global Climate Change effectively marked the entry of the theme on the governmental agenda, promoting discussions on the global phenomenon and the need to implement public policies at the state level. In 2008, the first Inventory of GHG Emissions in the State of Minas Gerais was presented for the base year of 2005 and, in 2013, the second was launched with 2010 as the reference year. Both, in identifying the main sources of GHG emissions in the state, served as an important tool for the management of GHG emissions at the regional level.

Decree no. 45229 of December 3rd, 2009, regulated mitigation measures by the State Government with emphasis on the "Voluntary Public Registration Program for Annual Greenhouse Gas Emissions of the State of Minas Gerais" and measures to promote biofuels.

In 2015, the Minas Gerais Energy and Climate Change Plan (PEMC) was launched. The Plan outlines guidelines for mitigating and adapting to climate change, to ensure the transition to a low carbon economy and sustainable development. One of the essential elements for the implementation of the PEMC is the measurement of GHG emissions in the territory of Minas Gerais, broken down by sector and socioeconomic sub-sectors, with the identification of the main carbon sources and sinks. In 2016, Minas Gerais officially joined the list of subnational governments that commit to the transparency of greenhouse gas emissions data periodically (Pact of States and Regions).

The Brazilian NDC defined the goal of reducing GHG by 37% in 2025 and by 43% in 2030, compared to 2005 emissions. Minas Gerais already has several initiatives in this direction. Many different actions and studies have already been carried out, within an integrated territorial strategy. However, the state intends to deepen its knowledge and articulation with stakeholders, through the PEMC.

In the PEMC, the low-carbon scenario sets a 9.4% GHG emissions reduction target comparing to the trend for 2030. This scenario considers additional actions for energy saving and reduction (or removal) of GHG and aims to promote the most ambitious, quick and robust way in the transition to a low carbon economy.

Although issued prior to the Brazilian NDC, since the creation of the Minas Gerais Forum on Global Climate Change, in 2005, some policies have been introduced in order to reduce GHG emissions and other main objectives, but also contributing to mitigation, for example:

- Decree no. 44043 (2005) - creates the program for prevention and fighting of forest fires, named Force Prevention Task (FTP), for the protection of conservation units, forest fragments, forestry and established actions to be developed.
- Law no. 15698 (2005) – disposes about the policy to encourage the use of wind energy and gives other provisions.

- Decree no. 44543 (2007) – modifies the Decree no. 44042, which institutes the Minas Gerais Forum on Global Climate Change.
- COPAM Normative Resolution no. 115 (2008) – disposes about the agricultural application of steel residue in areas planted with homogeneous forests of Eucalyptus species.
- Law no. 18722 (2010) – creates the state day of reflection on climate change.
- COPAM Normative Resolution no. 151 (2010) – regulates the "Voluntary Public Registry Program for the Annual Emissions of Greenhouse Gases in the State of Minas Gerais" and provides for the incentives for adhesion.
- Decree no. 46296 (2013) – disposes on the renewable energy program of Minas Gerais and measures to encourage the production and use of renewable energy.
- Law no. 20849 (2013) – state policy to encourage the use of solar energy.
- Law no. 20922 (2013) – disposes on forest and biodiversity protection policies in the state.
- Decree no. 46336 (2013) – disposes on the authorization for vegetation cutting or suppression.
- Decree no. 46674 (2014) – modifies decree no. 45229 (2009), regulates measures of the state of Minas Gerais regarding the climate change actions and management of effective GEE emissions.
- Decree no. 46818 (2015) – creates the Political Committee for the Energy and Climate Change Plan of Minas Gerais.
- Decree no. 47409 (2018) – modifies the Decree no. 45229 (2009), which regulates measures by the Government of the State of Minas Gerais regarding the fight against climate change and the management of greenhouse gas emissions and makes other arrangements.

2.2 GHG emissions inventory – methodology and structure

The state emissions summarized in this report are those obtained in the third Emissions Inventory for the State of Minas Gerais (Estimativas de Emissões de Gases de Efeito Estufa do Estado de Minas Gerais; and Estimativas de Emissões de Gases de Efeito Estufa do Estado de Minas Gerais: Setor de Mudança de Uso da Terra e Florestas) which covers emissions from 2005 to 2014.

The inventory followed the methodology of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), adapted, when necessary, for the state characteristics. Estimates include the following sectors and emission sources: Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) and Waste.

1. Energy – Emissions due to the burning of fuels and fugitive emissions. CO_2 emissions due to the reduction process in steel mills were considered in the Industrial Processes sector.
2. Industrial Processes – Emissions resulting from production processes in the chemical (ammonia), metals (aluminum, magnesium, ferroalloys, Iron and steel) and mineral products (cement and lime) industries.

3. Waste Treatment – Emissions from the disposal and treatment of waste, including composting, incineration, and treatment of domestic and industrial effluents.

4. Agriculture, Forestry and Other Land Use (AFOLU) - Emissions and removals resulting from variations in the amount of carbon in the biomass of areas with vegetation, considering the Atlantic Forest, Cerrado and Caatinga biomes (LULUCF Sector). Emissions due to enteric fermentation of livestock, manure management, agricultural soils, liming, rice cultivation and burning of agricultural waste (Agriculture Sector).

It is worth mentioning that the Land Use Change and Forestry sector was partly accounted for in this study, as it has limited spatial information for the years 2005 to 2009. Therefore, emissions were estimated only for the Forestry sub-sector in the period from 2010 to 2014.

The sectoral structure for measuring GHG emissions and removals, as well as the subsectors and categories is shown in Figure 12.

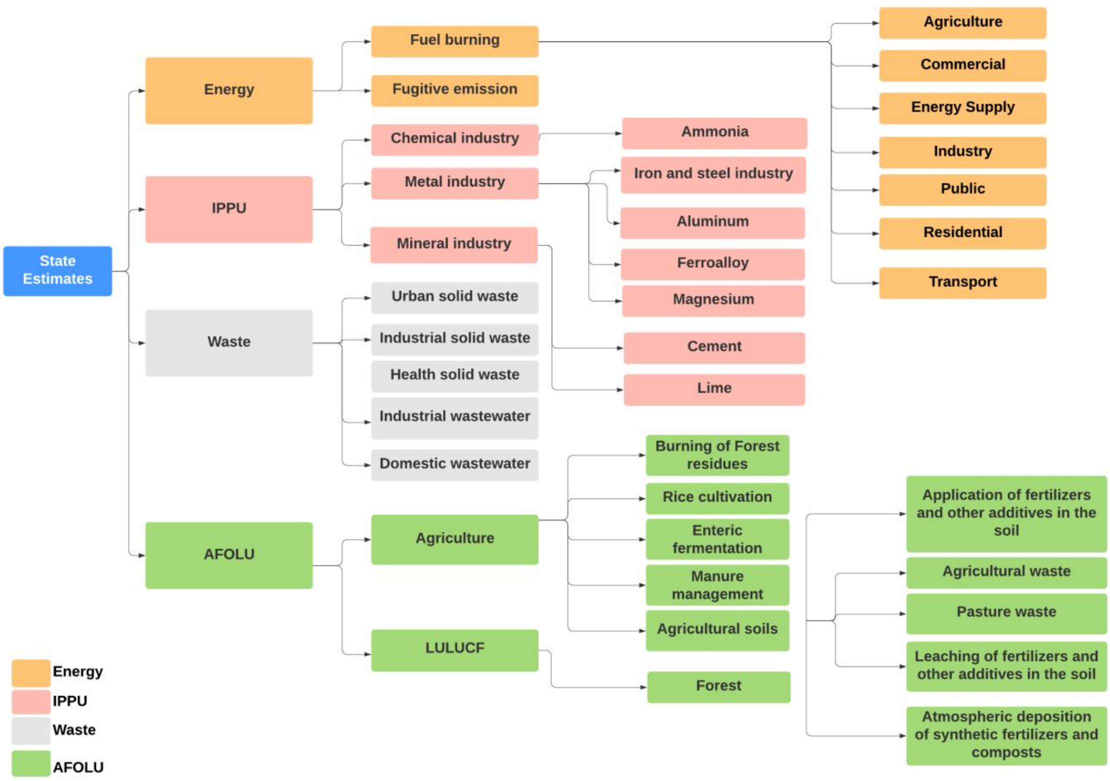

Figure 12. Structure of the Inventory of the State of Minas Gerais
Source: MG State GHG Inventory

Table 23. Greenhouse gases accounted for in the Inventory of the State of Minas Gerais, by sector

Sector	Energy	Industrial	AFOLU	Waste
Gases	CO_2	CO_2	CO_2	CO_2
	CH_4	CH_4	CH_4	CH_4
	N_2O	N_2O	N_2O	N_2O
		SF_6		
		C_2F_6		
		CF_4		

Source: MG State GHG Inventory

All gases were expressed in the unit of carbon dioxide equivalent (CO_2e), according to values of Global Warming Potential (GWP) proposed by the Second Assessment Report (SAR). The emissions of carbon dioxide (CO_2) whose source comes from the burning of planted biomass (charcoal, ethanol, bagasse, etc.) were considered null, since the emitted gas is reabsorbed in the photosynthetic process as recommended by the IPCC.

2.3 GHG emissions from the State of Minas Gerais (2005-2014)

2.3.1 Evolution of total emissions

The historical GHG data series from Minas Gerais allows a detailed assessment of the evolution of the emissions profile and the identification of priority areas for mitigation. Over the period 2005-2014, there was an increase of 23.66% in the state emissions disregarding LULUCF emissions as there is no available data for this sector prior to 2010. Among the sectors analysed, the participation of the Waste and Energy sectors stands out, whose emissions increased by approximately 121% and 35%, respectively, in relation to 2005. Emissions from LULUCF increased by approximately 45 % in relation to 2010. GHG emissions of each sector are presented in Table 24.

Table 24. Emissions of the State of Minas Gerais, by the IPCC sectors, in the period 2005-2014 (Mt CO_2e and %)

Emission Sources	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2005-2014
	Mt CO_2e										%
Agriculture	42.90	46.70	44.60	44.00	44.40	45.51	48.37	48.72	48.92	48.83	13.82%
Energy	34.05	34.28	36.70	38.19	35.32	40.03	42.88	44.28	45.36	46.05	35.24%
LULUCF	-	-	-	-	-	18.09	56.04	51.19	23.48	26.25	45.11%*
IPPU	19.39	19.75	20.87	21.90	18.21	22.08	22.07	22.32	22.30	20.53	5.88%
Waste	3.79	3.74	3.83	5.73	6.04	6.84	7.07	7.65	8.23	8.41	121.90%
Total w/o LULUCF	**100.13**	**104.47**	**106.00**	**109.82**	**103.97**	**114.46**	**120.39**	**122.97**	**124.81**	**123.82**	**23.66%**
Total with LULUCF	**-**	**-**	**-**	**-**	**-**	**132.55**	**176.43**	**174.16**	**148.29**	**150.07**	**13.22%***

Source: MG State GHG Inventory
*2014/2010 (%)

In Figure 13, we can see that the agricultural sector has been responsible for most of the state emissions, followed by the energy sector, except for the years 2011 and 2012. However, for the years 2011 and 2012, the land use change and forestry sector (LULUCF) was the largest contributor to state emissions. The peak of LULUCF emissions in 2011 was mainly due to deforestation in the Cerrado biome. In 2011, about 120,000 ha were deforested, with a reduction in the following years, when it gets to 45,000 ha in 2014. Deforestation of the Atlantic Forest and Caatinga biomes showed a more constant pattern, with an annual average of 7,400 ha and 1,500 ha, respectively.

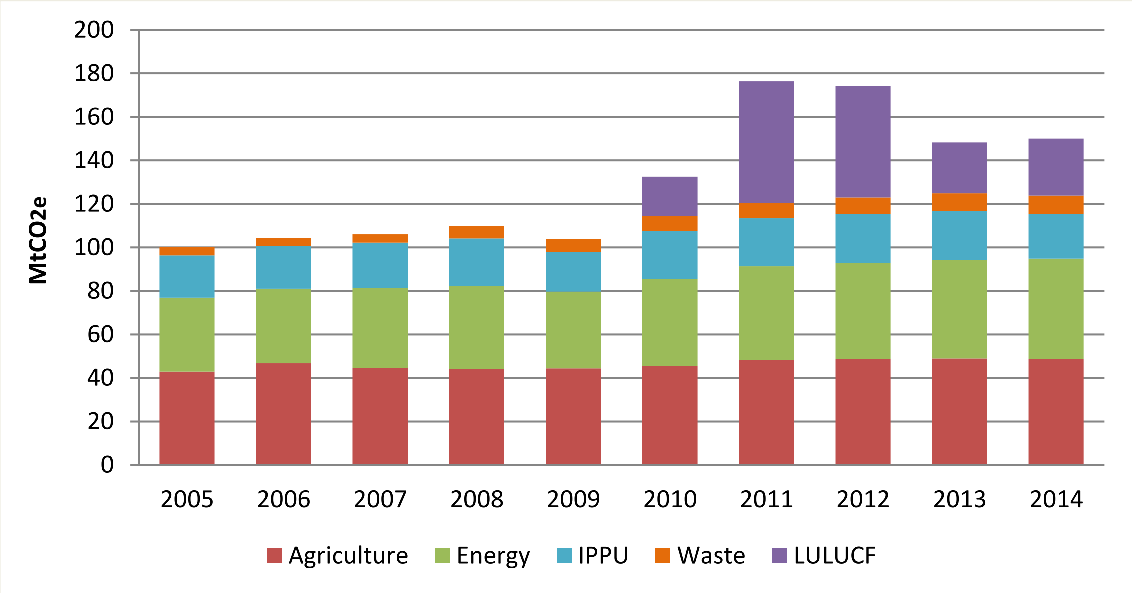

Figure 13. Emissions of the State of Minas Gerais, by sector, in the period 2005-2014 (Mt CO_2e)
Note: LULUCF data available only from 2010.

Source: MG State GHG Inventory

The state inventory indicates a drop in total emissions in 2009 of approximately 6% over the previous year, which coincides with a slowdown in the State's GDP growth rate (Figure 14). In 2010, the 27.5% increase in emissions comparing to 2009 includes LULUCF not accounted in previous years. When we disregard LULUCF, emissions increase only 10% and are influenced by the recovery of GDP (Figure 14).

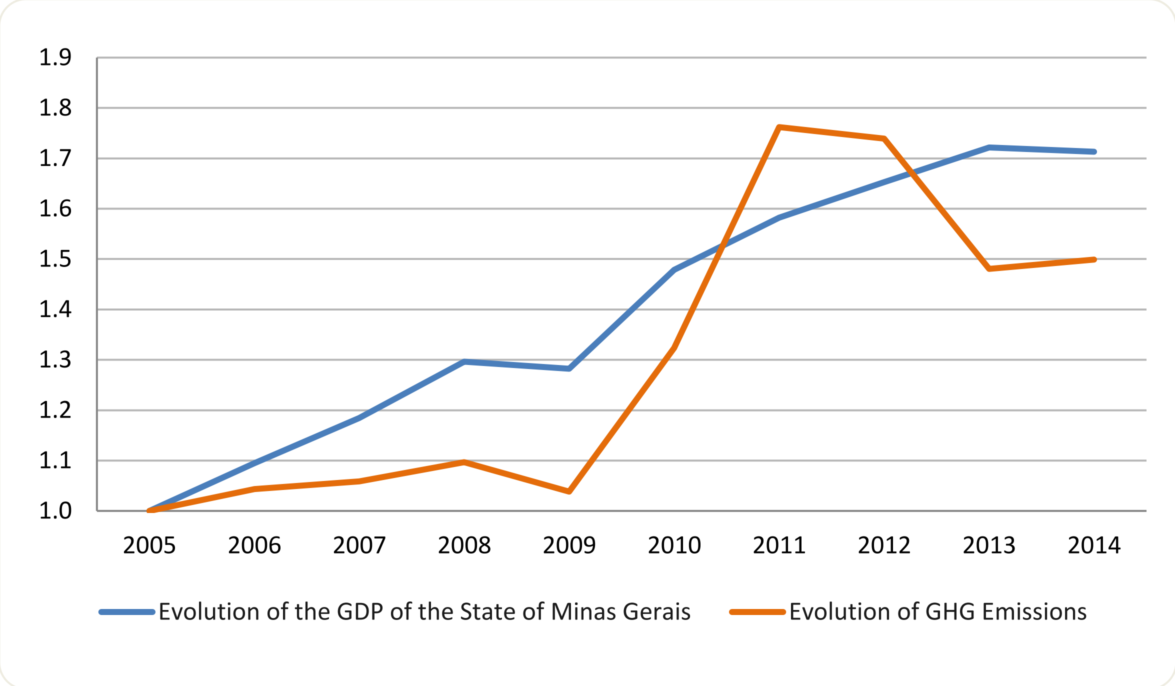

Figure 14. GDP (2014 basis) growth and GHG emissions curves of the State of Minas Gerais (2005=1)

Source: MG State GHG Inventory

2.3.2 Evolution of sectoral emissions

a. Energy Use

In the energy sector, anthropogenic emissions from energy production transformation and energy consumption are estimated, which covers both emissions resulting from the direct burning of fuels and leakages in the production, transformation, distribution, and consumption chains.

According to data from the 30th Energy Balance of the State of MG – BEEMG (CEMIG, 2016), between 1978-2014, the average demand for energy grew approximately 2.5% per year, following the national average of 3%. In 2014, the total state demand for energy reached about 38 million toe (ton of oil equivalent), equivalent to 12.5% of national demand. Of this total, the share of oil products reached 40%, mineral coal 10%, sugar cane products 16%, biodiesel 1%, hydro 13%, wood 18%, and others 2%. Of the subsectors considered, the sum of energy consumption in industry and transportation accounted for more than 85% of the total demand in 2014.

Emissions from the energy sector in 2014 accounted for approximately 46 Mt CO_2e. In the period from 2005 to 2014 there was an increase of approximately 35%, that is, an average growth of 3.5% per year (Table 25).

Table 25. Emissions from the energy sector of the State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2005-2014
	Mt CO_2e										%
Agriculture	1.62	1.64	1.6	1.81	1.71	1.76	1.78	1.88	1.89	1.8	11%
Commercial	0.09	0.09	0.1	0.1	0.11	0.1	0.11	0.09	0.09	0.09	0%
Energy Supply	5.1	5.39	5.02	5.69	4.12	5.53	5.4	6.27	5.85	5.93	16%
Charcoal	2.13	2.26	2	2.02	1.42	1.9	1.89	2.17	1.98	2.04	-4%
Auto-producers Power Plants	1.26	1.25	1.32	1.51	1.2	1.78	2.15	2.19	1.76	1.77	40%
Public Service Electric Power Plants	0.33	0.49	0.33	0.76	0.18	0.56	0.05	0.56	0.9	0.9	173%
Own consumption in transformation centers	1.37	1.39	1.38	1.4	1.31	1.29	1.31	1.35	1.22	1.22	-11%
Industry	8.18	8.17	9.06	9.1	8.42	9.49	10.39	10.06	9.97	9.93	21%
Food and Beverages	0.55	0.59	0.6	0.62	0.62	0.7	0.68	0.69	0.7	0.69	25%
Lime	0.63	0.62	0.66	0.66	0.57	0.7	0.72	0.67	0.65	0.62	-2%
Ceramic	0.33	0.32	0.36	0.36	0.34	0.38	0.4	0.42	0.42	0.42	27%
Cement	1.66	2.16	2.7	2.66	3	3.19	3.5	3.36	3.35	3.88	134%
Ferroalloy	0.11	0.12	0.11	0.11	0.1	0.1	0.06	0.06	0.04	0.05	-55%
Mining and pelletizing	0.83	0.9	1	0.99	0.75	0.91	0.91	0.91	0.84	0.85	2%
Non-Ferrous Metals and Other	0.43	0.42	0.45	0.44	0.39	0.45	0.57	0.57	0.57	0.5	16%
Other Steel	0.06	0.06	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.06	0%
Paper and Cellulose	0.33	0.23	0.21	0.19	0.15	0.18	0.26	0.26	0.27	0.26	-21%
Chemistry	0.44	0.46	0.49	0.48	0.42	0.49	0.5	0.52	0.52	0.51	16%
Textile	0.37	0.36	0.37	0.38	0.33	0.38	0.37	0.37	0.36	0.34	-8%
Integrated steelworks	2.23	1.7	1.79	1.88	1.45	1.68	2.09	1.92	1.93	1.51	-32%
Other industries	0.23	0.22	0.24	0.26	0.24	0.26	0.26	0.25	0.25	0.24	4%
Public	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0%
Residential	2.43	2.42	2.39	2.45	2.47	1.85	1.84	1.85	1.84	1.79	-26%
Transport	16.63	16.55	18.51	19.03	18.47	21.28	23.35	24.12	25.71	26.52	59%
Airways	0.28	0.32	0.34	0.4	0.48	0.6	0.76	0.87	0.86	0.85	204%
Railways Freight	0.36	0.38	0.38	0.41	0.38	0.57	0.65	0.73	0.71	0.63	75%

Road	15.99	15.86	17.8	18.21	17.61	20.11	21.94	22.52	24.14	25.04	57%
Total	**34.05**	**34.28**	**36.7**	**38.19**	**35.32**	**40.03**	**42.88**	**44.28**	**45.36**	**46.05**	**35%**

Source: MG State GHG Inventory

The state inventory indicates a drop in emissions in 2009 of approximately 8% over the previous year, which coincides with a slowdown in the growth of the State's gross domestic product (GDP) (Figure 15). That same year, there was a downturn in the industrial sector.

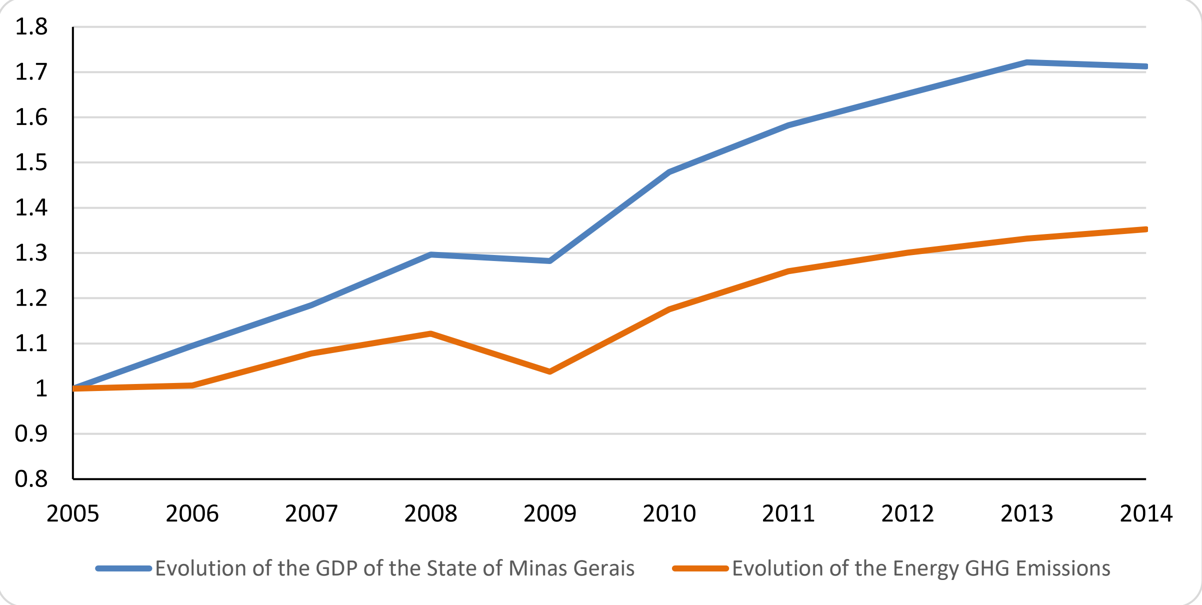

Figure 15. GDP (2014 basis) growth and energy emissions curves of the State of Minas Gerais (2005=1)

Source: MG State GHG Inventory

Among fossil fuels, diesel oil (46%) was the major contributor to emissions in the energy use sector, followed by gasoline (20%) and petroleum coke (10%). A large part of the diesel oil emissions occurred in the transportation and industry subsectors. The high share of petroleum coke is due to cement production.

Figure 16 shows the evolution of each fuel share in road transport between 2005 and 2014. Although the consumption of fossil fuel is predominant, it is possible to verify an increase in the share of renewables (biodiesel and ethanol) in recent years.

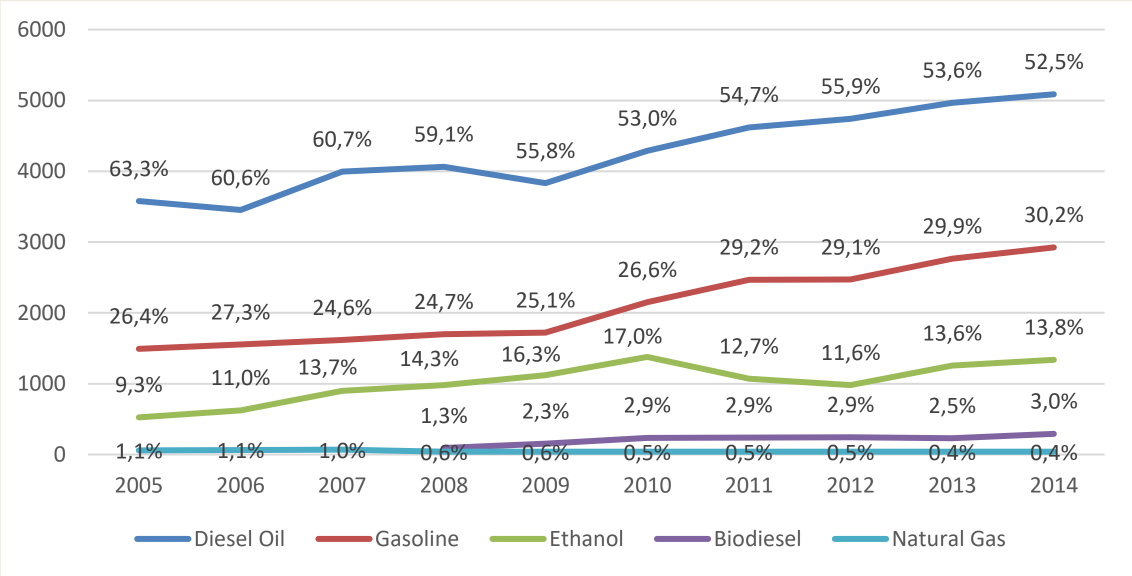

Figure 16. Fuel consumption in the road transport mode in the State of Minas Gerais (10³ toe)

Source: adapted from the MG State GHG Inventory

In respect to renewables, the state of Minas Gerais has over 393 MW of solar energy (photovoltaic), and 0.16 MW of wind energy already installed. In addition, 4.175 MW of solar power are approved, but the construction has not yet started (Figure 17).

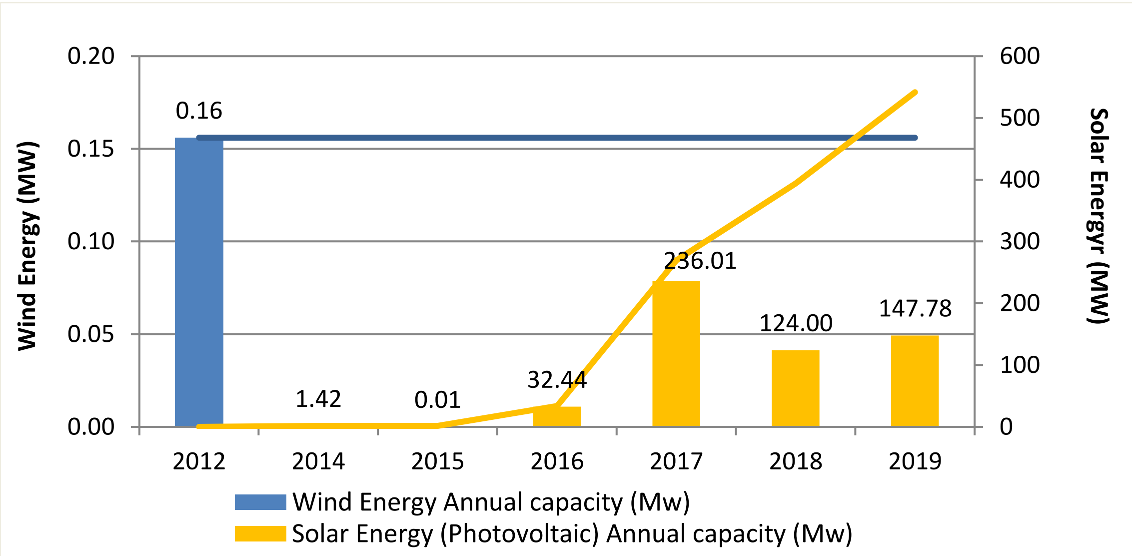

Figure 17. Annual and cumulative installed capacity of wind and solar energy in State of Minas Gerais

Source: ANEEL, 2020

b. Industrial Processes and Product Use (IPPU)

Between 2005 and 2014 the IPPU sector's total emissions grew 5%, totalling 20.5 Mt CO_2e on the last year. However, it should be noted that throughout this period emissions were not linear, coinciding with a market retraction in 2009 and 2014 (Table 26). The peak of emissions occurred in 2012, when emissions increased by 15% compared to 2005.

Table 26. Emissions from Industrial Processes and Product Use (IPPU) of the State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2005-2014
	Mt CO_2e										%
IPPU	**19.52**	**19.54**	**20.72**	**21.85**	**18.17**	**22.03**	**22.09**	**22.45**	**22.47**	**20.5**	**5%**
Minerals	6.17	6.72	7.2	7.82	7.56	8.58	9.27	9.68	9.5	9.31	51%
Metals	13.34	12.81	13.51	14.02	10.6	13.44	12.81	12.76	12.96	11.18	-16%
Chemical	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-8%

Source: Adapted from the MG State GHG Inventory

The 2009 financial crisis had an impact on several productive sectors, mainly in the metal industry. This subsector, which is responsible for 61% of emissions on average, experienced a sharp decline in steel production, which reflected in CO_2e emissions.

Metallurgical Industry Subsector

This subsector includes industries that produce aluminium, metallic magnesium, iron, steel and iron alloys. On average, 89% of the emissions from the metal industry comes from the production of iron and steel. The average CO_2e emissions from the metal industry sub-sector in the period from 2005 to 2014 was 11.47 Mt CO_2e for iron and steel, 0.78 Mt CO2e for aluminium, 0.35 Mt CO_2e for magnesium and 0.22 Mt CO_2e for ferroalloys.

Iron and steel manufactured in integrated and non-integrated plants are one of the main products exported by the State. According to Instituto Aço Brasil (Brazilian Institute of Steel), the country is the largest producer in Latin America and ranks sixth as a net steel exporter and ninth as producer in the world (IABR, 2016). In addition, the state of Minas Gerais produces about 50% of the country's Iron (SINDIEXTRA, 2016).

In 2010, about 44% of iron production used biomass for ore reduction. Likewise, most of the production of iron alloys relied on biomass as reductant. CO_2 emissions from charcoal burning are considered neutral since the gas emitted is reabsorbed in the photosynthesis process and are therefore not accounted for in total emissions.

According to data from the Brazilian Aluminium Association, the participation of Minas Gerais in national aluminium production has been decreasing (ABAL, 2016). In 2013 and 2014 state production of primary aluminium fell 26% and 74%, respectively, in relation to 2012. As consequence, CO_2e emissions also decreased.

As to produce metallic magnesium, there is only one producing company in Brazil, which is in Minas Gerais. The company was the first national metallurgical company to have Clean Development Mechanism (CDM) projects approved for the implementation of actions linked to the use of their own renewable resources. Also, as of 2010 the company replaced the use of sulphur hexafluoride (SF_6) with sulphur dioxide (SO_2), what resulted in a decrease of 79% in the sector emissions.

Chemical Industry Subsector

The production of various compounds, organic and inorganic, results in the emission of considerable amounts of GHG. In Minas Gerais, the production processes of the chemical industry that emit GHG in significant quantities are the production of ammonia and the production of phosphoric acid. However, due to the lack of data on phosphoric acid production, only emissions from ammonia production were accounted for, in which CO_2 is one of the by-products of its manufacturing process. CO_2 emissions were estimated based on production data released by the Brazilian Chemical Industry Association (ABIQUIM, 2014). Between 2005 and 2014, emissions remained relatively stable. The average annual production over these years was 7.868 thousand tons and the average emission was 11.4 kt.

Mineral industry Subsector

In this subsector, CO_2 emissions from the cement industry and lime manufacturing were estimated, being the first responsible for 57% of emissions in 2014 and the second for 43%. During cement production, about 90% of CO_2 emissions come from the clinker manufacturing process. Between 2005 and 2014, emissions increased by 61% mainly due to the production growth.

In lime production, CO_2 emissions occur during the limestone calcination process. In 2014, emissions accounted for 3.58 Mt CO_2e, 32% higher than in 2005. Total emissions were further broken down by type of lime: magnesite, dolomitic and calcite.

c. Waste

In this sector, emissions from the treatment and final disposal of solid waste and effluents both of urban and industrial origin were accounted for. The historical series show an increase in emissions from 2008 (Table 27). This trend may be associated with inconsistency and, often, with the lack of data on incineration activities and disposal of solid urban waste. Many of the industrial data – composting and incineration – used in the estimates came from the companies' self-declaration, where there was a great oscillation and lack of information in the period 2005-2007. In addition, data was also lacking from the municipalities that had their waste in landfills prior to 2009.

From 2013, emissions reached more than 8 Mt CO_2e. Emissions from urban solid waste and industrial effluents stand out due to the high generation in the State. Emissions increased by approximately 178% and 55%, respectively in relation to 2005.

Table 27. Emissions from the Waste Sector of the State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2005-2014
	Mt CO_2e										%
Urban solid waste	1.34	1.24	1.14	1.42	2.93	3.13	3.28	3.94	3.59	3.72	178%
Open dump	0.76	0.7	0.64	0.8	0.48	0.5	0.45	0.47	0.42	0.41	-46%
Composting	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.04	300%
AAF	0	0	0	0	0.09	0.08	0.07	0.07	0.06	0.04	-56%
Landfill	0	0	0	0	1.72	1.94	2.1	2.71	2.5	2.65	54%*
Unmanaged deep dump site	0.57	0.52	0.48	0.6	0.61	0.57	0.62	0.65	0.57	0.58	2%
Industrial Solid Waste	0	0	0	1.5	0.11	0.21	0.11	0.07	0.57	0.57	-62%**
Domestic wastewater	0.87	0.87	0.87	0.87	0.87	1.29	1.29	1.29	1.65	1.65	90%
Industrial wastewater	1.58	1.63	1.82	1.93	2.06	2.16	2.33	2.31	2.37	2.45	55%
Total	3.79	3.74	3.83	5.72	5.97	6.79	7.01	7.61	8.18	8.39	121%

*Variation between 2009-2014, since there is no data available before 2009.
**Variation between 2007-2014, since there is no data available before 2009.
Source: MG State GHG Inventory

The table above also shows that between 2005 and 2008, the most important CO_2e emissions source from solid waste treatment regarding the type of destination was the open dump. However, as the level of sanitation services increased and the operational conditions at disposal sites improved, emissions from landfills grew reinforcing the need to invest in methane capture and destruction or (preferably) energy use systems in landfills.

d. Agriculture, Forestry and Other Land Use – AFOLU Sector

Emissions from the AFOLU sector increased 18% from 2010, the first year with data for deforestation, to 2014 (Table 28 and Figure 18). In the entire period (2005-2014) emissions from Agriculture increased 14%, with crops increasing more (22.2%) than livestock (8.6%)

Table 28. Emissions from the Agriculture, Forestry and Land Use Change (AFOLU) Sector of the State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2005-2014
	Mt CO_2e										%
LULUCF	**0**	**0**	**0**	**0**	**0**	**18.09**	**56.04**	**51.19**	**23.48**	**26.25**	**45.1%***
Agriculture	**42.9**	**46.79**	**44.59**	**44.06**	**44.5**	**45.5**	**48.46**	**48.68**	**48.93**	**48.8**	**13.8%**
Crops	**16.2**	**18.09**	**17.59**	**17.16**	**17.2**	**17.9**	**19.36**	**19.58**	**19.43**	**19.8**	**22.2%**
Liming	0.99	1.47	1.3	1.33	0.87	1.63	1.89	2	1.85	2.02	104.0%
Rice cultivation	0.32	0.25	0.25	0.19	0.17	0.13	0.12	0.02	0.02	0.02	-93.8%
Burning of forest residues	0.29	0.37	0.44	0.54	0.66	0.14	0.15	0.16	0.16	0.16	-44.8%
Agricultural soils	14.6	16	15.6	15.1	15.5	16	17.2	17.4	17.4	17.6	20.5%
Livestock	**26.7**	**28.7**	**27**	**26.9**	**27.3**	**27.6**	**29.1**	**29.1**	**29.5**	**29**	**8.6%**
Enteric fermentation	24.8	26.7	25	24.8	25.1	25.4	26.7	26.7	27	26.5	6.9%
Manure management	1.92	2.02	2.04	2.06	2.15	2.23	2.36	2.39	2.5	2.53	31.8%
Total	**42.9**	**46.79**	**44.59**	**44.06**	**44.5**	**63.59**	**104.5**	**99.87**	**72.41**	**75.05**	**18.%***

*Only 2010-2014 variation
Source: MG State GHG Inventory

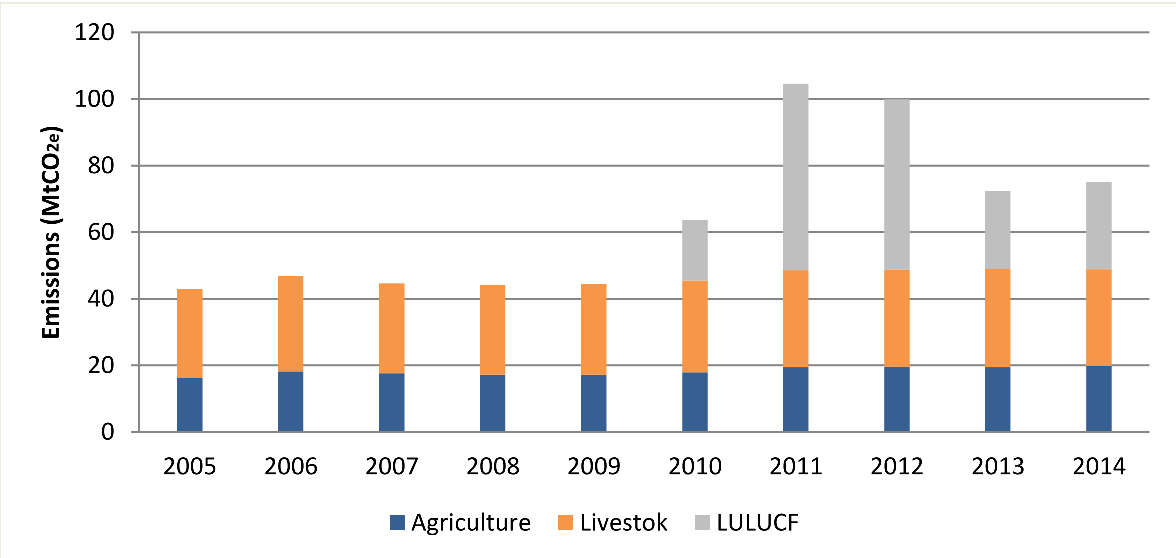

Figure 18. Emissions from the Agriculture, Forestry and Land Use Change (AFOLU) sector of the State of Minas Gerais (Mt CO_2e)
Source: MG State GHG Inventory

Land Use, Land-Use Change, and Forestry (LULUCF) subsector

The Land Use Change and Forestry sector (LULUCF), considering the Forestry sub-sector, presented a peak of emissions in 2011 (58.9 Mt CO_2e) with a sharp drop until reaching 29.1 Mt CO_2e in 2014 (Table 29). Federal, state, and municipal conservation units (CUs) had total removals of 2.8 Mt CO_2e / year.

Table 29. Emissions from deforestation in the State of Minas Gerais (Mt CO_2e and %)

Emission Sources (biome)	2010	2011	2012	2013	2014	2015	2016	2010-2016
	Mt CO_2e							%
Cerrado	13.5	51.4	42.1	16.7	22.3	7.6	8.1	-40%
Atlantic forest	6.8	6.6	11.7	9.1	6.1	8.5	7.8	15%
Caatinga	0.6	0.9	0.2	0.5	0.7	0.5	0.3	-50%
Total	**20.9**	**58.9**	**54**	**26.3**	**29.1**	**16.6**	**16.2**	**-22%**

Source: MG State GHG Inventory

From the results obtained in this work, it is not yet possible to clearly identify a trend for emissions from the land use change and forestry sector in Minas Gerais, requiring a more extensive historical series to carry out projections of future scenarios. However, the sector's role in mitigating GHG emissions in the Minas Gerais territory is evident in the short and medium term.

Agriculture subsector

In agriculture, the state is the fifth largest producer, contributing to 10.8% to national agricultural production in 2014 (IBGE, 2014b). The agricultural sector stands out from the rest, being responsible for approximately 46% of the state's total emissions in 2014. Between 2005 and 2014, the sector's emissions increased by about 15%. This trend is mainly justified by the increase in the cattle herd. It is also important to highlight that the significant emission reductions resulting from investments in low carbon technologies and agricultural practices (Plano ABC) were not accounted for due to the unavailability of disaggregated data for Minas Gerais.

Livestock (enteric fermentation and manure management)

In 2014, Minas Gerais had the second largest herd of cattle in the country, with around 23.8 million head (MAPA, 2015). In the same year, Minas was considered the largest producer of milk, with 26% of national production (IBGE, 2014a). Compared to other subsectors, enteric fermentation is an activity that has been contributing the most over the years.

Emissions from manure management, although less significant than enteric fermentation, represent an important emission source specially when added to the emissions from the application of manure as soil fertilizer (emissions accounted for in crops), reaching about 3 Mt CO_2e. According to data from Municipal Livestock Production in 2014 (Inventory Report), Minas Gerais is one of the largest pork producers, along with Paraná and São Paulo. Emissions from swine manure management alone accounted for almost 40% of emissions in this subsector in 2014.

Agricultural soils

As for the application of synthetic fertilizers, according to the National Association for the Dissemination of Fertilizers (ANDA), more than 600 thousand tons of nitrogen fertilizers were delivered to the final consumer in Minas Gerais in 2014, most of which were in the form of urea. As a result, that same year, around 2 Mt CO_2e were emitted.

Burning of agricultural residues (sugarcane)

It is observed that the emissions resulting from residues burning decreased 75% in relation to 2009. This trend is justified by the reduction of the burning practice in sugarcane plantations, encouraged by the "Protocol for Sugar Cane Burning Elimination set with the Sugar and Alcohol Sector" and reinforced by the Joint Resolution SEMAD / IEF no. 2075/2014. According to data from the Association of Sugar-Energy Industries of Minas Gerais – SIAMIG, the burning practices in sugarcane plantations occur only on land with more than 12% slope in recent years, which corresponds to approximately 2% of the total planted area (SIAMIG, 2014).

Rice cultivation

There is also a reduction in emissions from rice cultivation, specifically lowland rice, whose production data has progressively decreased over the period analysed.

2.4 Evaluation of aggregated values and intensity indicators

Table 30 shows the emission sources in a decrease order of magnitude, considering the year 2014. Table 31 shows the indicators used to assess the evolution of emissions. It shows that the total emissions grew 49.9% in the period 2005-2014. During this period, GDP grew 71%, resulting in a decrease in the carbon intensity of GDP of 12.5% in the period. On the other hand, per capita emissions increased 40.75%. Note that in tables 30 and 31 the economy sectors' structure was used, not the sector structure of the 2006 IPCC Guidelines.

Table 30. Total emissions of the State of Minas Gerais, by sector, in decreasing order of magnitude (Mt CO_2e and %)

Emission Sources	2005	2010	2014	Emissions share in 2014
	Mt CO_2e			%
Total agriculture emissions (Crops, Livestock and energy emissions)	44.52	47.26	50.6	33.7%
Industry emissions (Energy and IPPU)	27.7	31.52	30.43	20.2%
Transport emissions	16.63	21.28	26.52	17.6%
LULUCF net emissions	NA	18.09	26.25	17.5%
Energy supply emissions	5.1	5.53	5.93	3.9%
Urban solid Waste emissions	1.34	3.13	3.72	2.4%
Industry emissions from waste (Solid and wastewater)	1.58	2.37	3.02	2.0%
Households emissions	2.43	1.85	1.79	1.1%
Urban wastewater emissions	0.87	1.29	1.65	1.1%
Commercial emissions	0.09	0.1	0.09	0.0%
Public Sector emissions	0.01	0.01	0.01	0.0%
Total	100.27	132.43	150.01	100.0%

Source: based on MG State GHG Inventory

Table 31. Emission and economic indicators of the State of Minas Gerais in 2005, 2010 and 2014

Annual indicators		2005	2010	2014	2005-2010	2010-2014	2005-2014
Economy Wide	Total emissions (Mt CO_2e)	100	133	150	32.4% (1)	13.2%	49.9%(1)
	Total emissions without LULUCF (Mt CO_2e)	100	114	124	14.3%	8.2%	23.7%
	GDP (Million R$ of 2015)	333,815	493,652	571,774	47.9%	15.8%	71.3%
	Carbon intensity of GDP (t CO_2e/Million R$ 2015)	300	269	262	-10.5%(1)	-2.2%	-12.5%(1)
	Carbon intensity of GDP without LULUCF (t CO_2e without LULUCF emissions/Million R$ 2015)	300	232	217	-22.7%	-6.6%	-27.8%
	Population (Million people)	19.3	20.0	20.5	3.6%	2.8%	6.5%
	Per capita emissions (total t CO_2e/inhab.)	5.20	6.64	7.32	27.7%(1)	10.2%	40.7%(1)
	Per capita emissions without LULUCF (t CO_2e without LULUCF emissions/inhab.)	5.20	5.74	6.04	10.3%	5.3%	16.1%
Energy Supply and Other Energy Indicators	Total energy supply (M toe)	25.5	28.6	29.7	11.9%	3.8%	16.2%
	Total energy supply (Mt CO_2e)	5.10	5.53	5.93	8.4%	7.2%	16.3%
	TPES / capita (toe/capita)	1.33	1.43	1.45	7.9%	1.1%	9.1%
	Total electricity demand (TWh)	45.3	55.0	57.7	21.5%	4.8%	27.3%
	Electricity demand over GDP (MWh / Million R$ 2015)	136	111	101	-17.9%	-9.5%	-25.7%
	Share of electricity in total energy demand (%)	0.15	0.17	0.17	8.6%	0.9%	9.6%
	Carbon intensity of electricity consumed (Kg CO_2e/MWh) (2)	NA	NA	NA	NA	NA	NA
	Emissions from total energy supply over GDP (t CO_2e/Million R$ 2015)	15.3	11.2	10.4	-26.7%	-7.4%	-32.1%

Annual indicators		2005	2010	2014	2005-2010	2010-2014	2005-2014
Transport Sector	Transport emissions (Mt CO_2e)	16.6	21.3	26.5	28.0%	24.6%	59.5%
	Transport emissions/GDP (t CO_2e/Million R$ 2015)	49.8	43.1	46.4	-13.5%	7.6%	-6.9%
	Share of ethanol in the road mode (%)	9.3%	17.0%	13.8%	83.5%	-18.8%	48.9%
Industry	Industry emissions – energy and IPPU (Mt CO_2e)	27.7	31.5	30.4	13.8%	-3.5%	9.8%
	Industry Value Added (Million R$ 2015)	92,214	142,378	144,868	54.4%	1.7%	57.1%
	Industry emissions/GDP (t CO_2e/Million R$ 2015)	83.0	63.9	53.2	-23.1%	-16.6%	-35.9%
	Industry emissions/VA of Industry (t CO_2e/Million R$ 2015)	300	221	210	-26.3%	-5.1%	-30.1%
Other energy demand sectors	Commercial emissions (Mt CO_2e)	0.09	0.10	0.09	11.1%	-10.0%	0.0%
	Commercial emissions/GDP (t CO_2e/Million R$ 2015)	0.27	0.20	0.16	-24.9%	-22.3%	-41.6%
	Households emission (Mt CO_2e)	2.43	1.85	1.79	-23.9%	-3.2%	-26.3%
	Households per capita emissions (kg CO_2e/inhab.)	126	92.7	87.3	-26.5%	-5.8%	-30.8%
	Public Sector emissions (Mt CO_2e)	0.01	0.01	0.01	0.0%	0.0%	0.0%
	Agriculture energy emissions (Mt CO_2e)	1.62	1.76	1.80	8.6%	2.3%	11.1%
AFOLU	AFOLU net emissions (Mt CO_2e)	42.9	63.6	75.1	48.2%(1)	18.0%	74.9%(1)
	AFOLU emissions/VA of Agriculture (kt CO_2e /Million R$ 2015)	2.27	2.65	2.65	16.6%(1)	0.1%	16.7%(1)
LULUCF	Deforestation (km^2/year)	NA	319	532	NA	67.0%	NA
	Protected Areas and Indigenous Lands (Mha/year)	NA	NA	NA	NA	NA	NA
	LULUCF net emissions (Mt CO_2e)	NA	18.1	26.3	NA	45.1%	NA

Annual indicators		2005	2010	2014	2005-2010	2010-2014	2005-2014
	LULUCF net emissions/Annual deforestation area (kt CO_2e/km^2)	NA	56.8	49.3	NA	-13.1%	NA
	LULUCF net emission/GDP (t CO_2e/Million R$ 2015)	NA	36.6	45.9	NA	25.3%	NA
	LULUCF emissions/VA of Agriculture (t CO_2e/Million R$ 2015)	NA	753	927	NA	23.1%	NA
Agriculture	Number of cattle (cattle heads (million))	21.4	22.7	23.8	6.1%	4.8%	11.2%
	Total agriculture emissions (Crops & Livestock – Mt CO_2e)	42.9	45.5	48.8	6.1%	7.3%	13.8%
	Total agriculture emissions (Crops, Livestock and energy- Mt CO_2e)	44.5	47.3	50.6	6.2%	7.1%	13.7%
	Value Added of Agriculture (Million R$ 2015)	18,888	24,021	28,317	27.2%	17.9%	49.9%
	Total agriculture emissions (includes energy emissions)/VA of Agriculture (kt CO_2e/Million R$)	2.36	1.97	1.79	-16.5%	-9.2%	-24.2%
	Livestock Emission/ Meat production (Mt CO_2e / Mt)	59.2	49.3	38.9	-16.7%	-21.2%	-34.4%
	Meat production / VA of Agriculture (t/ Million R$ 2015)	23.9	23.3	26.3	-2.4%	13.1%	10.4%
	Livestock Emissions / VA of Agriculture (kt CO_2e/Million R$ 2015)	1.56	1.15	1.02	-26.6%	-10.9%	-34.5%
	Meat production / Pastureland Area (kt/Mha)	23.8	30.0	39.1	26.0%	30.4%	64.4%
	Livestock / Pastureland Area (cattle head / ha)	1.13	1.22	1.25	7.7%	2.5%	10.5%
	Pastureland area / VA of Agriculture (M ha/Billion R$ 2015)	1.00	0.78	0.67	-22.6%	-13.3%	-32.9%
	Agricultural area /VA of Agriculture (M ha/Billion R$ 2015)	0.28	0.23	0.20	-17.2%	-12.7%	-27.7%

Annual indicators		2005	2010	2014	2005-2010	2010-2014	2005-2014
Waste	Solid waste deposited in Managed Landfills (Mt)	NA	NA	NA	NA	NA	NA
	Waste Emissions (Mt CO_2e)	3.79	6.79	8.39	79.2%	23.6%	121.4%
	Per capita waste emissions (Total t CO_2e/inhab.)	0.20	0.34	0.41	72.9%	20.2%	107.9%
	Total solid Waste emissions (Mt CO_2e)	1.34	3.34	4.29	149.3%	28.4%	220.1%
	Total solid waste per capita emissions (t CO_2e/inhab.)	0.07	0.17	0.21	140.5%	25.0%	200.6%
	Total wastewater emissions (Mt CO_2e)	2.45	3.45	4.10	40.8%	18.8%	67.3%
	Total wastewater per capita emissions (t CO_2e/inhab.)	0.13	0.17	0.20	35.9%	15.6%	57.1%

[1] As there are no values for LULUCF prior to 2010, these values are merely illustrative.
Only data for the national grid is available
NA = not available
Source: Authors based on the MG State GHG Inventory and IBGE (2020)

2.5 Conclusion

Minas Gerais GHG historical data allowed a detailed assessment of the evolution of the emissions profile and the identification of priority areas for mitigation in the state. Over the analysis period, there was an increase of 49.9% in state emissions in 2014 (150.08 Mt CO_2e) in relation to 2005 (100.13 Mt CO_2e).

Regarding the evolution of sectoral emissions, it is worth mentioning that four sectors were responsible for 88.0% of emissions in 2014: agriculture (crops and livestock), industry, transport and LULUCF.

Considering the sectors and its subsectors, as presented in Table 30, the agriculture sector was the largest emitter with 33.7% of the total emissions from the state in 2014, the industry sector is the second largest emitter with a share of 20.2%, followed by the transport sector with 17.6% and the LULUCF sector with 17.5%. Others represent a smaller percentage of total emissions.

Ranking the emissions rate of increase in the period 2005-2014, the solid waste sector stands out with an increase of 220%, followed by the wastewater sector (67%) and the transport sector (59%). As there is no available data for LULUCF in 2005, the increase in emissions is available only for the period 2010-2014, when it was of 45.1%.

The energy supply, agriculture and industry sectors increased their emissions in 13.8, 11.1 and 9.8%, respectively. The emissions of the commercial and the public sectors remained constant, while those from households decreased by 26.3%.

3 State of Amazonas

This section presents the study on the state of Amazonas, describing its historical greenhouse gas (GHG) emissions and assessing its emissions trends.

3.1 Commitments assumed by the state of Amazonas

The Amazonas State instituted the State Policy on Climate Change, Environmental Conservation and Sustainable Development (PEMC-AM, Law no. 3135/07) in 2007. The main objectives of the PEMC-AM are to create programs and incentives that promote the mitigation of greenhouse gas emissions and adaptation measures in the Amazon state. Still in 2007, the government approved the Decree no. 26958/07 establishing the Bolsa Floresta Program - and the Law no. 3184/07- modifying the Law no. 3135/07 and regulating the PEMC-AM. In 2009, the state created the Amazonas Forum on Climate Change, Biodiversity and Environmental Services (FAMC), with three thematic chambers: (1) land use, forests and environmental services, (2) energy, and (3) adaptation and mitigation of climate change.

In 2015, the Amazonas state instituted the State Policy on Environmental Services and the Environmental Services Management System (Law no. 4266/2015), which creates the State Fund for Climate Change, Environmental Conservation and Environmental Services (altering state laws no. 3135/2007 and 3184/2007). The objective of that law is to reduce state GHG emissions progressively and consistently and promote the long-term maintenance of existing carbon stocks, with a view to achieving the state's voluntary goal of reducing emissions from deforestation and forest degradation, social and environmental criteria.

As mentioned, the State Policy that creates the State Fund for Climate Change, was launched in 2015, in the same year of the Brazilian NDC pledges. After that, some state policies have been introduced with other main objectives, but also contributing to the mitigation of GHG emissions, as follows:

- Law no. 249/2015 - provides for the separation of recyclable waste discarded by the public agencies and its destination to associations and cooperatives of recyclable material collectors.
- Law no. 4419/2016 - Institutes the Amazonas State Economic and Environmental Policy for Sustainable Development, called “Amazonas Economic and Environmental Matrix”.
- Law no. 4415/2016 - provides on the management of forests located in areas of the state's domain for sustainable production, establishes in the structure of the State Secretariat for the Environment (SEMA) the Deputy Executive Secretariat for Forest Management - SEAGF, and creates the State Fund for Forest Development - FEDF among other measures.
- Law no. 4406/2016 - establishes the State Policy for Environmental Regularization, provides for the Rural Environmental Registry (CAR), the Rural Environmental Registry System (SISCAR-AM), the Environmental Regularization Program (PRA), in the State of Amazonas and provides other measures.

3.2 GHG emissions inventory – methodology and structure

As the state does not provide his own inventory report, the present study uses the emissions estimates from the SEEG (Greenhouse Gas Emissions Estimation System) Brazil database, considering the 2005-2018 period and following the structure showed in Figure 1. All gases are expressed in carbon dioxide equivalent (CO_2e), using the IPCC AR5 Global Warming Potential (GWP) (IPCC, 1995; 2013)

The inventory is divided into sectors, according to the IPCC methodology (2006), as follows:

1. Energy – emissions from fuel consumption in the energy transformation, residential, commercial, public, agricultural, transportation and industrial sectors, and fugitive emissions from the oil and gas industry.
2. Industrial Processes and Use of Products (IPPU) – emissions from productive processes in industries and which are not the result of the energy use of fuels. Cement is the segment considered in the Amazonas state;
3. Agriculture, Forests and Other Land Use (AFOLU) – emissions and removals resulting from variations in the amount of biomass in areas with vegetation. Emissions due to cattle enteric fermentation, manure management, agricultural soils and burning of forest residues; and
4. Waste – emissions from the disposal of urban and health solid waste and from the treatment of urban and industrial sewage/wastewater.

The sectoral structure for estimating GHG emissions and removals, as well as the subsectors and categories are shown in Figure 19. It is noteworthy that the report used the 2006 IPCC guidelines structure to estimate the emissions, as above.

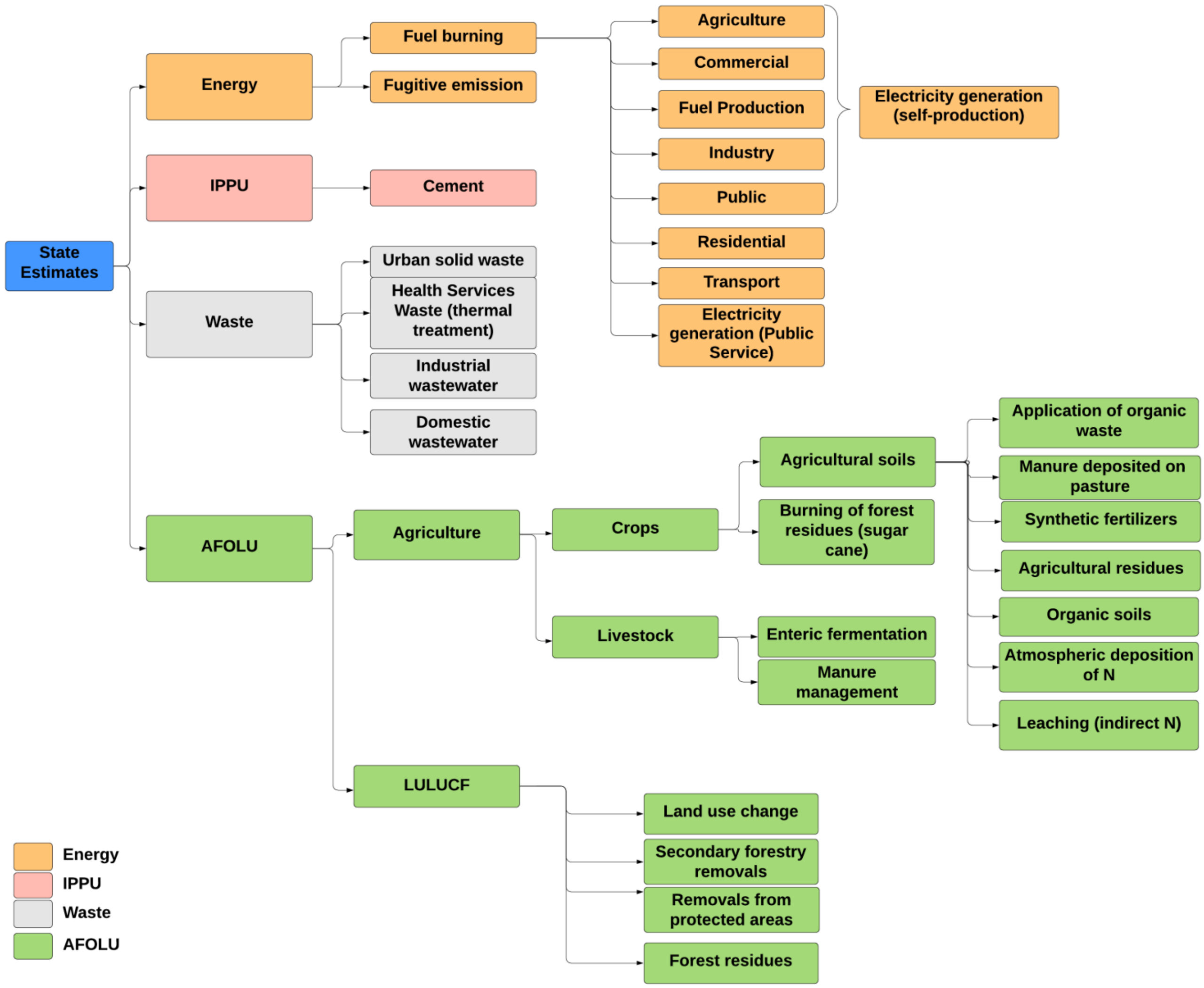

Figure 19. Structure of the inventory of the State of Amazonas.

Note: based on the SEEG database

The inventory accounts for emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (Table 32). Data on the other GHG are not available.

Table 32. Greenhouse gases accounted for in the Inventory of the State of Rio de Janeiro, by sector

Sector	Energy	Industrial	AFOLU	Waste
Gases	CO_2	CO_2	CO_2	CO_2
	CH_4	CH_4	CH_4	CH_4
	N_2O	N_2O	N_2O	N_2O

3.3 GHG emissions from the State of Amazonas (2005-2018)

3.3.1 Evolution of total emissions

From 2005 to 2018 there was a reduction of 7.5% in total net emissions, what occurred due to an increase in removals from LULUCF (29.6%) and a reduction of emissions from the IPPU sector (48.9%). Although there was a significant increase in emissions from the waste (44.9%), energy (33.8%), agriculture (59.6%) and LULUCF (32%, gross emissions) sectors.

It is worth mentioning that although there was an increase in emissions from waste, energy and agriculture, only gross LULUCF emissions is really relevant as they represent 79.2% of total gross emissions in 2018 and therefore the most important source of emissions in the state. It is also important to highlight that from 2005 to 2009, emissions from this source decreased by 48.8%, remaining almost constant until 2014, when it increased again. In 2018, these emissions were 158.0% higher than in 2009.

The aggregate emissions from the sectors and variations overtime are shown in Table 33.

Table 33. Emissions from the State of Amazonas by sector in the period 2005-2018 (Mt CO_{2e} and %)

Sector (Mt CO2e)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2005-2018
LULUCF (Gross emissions)	60.4	60.1	46.5	46.0	30.9	45.4	38.3	39.9	44.4	38.1	54.3	86.1	76.3	79.7	32.0%
LULUCF (Removals)	96.1	101.7	103.2	110.6	114.6	118.4	118.4	118.4	118.4	119.4	120.4	124.6	124.6	124.6	29.6%
Agriculture (Gross emissions)	6.96	7.48	9.27	6.60	7.76	11.77	9.40	8.63	8.43	9.73	9.61	11.78	11.90	11.11	59.6%
Agriculture (Removals)	0.992	1.036	0.097	0.128	0.156	0.028	0.034	0.040	0.046	0.181	0.059	0.064	0.071	0.077	-92.3%
Energy	6.705	6.90	7.80	7.99	7.93	9.50	8.71	9.00	8.10	10.20	9.24	7.79	7.09	8.97	33.8%
IPPU	0.232	0.234	0.252	0.282	0.241	0.261	0.293	0.283	0.278	0.248	0.232	0.217	0.201	0.119	-48.9%
Waste	0.524	0.547	0.564	0.607	0.619	0.638	0.665	0.695	0.726	0.750	0.757	0.764	0.763	0.759	44.9%
Total Gross Emissions	**74.8**	**75.2**	**64.4**	**61.5**	**47.4**	**67.5**	**57.3**	**58.5**	**62.0**	**59.1**	**74.1**	**106.6**	**96.3**	**100.6**	**34.6%**
Total Net Emissions	**-22.4**	**-27.5**	**-38.9**	**-49.2**	**-67.4**	**-50.9**	**-61.1**	**-59.9**	**-56.4**	**-60.5**	**-46.3**	**-18.0**	**-28.4**	**-24.0**	**-7.5%**

Source: SEEG, 2020

Carbon removals from the AFOLU sector (LULUCF and Crops) due to forest regrowth, conservation units and indigenous land, and pasture and crop management, are truly relevant in the state of Amazonas. Figure 20 shows both emissions and removals.

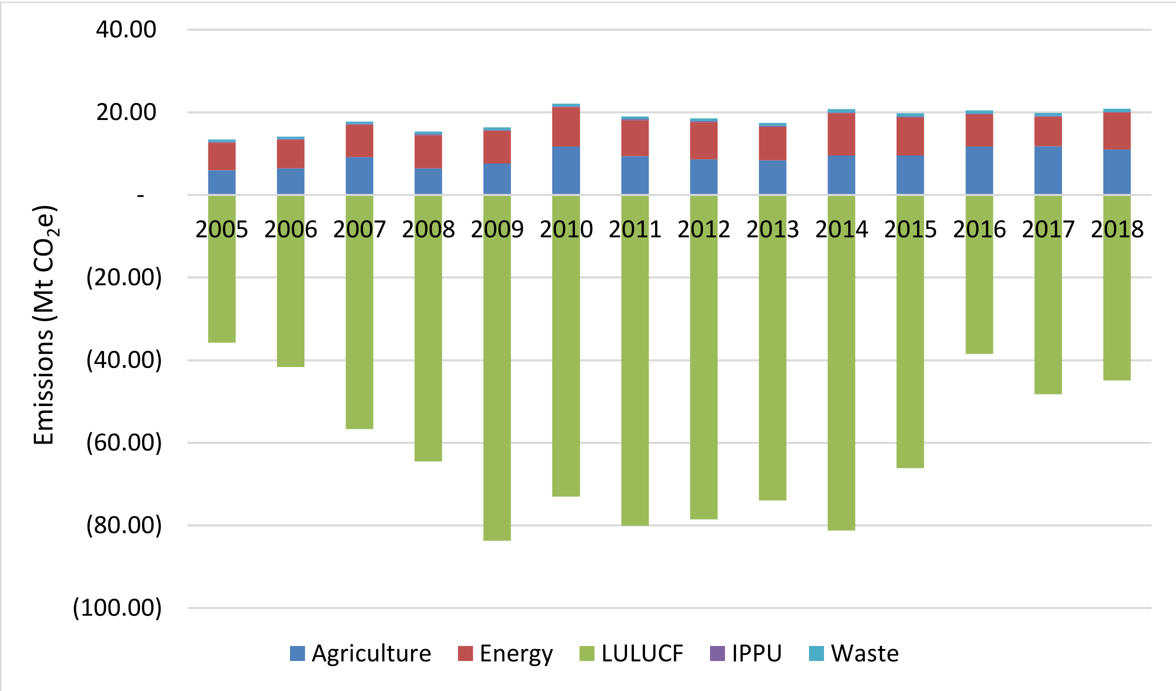

Figure 20. Net emissions from the State of Amazonas by sector in the period 2005-2018 (Mt CO_2e)

Source: Based on SEEG, 2020

3.3.2 Evolution of sectoral results

a. Energy Use

The energy sector comprises the activities of exploitation and transportation of oil and gas, the transformation centers, and final consumption of fuels. Emissions from both burning of fuels as well as fugitive emissions are accounted whenever applicable and available. In the period analysed, there was a substantial increase in emissions from residential and transport sectors, and a substantial decrease in emissions from public and industrial sectors, as can be observed in Table 34 and in Figure 21. Emissions from public services thermo-power plants are higher than from the other sectors. Emissions from fuel consumption in the agricultural, commercial, industrial, fuel production and public sectors include those from self-produced power plants and direct fuel consumption in the sectors' activities (final energy consumption). In the residential sector, energy emissions include only the final energy consumption.

Table 34. Fugitive and energy use emissions by sector from the State of Amazonas in the period 2005-2018 (Mt CO_2e and %)

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2005-2018
Fugitive Emissions in Fuel Production	**0.72**	**0.52**	**0.53**	**0.54**	**0.81**	**0.60**	**0.52**	**0.50**	**0.63**	**0.68**	**0.67**	**0.64**	**0.59**	**0.63**	**-11.7%**
Emissions from Fuel Burning	**5.99**	**6.38**	**7.26**	**7.45**	**7.12**	**8.90**	**8.19**	**8.50**	**7.47**	**9.53**	**8.57**	**7.15**	**6.49**	**8.34**	**39.2%**
Agriculture	0.002	0.001	0.001	0.001	0.001	0.034	0.039	0.046	0.043	0.045	0.047	0.039	0.035	0.037	1749.2%
Commercial	0.016	0.014	0.018	0.014	0.008	0.010	0.011	0.008	0.003	0.017	0.015	0.013	0.015	0.015	-10.6%
Electricity generation (Public Service)	3.41	3.67	4.26	4.21	3.79	5.14	4.41	4.72	3.93	5.60	4.85	3.49	2.55	4.30	26.0%
Industrial	0.158	0.148	0.241	0.254	0.262	0.133	0.159	0.153	0.071	0.092	0.058	0.056	0.059	0.069	-56.2%
Fuel Production	0.624	0.593	0.624	0.750	0.763	0.762	0.796	0.765	0.803	0.827	0.776	0.715	0.667	0.670	7.4%
Public	0.060	0.042	0.023	0.021	0.020	0.018	0.016	0.010	0.001	0.009	0.008	0.011	0.014	0.016	-73.6%
Residential	0.134	0.137	0.185	0.194	0.196	0.216	0.227	0.238	-	0.249	0.252	0.252	0.256	0.256	91.5%
Transport	1.58	1.78	1.91	2.00	2.08	2.59	2.54	2.57	2.62	2.68	2.56	2.57	2.90	2.98	88.1%
Total energy	**6.71**	**6.90**	**7.80**	**7.99**	**7.93**	**9.50**	**8.71**	**9.00**	**8.10**	**10.20**	**9.24**	**7.79**	**7.09**	**8.97**	**33.8%**

Source: SEEG, 2020

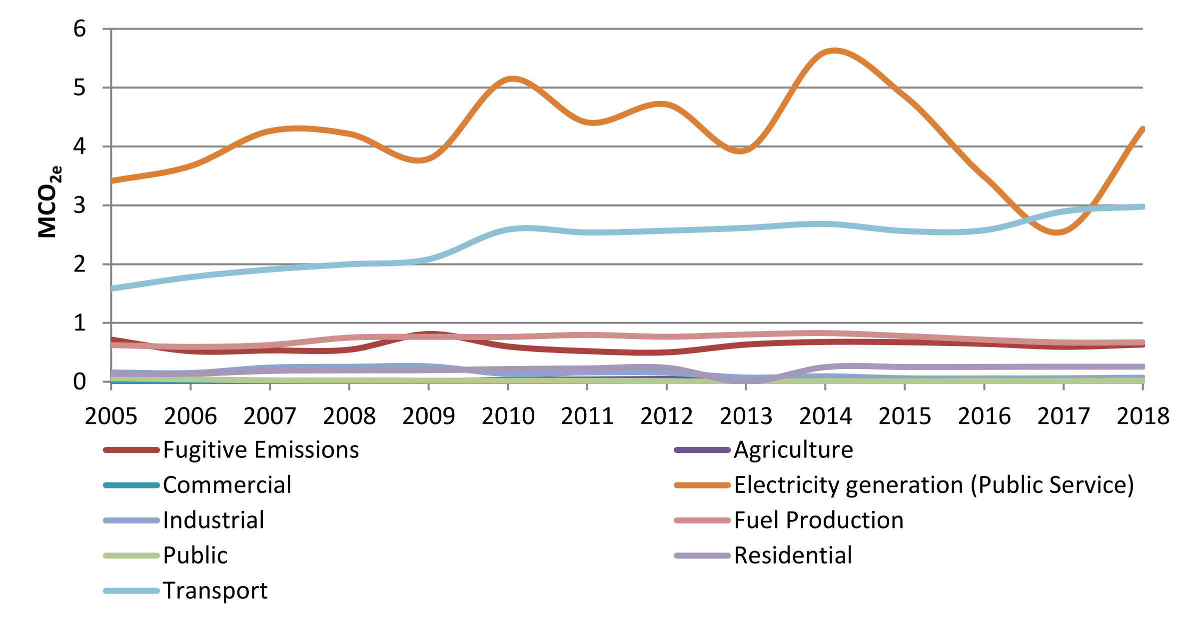

Figure 21. Fugitive and energy use emissions by sector from the State of Amazonas in the period 2005-2018 (Mt CO_2e)

Source: Based on data from SEEG, 2020

The emissions from this subsector are presented by energy sources in Figure 22 (only emissions from public electricity generation are accounted for in this subsector). From 2010 to 2015, diesel oil was the largest source of emissions. Natural gas fired plants came into operation in 2013, and from 2016 natural gas became responsible for most emissions. It is worth noting that the state of Amazonas has cumulatively installed only 176 kW of solar energy (photovoltaic).

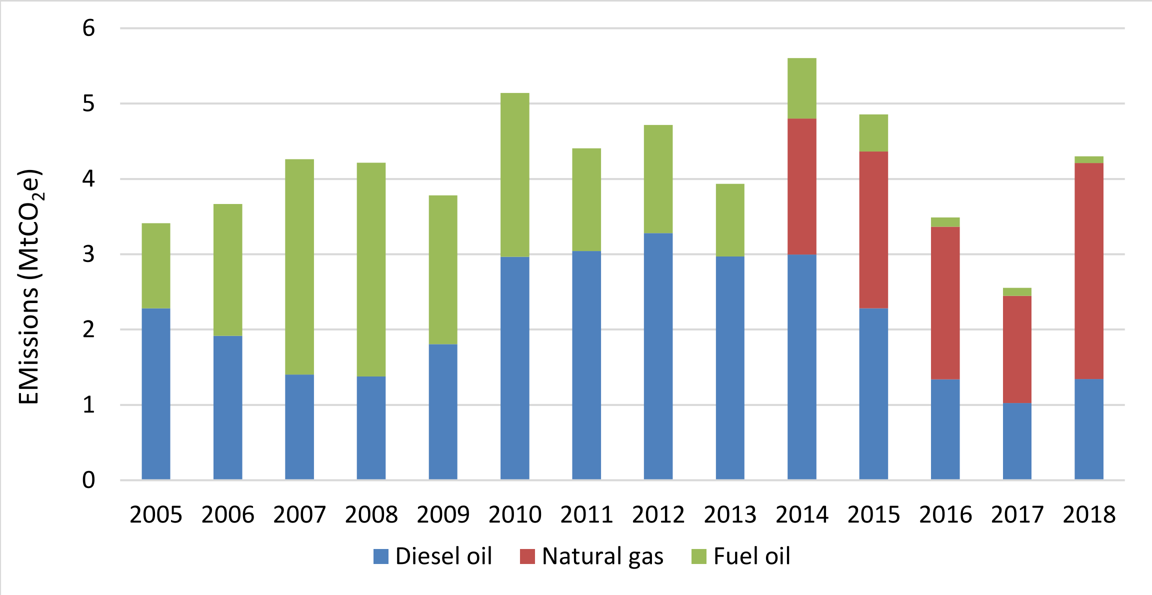

Figure 22. Emissions from electricity generation by energy sources from the State of Amazonas in the period 2005-2018 (Mt CO_2e)

Source: Based on date from SEEG, 2020

Transport

The emissions from the transport subsector increased by 88.1% in 2018 compared to 2005. Road transport has the largest contribution, with almost 80% in 2018. However, the transport mode which emissions have increased the most is waterways, with a variation of 212 % in the same period (Table 35). Figure 23 shows the share of emissions in the years analysed, comparing all modes.

Table 35. Emissions from the transport modes from the State of Amazonas (Mt CO_2e and %)

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2005-2018
Road	1.15	1.31	1.39	1.47	1.59	1.66	1.74	1.89	1.93	2.01	1.90	2.02	2.31	2.35	105.45%
Airways	0.322	0.319	0.372	0.356	0.347	0.356	0.376	0.380	0.365	0.350	0.324	0.271	0.283	0.295	-8.20%
Waterways	0.105	0.140	0.137	0.163	0.132	0.568	0.416	0.296	0.322	0.328	0.339	0.286	0.301	0.327	212.60%
Railways Freight	0.010	0.014	0.012	0.010	0.010	-	-	-	-	-	-	-	-	-	-100.00%
Transport (Total)	**1.58**	**1.78**	**1.91**	**2.00**	**2.08**	**2.59**	**2.54**	**2.57**	**2.62**	**2.68**	**2.56**	**2.57**	**2.90**	**2.98**	**88.10%**

Source: SEEG, 2020

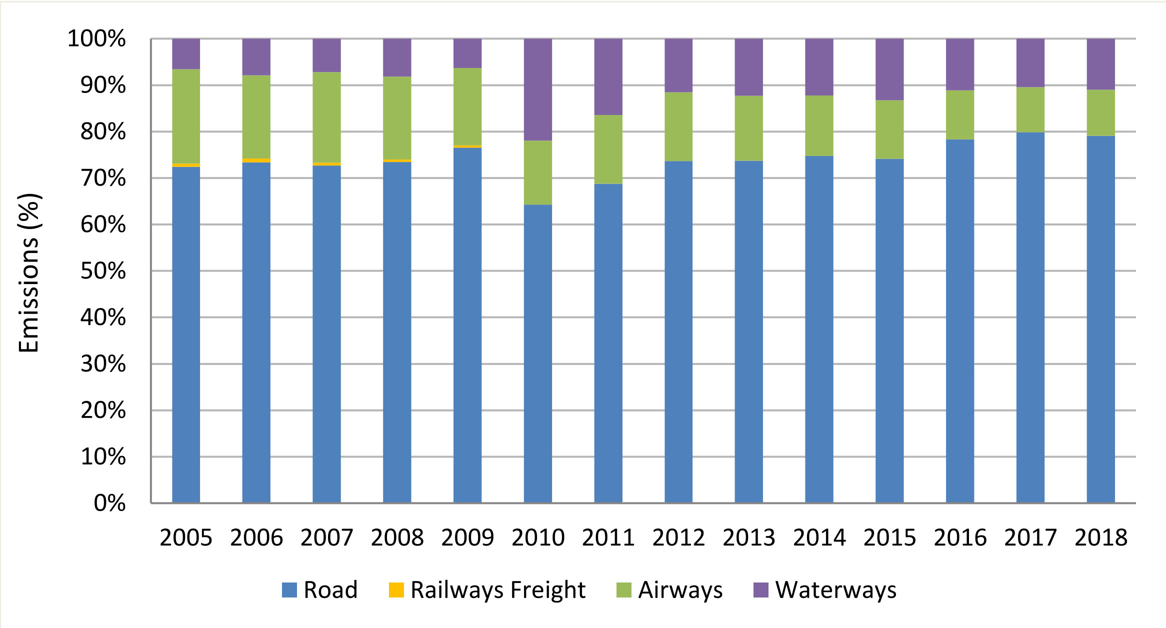

Figure 23. Share of transport modes in the sector energy consumption from the State of Amazonas (%)

Source: Based on data from SEEG, 2020

Figure 24 shows de evolution of total emissions between 2005 and 2018, where we can see the importance of diesel and gasoline in total transport emission.

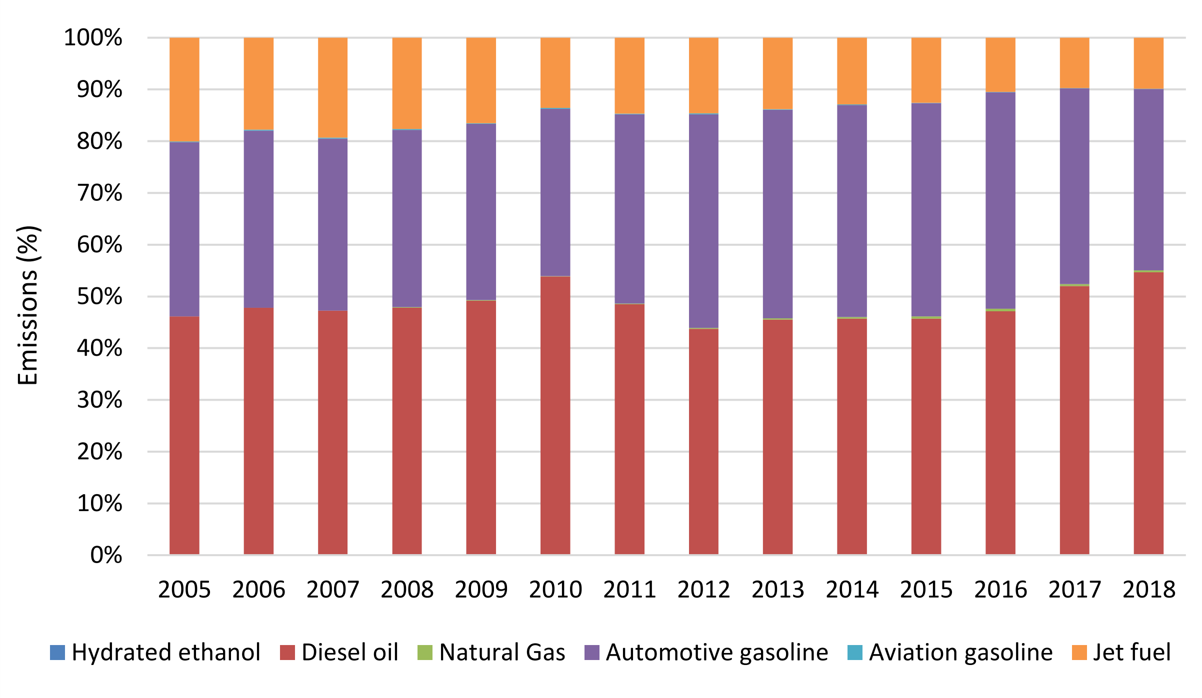

Figure 24. Share of emissions from the transport sector of the State of Amazonas (%)

Source: Based on data from SEEG, 2020.

Industry Energy Use

The most emitting industrial subsectors regarding energy use in the state of Amazonas have been changing over the analysed period (2005-2018), as shown in Table 36 and Figure 25. In the beginning of the period, Other Industries, Pulp and Paper, and Food and Beverage were those that emitted the most. However, Chemical and Mining and Pelletizing, became the most important currently, followed by Pulp and Paper and Other Industries. It is worth noting that the entire industrial sector has reduced its energy use emissions considerably in this period (56.2%), while the GDP grew 9.7% between 2005 and 2017 (the last year with available data).

Table 36. Emissions from energy use, by source, in the industry subsectors from the State of Amazonas (Mt CO_2e and %)

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2005-2018
Food and beverage	0.026	0.028	0.049	0.050	0.055	0.032	0.030	0.025	0.012	0.014	0.011	0.008	0.008	0.008	-69.0%
Ceramics	0.00009	0.00009	0.00012	0.00013	0.00013	0.00024	0.00054	0.00056	0.00059	0.00115	0.00102	0.00068	0.00089	0.00095	1007.0%
Cement	0.000	0.000	0.001	0.001	0.000	0.002	0.003	0.005	0.002	0.001	0.001	0.001	0.001	0.002	7139.3%
Iron and steel	0.004	0.004	0.006	0.007	0.007	-	0.003	0.000	-	0.001	0.000	0.000	0.000	0.000	-98.3%
Ferroalloy	0.001	0.001	0.001	0.001	-	-	-	-	-	-	-	-	-	-	-
Mining and Pelletizing	0.005	0.006	0.005	0.005	0.005	0.009	0.025	0.020	0.014	0.011	0.011	0.019	0.010	0.012	129.4%
Non-Ferrous and Other Metallurgy	0.012	0.014	0.021	0.021	0.022	0.019	0.016	0.015	0.008	0.003	0.000	0.000	0.000	0.002	-87.1%
Other Industries	0.071	0.072	0.120	0.129	0.130	0.046	0.048	0.046	0.016	0.026	0.012	0.009	0.012	0.011	-84.4%
Pulp and paper	0.029	0.018	0.026	0.030	0.032	0.015	0.011	0.011	0.009	0.008	0.007	0.006	0.012	0.012	-57.1%
Chemical	0.009	0.008	0.012	0.010	0.010	0.011	0.022	0.030	0.010	0.026	0.014	0.013	0.014	0.020	132.9%
Textile	0.00001	0.00002	0.00003	0.00002	0.00002	0.00006	0.00068	0.00061	0.00016	0.00078	0.00020	0.00024	0.00024	0.00025	1714.3%
Total energy use emissions	**0.158**	**0.148**	**0.241**	**0.254**	**0.262**	**0.133**	**0.159**	**0.153**	**0.071**	**0.092**	**0.058**	**0.056**	**0.059**	**0.069**	**-56.2%**

Source: SEEG, 2020

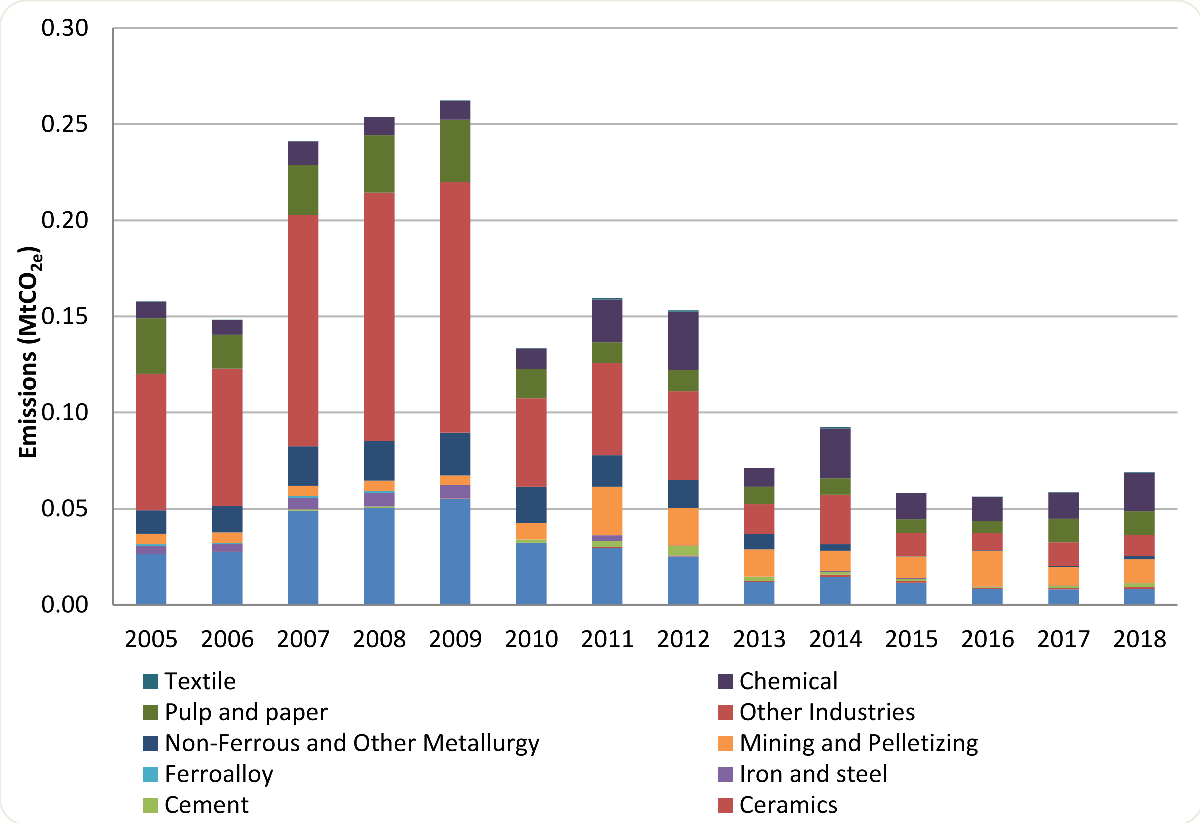

Figure 25. Emissions from energy use in the industry subsectors from the State of Amazonas (Mt CO_2e)

Source: Based on data from SEEG, 2020.

It is also important to highlight the changes in the energy matrix of the industrial sector that took place recently with a reduction in the demand for fuel oil which is a fuel with a high carbon content. Figure 26 shows the share of fuels in emissions.

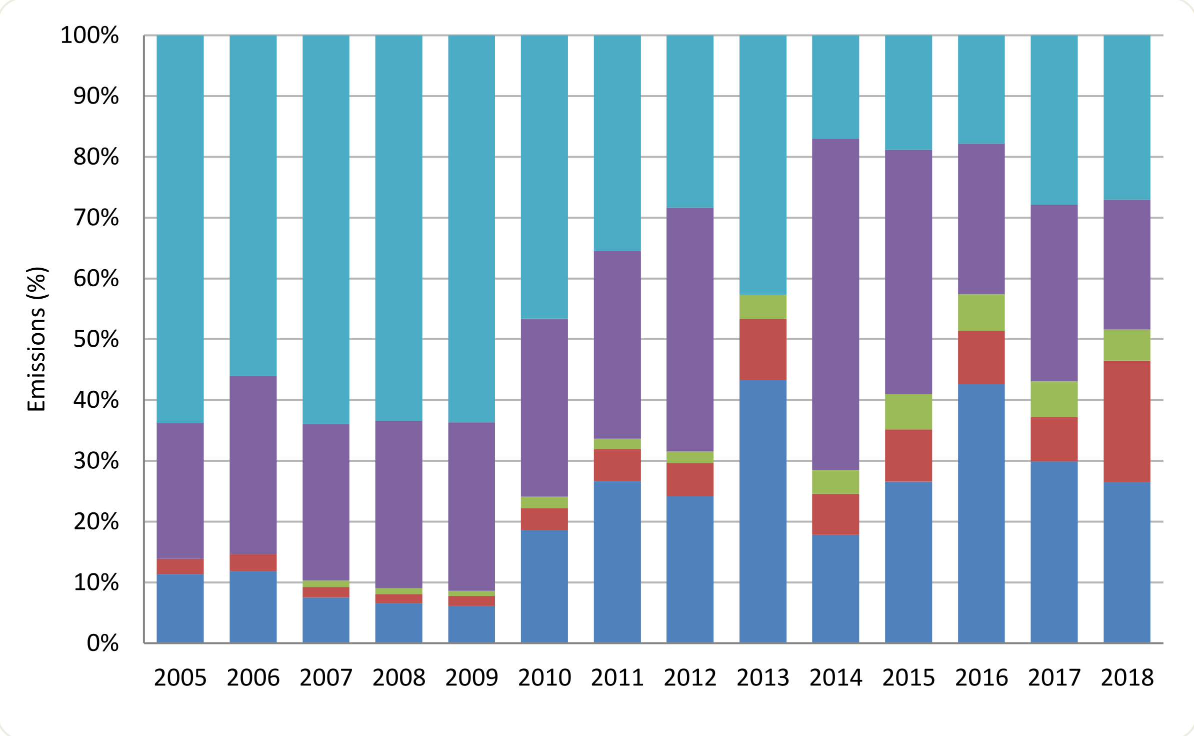

Figure 26. Share of energy sources in the emissions of the industry sector of the State of Amazonas (%)

Source: Based on data from SEEG, 2020

b. Industry (Industrial Processes and Product Use - IPPU)

Data regarding IPPU emissions are available for the cement industry only. It had a 48.9% reduction in its emissions in 2018 compared to 2005, totalling 118,719 t CO_2e on the last year of the period (Table 37). It should be noted that throughout this period emissions were not linear, coinciding with a market retraction in 2009 and 2014, remaining in decay until the end of the period. The peak of emissions occurred in 2011, when emissions increased by 25% compared to 2005.

Table 37. Emissions from Industrial Processes and Product Use (IPPU) Sector from the State of Amazonas (Mt CO_2e and %)

Sector	2005	2006	2007	2008	2009	2010	2011	
IPPU (cement)	0.232	0.234	0.252	0.282	0.241	0.261	0.293	
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2005-2018**
	0.283	0.278	0.248	0.232	0.217	0.201	0.119	-48.9%

Source: SEEG, 2020

c. Waste

GHG emissions from the waste sector increased by 44.8 % between 2005 and 2018. Table 38 presents the results of the estimates and the evolution of GHG emissions in the subsectors in this period. Figure 27 shows the contribution of each subsectors in the total waste emissions.

Table 38. Emissions of the Waste Sector from the State of Amazonas (Mt CO_2e and %)

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2005-2018
Wastewater Treatment and Discharge	**0.23**	**0.241**	**0.247**	**0.28**	**0.282**	**0.294**	**0.307**	**0.328**	**0.343**	**0.353**	**0.359**	**0.369**	**0.376**	**0.381**	**65.7%**
Domestic Wastewater	0.212	0.219	0.226	0.234	0.243	0.252	0.263	0.276	0.288	0.294	0.299	0.304	0.308	0.31	46.2%
Industrial Wastewater	0.018	0.022	0.02	0.045	0.039	0.042	0.044	0.052	0.055	0.059	0.061	0.066	0.068	0.071	294.4%
Solid Waste	**0.293**	**0.306**	**0.317**	**0.328**	**0.337**	**0.344**	**0.358**	**0.367**	**0.383**	**0.398**	**0.397**	**0.395**	**0.387**	**0.377**	**28.7%**
Urban Solid Wastes	0.293	0.305	0.317	0.327	0.336	0.343	0.357	0.366	0.382	0.396	0.396	0.394	0.386	0.376	28.3%
Disposal in controlled landfill	0.062	0.065	0.068	0.071	0.073	0.074	0.078	0.081	0.085	0.088	0.089	0.089	0.087	0.086	38.7%
Disposal at landfill	0.139	0.152	0.165	0.177	0.188	0.198	0.211	0.222	0.236	0.248	0.251	0.251	0.248	0.242	74.1%
Disposal in open dumps	0.092	0.088	0.083	0.079	0.075	0.071	0.067	0.064	0.061	0.06	0.057	0.054	0.051	0.049	-46.7%
Waste by incineration (Health Services Waste)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0%
Waste (Total)	**0.524**	**0.547**	**0.564**	**0.607**	**0.619**	**0.638**	**0.665**	**0.695**	**0.726**	**0.75**	**0.757**	**0.764**	**0.763**	**0.759**	**44.8%**

Source: SEEG, 2020

There was a substantial increase in emissions from the industrial wastewater and waste disposal in landfill in 2018, compared to 2005 (294,4% and 74.1%, respectively). The main decrease in emissions occurred in open dump disposal (46.7%) as shown in Table 38. Figure 27 shows the share of emissions by sources.

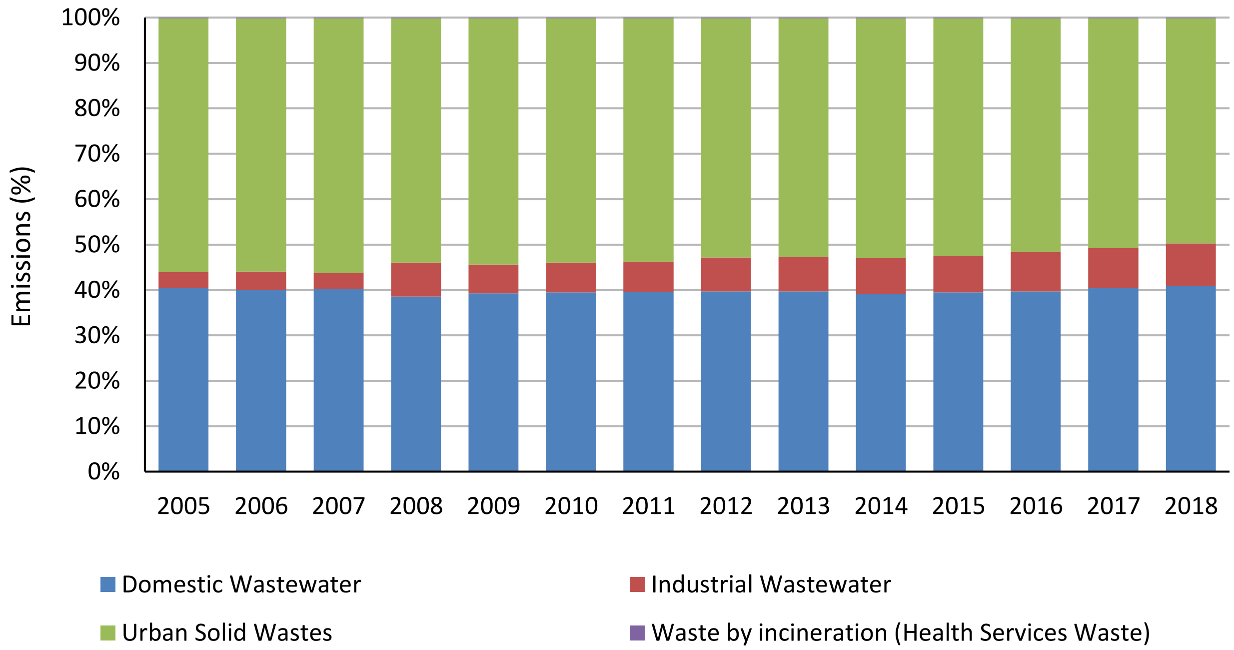

Figure 27. Share of emissions from the waste subsectors from the State of Amazonas (%).

Source: Based on data from SEEG, 2020

d. Agriculture, Forestry and Other Land Use – AFOLU

Net emissions from the AFOLU sector decreased by 13.6% in 2018 compared to 2005. The greatest reduction occurred in the period 2005-2009. In the whole period, the reduction was mainly due to the contribution of negative land use emissions, because of carbon removals. Such accounting considers the natural carbon sequestration that occurs in protected areas (conservation units and indigenous lands).

Net emissions from the land use, land use change and forestry subsector (LULUCF) presented a sharp drop until reaching -83.8 Mt CO_2e in 2009, remaining relatively stable until 2014, and then increased until it achieved -44.9 Mt CO_2e in 2018. Net emissions from livestock remained relatively constant throughout the period, reaching 2.09 Mt CO_2e in 2018. Net emissions from crops increased over the years reaching 8.95 Mt CO_2e in 2018. Table 39 and Figures 28 and 29 show the results during the analysed period.

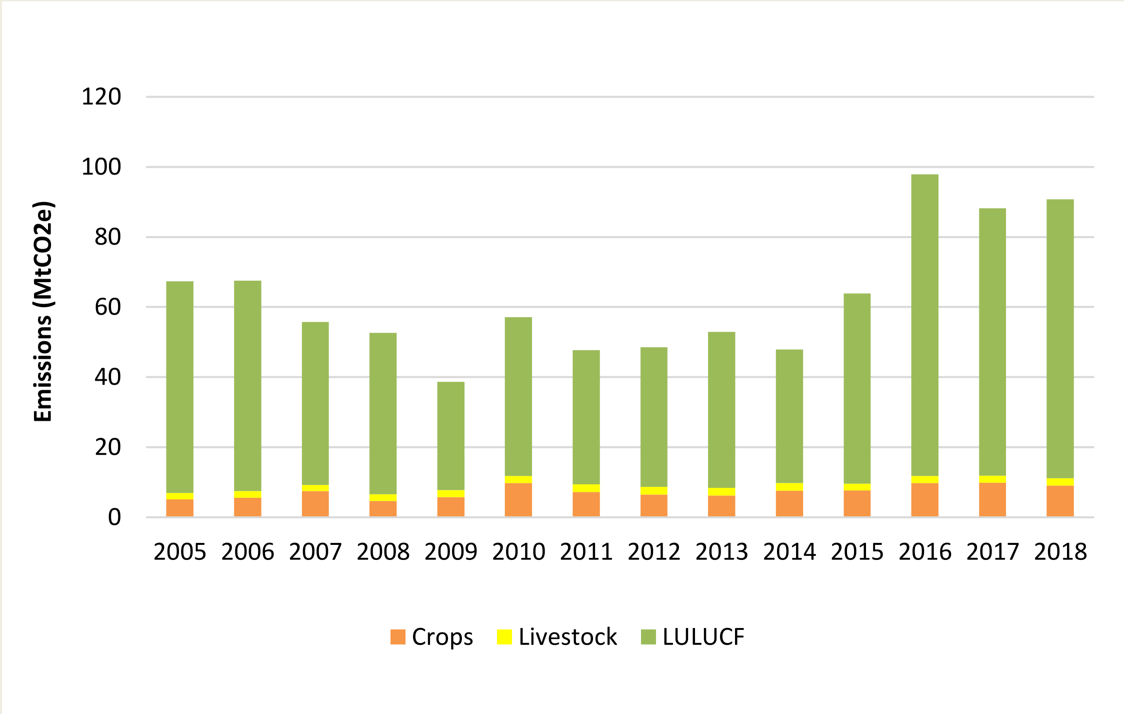

Figure 28. Gross emissions from the AFOLU sector from the State of Amazonas (Mt CO_2e)
Source: Based on data from SEEG, 2020

Table 39. Emissions from Agriculture, Forestry and Land Use Change (AFOLU) Sector from the State of Amazonas (Mt CO_2e and %)

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2005-2018
Agriculture															
Agriculture (Emissions)	**6.96**	**7.48**	**9.27**	**6.60**	**7.76**	**11.77**	**9.40**	**8.63**	**8.43**	**9.73**	**9.61**	**11.78**	**11.90**	**11.11**	**59.6%**
Livestock	**1.81**	**1.88**	**1.78**	**1.96**	**2.01**	**2.03**	**2.18**	**2.18**	**2.22**	**2.12**	**1.97**	**1.99**	**2.03**	**2.09**	**15.4%**
Enteric Fermentation	**1.73**	**1.80**	**1.71**	**1.88**	**1.93**	**1.95**	**2.09**	**2.10**	**2.13**	**2.04**	**1.89**	**1.91**	**1.95**	**2.01**	**15.9%**
Manure management	**0.078**	**0.082**	**0.071**	**0.078**	**0.080**	**0.080**	**0.086**	**0.085**	**0.085**	**0.083**	**0.079**	**0.082**	**0.079**	**0.081**	**3.8%**
Crops	**5.15**	**5.60**	**7.49**	**4.64**	**5.76**	**9.73**	**7.22**	**6.45**	**6.21**	**7.61**	**7.65**	**9.78**	**9.87**	**9.02**	**75.2%**
Burning of forest residues (Sugar cane)	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	**0.004**	**0.004**	**0.004**	**0.004**	**0.003**	**0.003**	**0.003**	**0.003**	**-25.7%**
Agricultural Soils	**0.505**	**0.521**	**0.468**	**0.535**	**0.548**	**0.556**	**0.604**	**0.599**	**0.606**	**0.584**	**0.544**	**0.549**	**0.560**	**0.572**	**13.3%**
Application of organic waste	0.028	0.029	0.021	0.022	0.023	0.022	0.023	0.022	0.021	0.021	0.021	0.020	0.020	0.020	-25.5%
Animal	0.027	0.029	0.021	0.022	0.022	0.021	0.023	0.021	0.021	0.021	0.021	0.020	0.020	0.020	-25.7%
Vinasse	0.00018	0.00023	0.00021	0.00031	0.00030	0.00018	0.00027	0.00024	0.00015	0.00018	0.00011	0.00022	0.00021	0.00018	4.0%
Manure deposited on pasture	0.254	0.264	0.244	0.276	0.286	0.295	0.320	0.319	0.324	0.311	0.289	0.291	0.296	0.304	19.9%
Synthetic Fertilizers	0.002	0.003	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.003	0.004	0.004	0.004	72.9%
Agricultural Residues	0.029	0.026	0.023	0.036	0.032	0.026	0.032	0.031	0.031	0.028	0.026	0.029	0.030	0.028	-3.9%
Rice	0.00051	0.00059	0.00045	0.00030	0.00030	0.00027	0.00034	0.00039	0.00025	0.00022	0.00013	0.00003	0.00002	0.00004	-92.8%
Sugar cane	0.00030	0.00031	0.00030	0.00033	0.00033	0.00030	0.00027	0.00027	0.00026	0.00027	0.00021	0.00020	0.00021	0.00022	-25.8%
Bean	0.00053	0.00059	0.00052	0.00030	0.00029	0.00040	0.00044	0.00049	0.00036	0.00017	0.00022	0.00018	0.00020	0.00012	-76.9%

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2005-2018
Manioc	0.025	0.022	0.020	0.033	0.029	0.023	0.028	0.027	0.027	0.025	0.023	0.027	0.028	0.026	1.4%
Corn	0.0015	0.0016	0.0013	0.0013	0.0013	0.0015	0.0016	0.0016	0.0012	0.0009	0.0007	0.0004	0.0004	0.0004	-76.8%
Other cultures	0.0004	0.0005	0.0006	0.0005	0.0005	0.0012	0.0014	0.0017	0.0018	0.0016	0.0012	0.0013	0.0014	0.0014	228.9%
Soy	0.000332	0.000332	0.000125	0.000039	0.000040	0.000035	0.000035	0.000043	0.000004	0	0	0	0	0	-100.0%
Organic soils	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
Atmospheric Deposition of N	0.040	0.042	0.037	0.042	0.043	0.044	0.048	0.047	0.048	0.046	0.043	0.043	0.044	0.045	12.2%
Animal	0.040	0.041	0.037	0.041	0.043	0.044	0.047	0.046	0.047	0.045	0.042	0.042	0.043	0.044	11.2%
Synthetic Fertilizers	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	72.8%
Leaching (indirect N)	0.151	0.158	0.141	0.157	0.163	0.166	0.179	0.177	0.179	0.174	0.162	0.163	0.165	0.170	12.1%
Animal	0.149	0.155	0.138	0.155	0.160	0.164	0.176	0.174	0.176	0.170	0.159	0.159	0.162	0.166	11.2%
Synthetic Fertilizers	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.003	0.003	0.004	0.004	72.9%
Vinasse	0.000068	0.000087	0.000082	0.000120	0.000115	0.000069	0.000103	0.000093	0.000059	0.000071	0.000042	0.000084	0.000080	0.000070	2.9%
Carbon in Soil	4.64	5.07	7.02	4.10	5.20	9.17	6.61	5.85	5.60	7.02	7.10	9.23	9.31	8.45	82.0%
Planted Forests	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
Degraded Pasture	4.64	5.07	7.02	4.10	5.20	9.17	6.61	5.85	5.60	7.02	7.10	9.23	9.31	8.45	82.0%
Agriculture (Removals)	**0.992**	**1.036**	**0.097**	**0.128**	**0.156**	**0.028**	**0.034**	**0.040**	**0.046**	**0.181**	**0.059**	**0.064**	**0.071**	**0.077**	**-92.3%**
Carbon in Soil	0.992	1.036	0.097	0.128	0.156	0.028	0.034	0.040	0.046	0.181	0.059	0.064	0.071	0.077	-92.3%
Well-managed Pasture	0.983	1.022	0.080	0.107	0.132	0	0	0	0	0.128	0	0	0	0	-
Integrated Crop-Livestock-Forest Systems	0.010	0.013	0.017	0.021	0.024	0.028	0.034	0.040	0.046	0.053	0.059	0.064	0.071	0.077	701.4%

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2005-2018
Agriculture (Net emissions)	**5.97**	**6.44**	**9.17**	**6.47**	**7.61**	**11.74**	**9.36**	**8.59**	**8.38**	**9.55**	**9.56**	**11.71**	**11.83**	**11.03**	**84.9%**
LULUCF															
LULUCF (Emissions)	**60.4**	**60.1**	**46.5**	**46.0**	**30.9**	**45.4**	**38.3**	**39.9**	**44.4**	**38.1**	**54.3**	**86.1**	**76.3**	**79.7**	**32.0%**
Deforestation and other Land Use Changes	**58.1**	**57.8**	**44.7**	**44.3**	**29.7**	**43.6**	**36.8**	**38.4**	**42.8**	**36.7**	**52.2**	**82.8**	**73.4**	**76.7**	**31.9%**
Forest Residues	**2.23**	**2.27**	**1.76**	**1.74**	**1.17**	**1.72**	**1.45**	**1.51**	**1.68**	**1.44**	**2.05**	**3.26**	**2.89**	**3.01**	**34.8%**
LULUCF (Removals)	**96.1**	**101.7**	**103.2**	**110.6**	**114.6**	**118.4**	**118.4**	**118.4**	**118.4**	**119.4**	**120.4**	**124.6**	**124.6**	**124.6**	
Secondary Forest Removals	**2.57**	**3.50**	**4.44**	**5.37**	**6.30**	**10.04**	**10.04**	**10.04**	**10.04**	**10.04**	**10.04**	**10.04**	**10.04**	**10.04**	**291.1%**
Removals in Protected Areas	**93.6**	**98.2**	**98.8**	**105.2**	**108.3**	**108.3**	**108.3**	**108.3**	**108.3**	**109.3**	**110.4**	**114.5**	**114.5**	**114.5**	**22.4%**
Indigenous Land	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	59.8	60.6	60.6	60.6	1.3%
Conservation Unit	33.8	38.4	39.0	45.4	48.6	48.6	48.6	48.6	48.6	49.6	50.6	54.0	54.0	54.0	59.8%
LULUCF (Net emissions)	**-35.8**	**-41.6**	**-56.7**	**-64.5**	**-83.8**	**-73.0**	**-80.1**	**-78.5**	**-73.9**	**-81.3**	**-66.1**	**-38.5**	**-48.3**	**-44.9**	**25.5%**
TOTAL AFOLU (Gross emissions)	**67.3**	**67.5**	**55.8**	**52.6**	**38.6**	**57.1**	**47.7**	**48.5**	**52.9**	**47.8**	**63.9**	**97.8**	**88.2**	**90.8**	**34.9%**
TOTAL AFOLU (Net emissions)	**-29.8**	**-35.2**	**-47.5**	**-58.1**	**-76.2**	**-61.3**	**-70.7**	**-69.9**	**-65.5**	**-71.7**	**-56.6**	**-26.8**	**-36.4**	**-33.9**	**-13.6%**

Source: SEEG, 2020

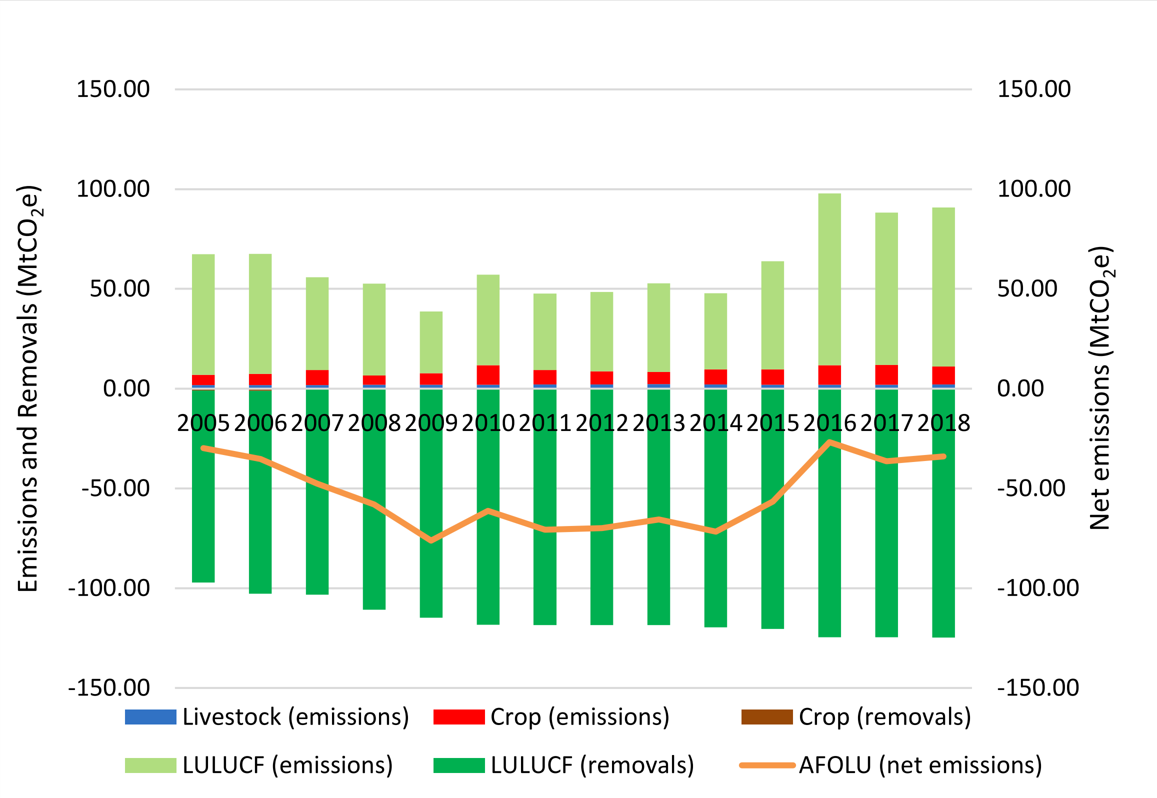

Figure 29. Net emissions from the AFOLU sector from the State of Amazonas (Mt CO_2e)

Source: Based on data from SEEG, 2020

Land Use, Land Use Change and Forestry (LULUCF) subsector

Land Use Land-Use Change and Forestry (LULUCF) subsector includes emissions from deforestation and forest residues, and removals in secondary forests and protected areas, the last being the most relevant. Net emissions have been negative throughout the period (Figure 30), however emissions from deforestation and other land use changes increased significantly in the last four years.

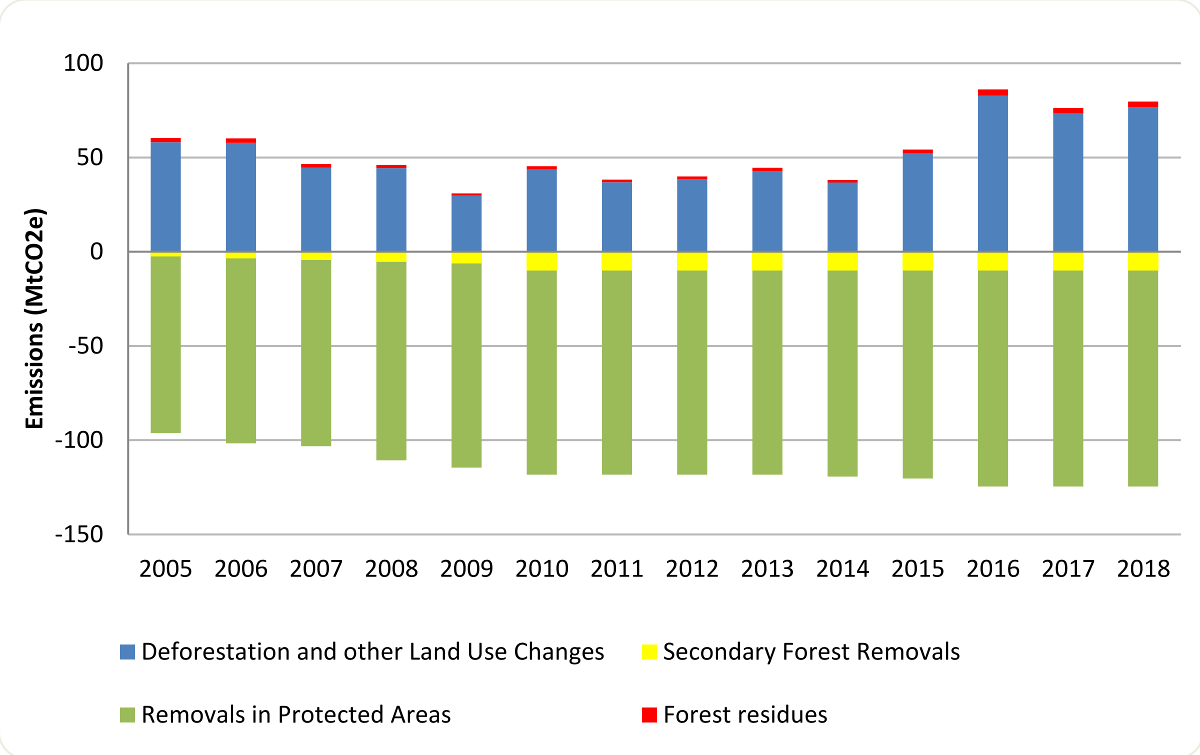

Figure 30. Emissions from LULUCF by subsectors from the State of Amazonas (emissions and removals) (Mt CO_2e)
Source: Based on data from SEEG, 2020

Agriculture subsector

Agriculture subsector emissions, which includes both crops and livestock, increased throughout the analysed period (89.9%), with a peak of 11.8 Mt CO_2e in 2010. This increase is driven by emissions from agricultural soils, the largest source. The second largest source of emissions is enteric fermentation, which has remained relatively stable over the period (Figure 31).

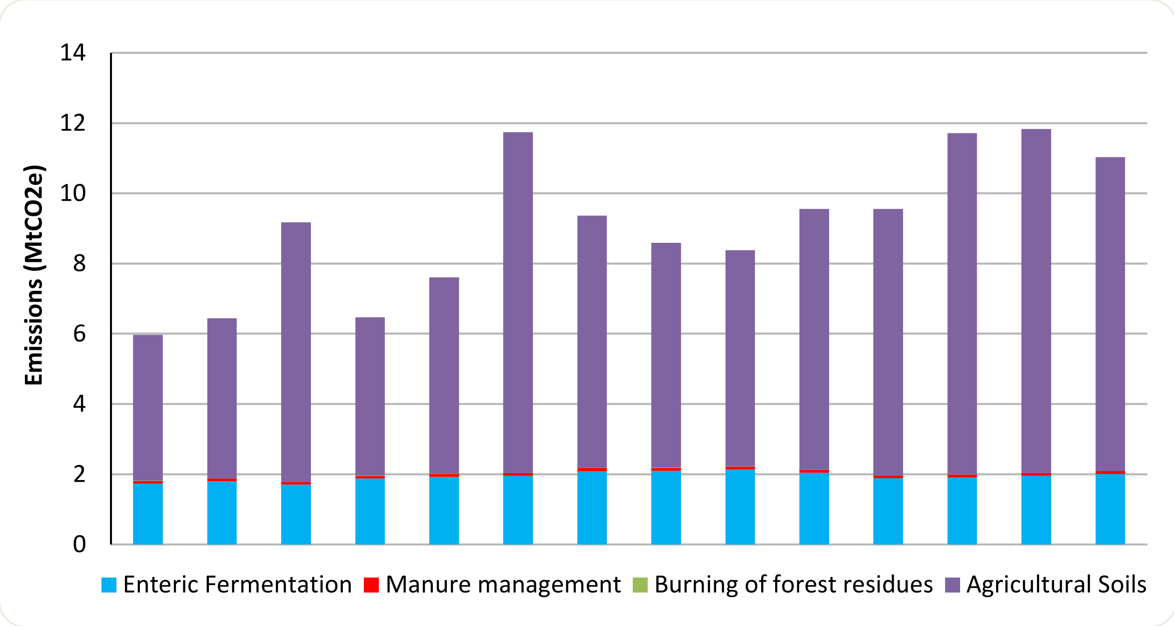

Figure 31. Emissions from the Agriculture subsector from the State of Amazonas (emissions and removals) (Mt CO_2e).

Note: removals in agriculture as negligible
Source: Based on data from SEEG, 2020

Considering livestock emissions, beef cattle are the herd that emits the most as shown in Figure 32.

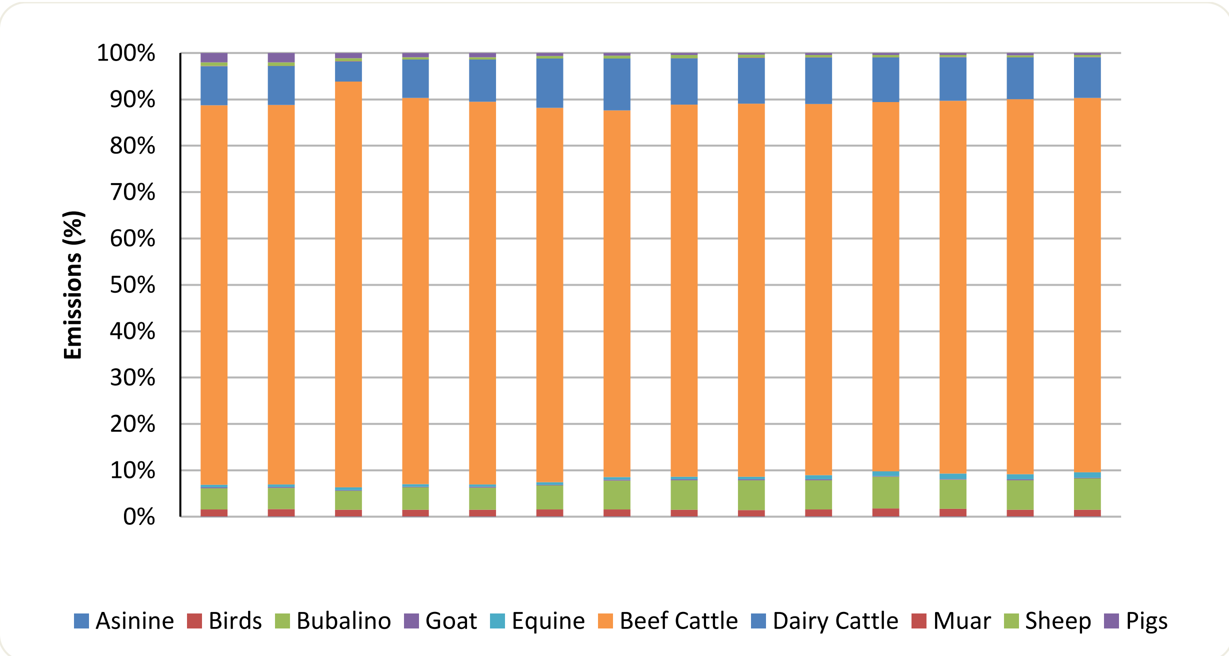

Figure 32. Emissions share of Agriculture activities by species from the State of Amazonas (%)

Source: Based on data from SEEG, 2020

3.3 Evaluation of aggregated values and intensity indicators

Table 40 shows the emission sources in decreasing order of magnitude, considering the year 2018. It is observed that in the period of 2005-2018, total net emissions reduced and then increased again, remaining relatively constant comparing both years. Considering net emissions, agriculture is the activity that most generates emissions in the state, followed by energy and transport. It is also important to note that LULUCF net emissions are negative because of the carbon removals, despite the sector being responsible for a large part of emissions, mainly because of deforestation.

Furthermore, Table 41 shows the indicators that better reflect the emissions pattern of the state of Amazonas.

Table 40. Emission sources in decreasing order of magnitude in 2018 in the State of Amazonas (Mt CO_2e and %)

Emission sources	2005	2010	2015	2018	Emissions share in 2018
	(Mt CO_2e)				%
LULUCF gross emissions	60.40	45.40	54.30	79.70	80.09%
Agriculture gross emissions (Crops, Livestock and energy emissions)	6.96	11.80	9.66	11.15	11.20%
Energy supply emissions*	4.75	6.54	6.35	4.46	4.48%
Transport emissions	1.58	2.59	2.56	2.98	2.99%
Urban solid Waste emissions	0.293	0.343	0.396	0.376	0.38%
Urban wastewater emissions	0.212	0.252	0.299	0.310	0.31%
Households emission	0.134	0.216	0.252	0.256	0.26%
Industry emissions (Energy and IPPU)**	0.390	0.394	0.290	0.188	0.19%
Industry emissions from waste (wastewater)	0.018	0.042	0.061	0.071	0.07%
Public Sector emissions**	0.060	0.018	0.008	0.016	0.02%
Commercial emissions**	0.016	0.010	0.015	0.015	0.01%
Total gross emissions	**74.8**	**67.5**	**74.1**	**100.6**	**100.00%**
Carbon Uptake in Agriculture	0.992	0.028	0.059	0.077	0.06%
Carbon Uptake in LULUCF	96.1	118.4	120.4	124.6	99.94%
Total Carbon Uptake	97.14	118.40	120.46	124.66	100.00%
Total Net emissions	**-22.4**	**-50.9**	**-46.3**	**-24.0**	**-**

* includes fugitive emissions and emissions from fuel production and public service generated electricity
** includes emissions from fuel consumption and self-generated electricity
Source: Based on data from SEEG, 2020

Table 41. Emission and economic indicators from the State of Amazonas in 2005, 2010, 2015, 2016, 2017 and 2018.

Annual indicators		2005	2010	2015	2016	2017	2018	2005-2010	2010-2015	2015-2018	2005-2018
Economy Wide	Total net emissions (Mt CO_2e)	-22.36	-50.88	-46.34	-18.03	-28.39	-24.04	-127.5%	8.9%	48.1%	-7.5%
	Total emissions without LULUCF (Mt CO_2e)	13.43	22.14	19.79	20.49	19.88	20.88	64.9%	-10.6%	5.5%	55.5%
	GDP (million R$ of 2015)	60,220.03	85,588.45	86,568.18	83,772.20	85,179.62	NA	42.1%	1.1%	NA	NA
	Carbon intensity of GDP (t CO_2e/million R$)	-371.3	-594.4	-535.2	-215.3	-333.3	NA	-60.1%	10.0%	NA	NA
	Carbon intensity of GDP without LULUCF (t CO_2e without LULUCF emissions/million R$)	223.0	258.7	228.6	244.5	233.4	NA	16.0%	-11.6%	NA	NA
	Carbon intensity of GDP without removals (t CO_2e/million R$)	1,241.7	789.0	856.3	1,272.7	1,130.1	NA	-36.5%	8.5%	NA	NA
	Population (million people)	3.21	3.55	3.62	3.68	3.75	3.82	10.8%	1.8%	5.6%	19.1%
	Per capita net emissions (total t CO_2e/inhab.)	-6.97	-14.32	-12.81	-4.89	-7.57	-6.29	-105.4%	10.6%	50.9%	9.7%

Annual indicators		2005	2010	2015	2016	2017	2018	2005-2010	2010-2015	2015-2018	2005-2018
	Per capita emissions without LULUCF (t CO_2e without LULUCF emissions/inhab.)	4.19	6.23	5.47	5.56	5.30	5.47	48.8%	-12.2%	0.0%	30.6%
Energy Supply and Other Energy Indicators	Total energy supply (M toe)	NA	NA	5,147	NA	NA	NA	NA	NA	NA	NA
	Total energy demand (M toe)	NA	NA	2,451	NA	NA	NA	NA	NA	NA	NA
	Total energy supply (Mt CO_2e)	6.71	9.50	9.24	7.79	7.09	8.97	41.7%	-2.7%	-3.0%	33.8%
	TPES / capita (toe/capita)	NA	NA	1.42	NA	NA	NA	NA	NA	NA	NA
	Total electricity supply (TWh)	6.06	8.54	9.14	6.70	7.07	8.81	40.9%	7.1%	-3.6%	45.4%
	Total electricity demand (TWh)	3.92	4.82	6.36	5.99	5.85	5.97	22.7%	32.0%	-6.2%	52.0%
	Electricity supply over GDP (MWh / Million R$)	0.101	0.100	0.106	0.080	0.083	NA	-0.9%	5.9%	NA	NA
	Electricity demand over GDP (MWh / Million R$)	65.16	56.26	73.43	71.52	68.70	NA	-13.7%	30.5%	NA	NA
	Share of electricity in total energy demand (%)	NA	NA	22.7%	NA	NA	NA	NA	NA	NA	NA

Annual indicators		2005	2010	2015	2016	2017	2018	2005-2010	2010-2015	2015-2018	2005-2018
	Carbon intensity of electricity consumed (Mt CO_2e/TWh)	1.71	1.97	1.45	1.30	1.21	1.50	15.5%	-26.3%	3.4%	-12.0%
	Emissions from total energy supply over GDP (t CO_2e / Million R$)	NA	NA	0.11	NA	NA	NA	NA	NA	NA	NA
Transport Sector	Transport emissions (Mt CO_2e)	1.58	2.59	2.56	2.57	2.90	2.98	63.5%	-1.0%	16.2%	88.1%
	Transport emissions/GDP (t CO_2e /million R$)	26.28	30.22	29.59	30.74	33.99	NA	15.0%	-2.1%	NA	NA
	Share of ethanol in the road mode (%)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Industry	Industry emissions - energy and IPPU (Mt CO_2e)	0.390	0.394	0.291	0.273	0.260	0.188	1.1%	-26.3%	-35.4%	-51.9%
	Industry Value Added (million R$ 2015)	21,678.33	30,221.40	24,230.54	24,789.90	23,786.78	NA	39.4%	-19.8%	NA	NA
	Industry emissions/GDP (t CO_2e/million R$)	6.48	4.61	3.36	3.26	3.05	NA	-28.9%	-27.1%	NA	NA

Annual indicators		2005	2010	2015	2016	2017	2018	2005-2010	2010-2015	2015-2018	2005-2018
	Industry emissions/VA of Industry (t CO_2e/million R$)	17.99	13.05	12.00	11.02	10.93	NA	-27.5%	-8.1%	NA	NA
Other energy demand sectors	Commercial emissions (Mt CO_2e)	0.016	0.010	0.015	0.013	0.015	0.015	-38.7%	44.9%	0.6%	-10.6%
	Commercial emissions/GDP (t CO_2e /million R$)	0.272	0.117	0.168	0.159	0.177	NA	-56.8%	43.2%	NA	NA
	Households emission (Mt CO_2e)	0.134	0.216	0.252	0.252	0.256	0.256	61.5%	16.4%	1.9%	91.5%
	Households per capita emissions (kg CO_2e/inhab.)	41.72	60.82	69.54	68.51	68.30	67.09	45.8%	14.3%	-3.5%	60.8%
	Public Sector emissions (Mt CO_2e)	0.060	0.018	0.008	0.011	0.014	0.02	-70.1%	-58.1%	110.1%	-73.6%
	Agriculture energy emissions (Mt CO_2e)	0.002	0.034	0.047	0.039	0.035	0.04	1590.9%	39.0%	-21.3%	1748.8%
AFOLU	AFOLU net emissions (Mt CO_2e)	-29.82	-61.28	-56.57	-26.81	-36.45	-33.89	-105.5%	7.7%	40.1%	-13.6%
	AFOLU emissions/VA of	-0.016	-0.020	-0.010	-0.005	-0.01	NA	-24.0%	50.3%	NA	NA

Annual indicators		2005	2010	2015	2016	2017	2018	2005-2010	2010-2015	2015-2018	2005-2018
	Agricultured (kt CO_2e /million R$)										
LULUCF	Deforestation (Km^2/year)	775	595	712	1,129	1,001	1,045	-23.2%	19.7%	46.8%	34.8%
	Protected Areas and Indigenous Lands (Mha/year)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	LULUCF net emissions (Mt CO_2e)	-35.79	-73.02	-66.12	-38.52	-48.28	-44.92	-104.0%	9.4%	32.1%	-25.5%
	LULUCF net emissions/Annual deforestation area (Kt CO_2e/km2)	-46.18	-122.72	-92.87	-34.12	-48.23	-42.99	-165.7%	24.3%	53.7%	6.9%
	LULUCF emission/GDP (t CO_2e /million R$)	-594.34	-853.10	-763.82	-459.81	-566.77	NA	-43.5%	10.5%	NA	NA
	LULUCF emissions/VA of Agriculture (t CO_2e /million R$)	-19,001.14	-23,400.64	-11,413.32	-6,962.78	-9,426.25	NA	-23.2%	51.2%	NA	NA
Agriculture	Number of cattle (cattle heads (million)	1.20	1.36	1.29	1.32	1.34	1.38	13.7%	-5.0%	6.4%	15.0%

Annual indicators		2005	2010	2015	2016	2017	2018	2005-2010	2010-2015	2015-2018	2005-2018
	Total agriculture emissions (Crops & Livestock-Mt CO_2e)	5.97	11.74	9.56	11.71	11.83	11.03	96.7%	-18.6%	15.5%	84.9%
	Total agriculture emissions (Crops, Livestock, and energy- Mt CO_2e)	5.97	11.77	9.60	11.75	11.87	11.07	97.2%	-18.4%	15.3%	85.4%
	Value Added of Agriculture (million R$ 2015)	1,884	3,120	5,793	5,532	5,122	NA	65.6%	85.7%	NA	NA
	Total agriculture emissions (includes energy emissions)/VA of Agriculture (t CO_2e /million R$)	3,169	3,773	1,657	2,124	2,317	NA	19.0%	-56.1%	NA	NA
	Livestock Emission/ Meat production (t CO_2e / t)	52.34	13.83	10.99	10.01	10.06	10.53	-73.6%	-20.5%	-4.1%	-79.9%
	Meat production / VA of Agriculture (t/ Million R$)	5.16	12.99	8.59	9.98	10.93	NA	151.6%	-33.9%	NA	NA
	Livestock Emissions / VA of Agriculture (t CO_2e/ Million R$)	270.30	179.65	94.38	99.86	109.89	NA	-33.5%	-47.5%	NA	NA

Annual indicators		2005	2010	2015	2016	2017	2018	2005-2010	2010-2015	2015-2018	2005-2018
	Meat production / Pastureland Area (kg / ha)	12.29	43.24	45.93	49.60	49.02	45.46	251.9%	6.2%	-1.0%	269.9%
	Livestock / Pastureland Area (cattle head / ha)	1.51	1.45	1.19	1.18	1.18	1.15	-4.0%	-17.8%	-4.0%	-24.3%
	Pastureland area / Va of Agriculture (ha / Million R$)	420.21	263.02	146.70	158.90	177.34	NA	-37.4%	-44.2%	NA	NA
	Agricultural area / VA of Agriculture (ha / Million R$)	426.43	277.65	139.44	135.46	134.91	NA	-34.9%	-49.8%	NA	NA
Waste	Solid Waste Deposited in Managed Landfills (Mt)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Waste Emissions (Mt CO_2e)	0.524	0.638	0.757	0.764	0.763	0.759	21.8%	18.6%	0.3%	44.9%
	Per capita waste emissions (Total t CO_2e/inhab.)	0.163	0.179	0.209	0.207	0.203	0.199	10.0%	16.5%	-5.0%	21.7%
	Total solid Waste emissions (Mt CO_{2e})	0.293	0.344	0.397	0.395	0.387	0.377	17.3%	15.5%	-5.1%	28.6%
	Total Solid Waste per capita	91.47	96.83	109.85	107.20	103.25	98.79	5.9%	13.4%	-10.1%	8.0%

Annual indicators		2005	2010	2015	2016	2017	2018	2005-2010	2010-2015	2015-2018	2005-2018
	emissions (kg CO_2e/inhab.)										
	Total wastewater emissions (Mt CO_2e)	0.230	0.294	0.359	0.369	0.376	0.381	27.6%	22.3%	6.2%	65.7%
	Total wastewater per capita emissions (kg CO_2e/inhab.)	71.75	82.65	99.26	100.25	100.21	99.84	15.2%	20.1%	0.6%	39.2%

Source: Based on data from SEEG, 2020

Analysing the evolution of the indicators, it is possible to conclude that:

- The carbon intensity of GDP without considering carbon removals - that has no direct relation with the economic activity - increased by 9.0% in the period 2005-2017.
- Analysing the sectors' shares in total gross emissions in 2018, the last year with available data, the most relevant emissions arise from LULUCF with 80.1% of the total. Agriculture comes next with 11.2% (including all emission sources), followed by the energy supply sector that comprises fugitive, fuel production and public service electricity plants emissions, with a share of 4.5%. The other sectors emit altogether 4,2%.
- Considering the population of the Amazonas state in the period 2005-2018, net per capita emissions were -6.97 t CO_2e/inhab. in 2005, reaching the lowest value in 2010 (-14.32 t CO_2e/inhab.) and then increasing until reaching its peak in 2016 (-4.89 t CO_2e/inhab.), but then slightly reduced to reach -6.29 in 2018.

3.4 Conclusion

GHG historical series of the Amazonas State allowed an assessment of the evolution of the emissions profile and the identification of priority areas for mitigation in the state. Over the analysis period, there was an increase of 34.5% in total emissions (without removals) in 2018 (100.7 Mt CO_2e) in relation to 2005 (74.8 Mt CO_2e). Among the sectors analysed, the participation of LULUCF (without carbon removals), agriculture (without carbon removals) and energy sectors stands out, whose emissions increased by approximately 32%, 60% and 34%, respectively, in 2018 compared to 2005.

The estimates indicate that LULUCF (gross emissions) was the main contributor to GHG emissions in all the analysed period, with peaks in 2016 and 2018. These estimates demonstrate how the dynamics of deforestation significantly influence the pattern of GHG emissions in the state, as expected. On the other hand, the same sector plays an important role in mitigating GHG emissions in the state territory, because of the GHG removals from the protected areas.

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