Initiative for Climate Action Transparency – ICAT –

Report with assessment of the mitigation actions that could be implemented in the three selected states and an evaluation of their potential

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Deliverable #6

AUTHORS

Centro Clima/COPPE/UFRJ

Emilio Lèbre La Rovere
Carolina Burle Schmidt Dubeux
Bruna Silveira Guimarães
Erika Carvalho Nogueira

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1. 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], the ICAT 1 project. ICAT 2 project focuses on the MRV (measuring/monitoring, reporting, and verification) process of Brazilian NDC at the subnational level. It is based on the key achievements and lessons learned, from a technical point of view, in the ICAT 1 project.

ICAT 1 Project developed a methodology to estimate the effect of different sets of mitigation actions (grouped in mitigation scenarios) in avoiding GHG emissions to help MRV of the progress achieved in the implementation of quantified commitments of the Brazilian NDC. The project elaborated three indicators: absolute emission indicators, emission driver indicators, and intensity indicators.

To broaden national efforts toward achieving the NDC targets, the ICAT 2 Project will help subnational governments understand how they can contribute to achieving the NDC commitments, prioritizing actions and capacities at the state level. This new phase will build on the ICAT 1 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, and Innovations (MCTI), local governments, and civil society, to monitor and report Brazilian emissions and mitigation efforts.

Following a kick-off workshop involving stakeholders from many states, Rio de Janeiro, Minas Gerais, and Amazonas were selected as pilot cases. The pilot cases aim to develop a process for estimating their potential contribution to the NDC and develop emissions indicators to monitor their emissions trajectories. In addition, it will provide the basis for expanding these analyses to other states in the future.

The project uses the scenario-building methodology. This tool helps to map a possible set of pathways into different plausible futures. A scenario is a set of hypothetical events set in the future constructed to clarify a possible chain of causal events and their decision points (Kahn et al., 1967). They are not predictions but rather simulations of some possible futures. They are an alternative future resulting from a combination of trends and policies. For example, the development of scenarios allows new insights into the opportunities and risks involved in making decisions about climate change policies that would have major consequences for developing a region over the next few decades.

The first step of ICAT2 (Output 3) assessed historical sectoral GHG emissions of Rio de Janeiro, Minas Gerais, and Amazonas states. Then, output 5 assessed the current emissions trends from these states up to 2030 (Reference Scenario) and evaluated their contribution to the Brazilian NDC targets. This scenario considers the pre-NDC Brazilian commitments to the UNFCCC and the current mitigation actions. Thus, it allows a more realistic assumption of a baseline for 2025 and 2030 and the actual effort needed to meet NDC targets.

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

The present report (Output 6) assesses a set of more ambitious mitigation actions that could be implemented in the three selected states and the consequences that they would bring to their emission levels. As in the Reference Scenario, the quantified mitigation actions in the Mitigation Scenario are estimated up to 2030 in the following sectors: AFOLU, transport, industry, other energy use, energy supply, and waste.

The next step includes elaborating MRV indicators (Output 7) to track down the GHG emissions pathways relevant to each state and consistent with the national indicators proposed in Phase 1 of the ICAT Project in Brazil.

2. Reference Scenario and General Assumptions in the Mitigation Scenario for the States of Rio de Janeiro, Minas Gerais and Amazonas

The state inventory reports carried out by Rio de Janeiro and Minas Gerais states provided the historical sectoral GHG emissions information required as the basis for the estimates. For the Amazonas states, the values came from the SEEG (Greenhouse Gas Emissions Estimation System) database. Historical data for the state of Rio de Janeiro covers the period 2005-2015, Minas Gerais 2005-2014, and Amazonas 2005-2018.

The reference scenario assesses the current emissions trends from these states up to 2030, and it considers the pre-NDC Brazilian commitments to the UNFCCC and the current mitigation actions. Besides the historical emissions data, the assessment made use of the emissions growth rates of each economic sector in Brazil modeled in both the ICAT 1 project, for 2015 until 2018, and in the DDP-BIICS project, for 2019 until 2050 (more methodological information and assumptions on Output 5). The scenarios already consider the economic impacts of the Brazilian most severe recession in history, as the substantial GDP decline from 2015 to 2020 due to a political-economic crisis and the COVID-19 pandemic (Figure 1).

The projections of total GHG net emissions in Rio de Janeiro's reference scenario – emissions that would occur in the absence of additional mitigation policies and projects– would increase from 66 Mt CO_2e in 2005, the base year, to 96 Mt CO_2e in 2025 and 103 Mt CO_2e in 2030, 46% and 56%, respectively. In 2005, Minas Gerais emitted 118 Mt CO_2e, and in the reference scenario projections, emissions would reach 152 Mt CO_2e in 2025 and 158 Mt CO_2e in 2030, an increase of 29% and 34%, respectively. In Amazonas, net emissions would grow from -22.27 Mt CO_2e in 2005 to -16 Mt CO_2e in 2025, an increase of 28 %, reaching -15 Mt CO_2e in 2030, a 31% rise, due to an increase in gross emissions that is not followed by the same increase in removals.

The Mitigation Scenario (Output 6) assesses the mitigation actions that could be implemented in the three selected states to increase their mitigation levels. The GHG mitigation measures are based on ICAT 1 Scenario C assumptions.

The projections for the Mitigation Scenarios were calculated based on the percentage change in emissions from Scenario C to Scenario A, obtained in the ICAT 1 project. The percentage was applied in the ICAT 2 Reference Scenarios to project the Mitigation Scenarios values for each State. The quantified mitigation actions are grouped in the Mitigation Scenario, with emissions estimated up to 2030.

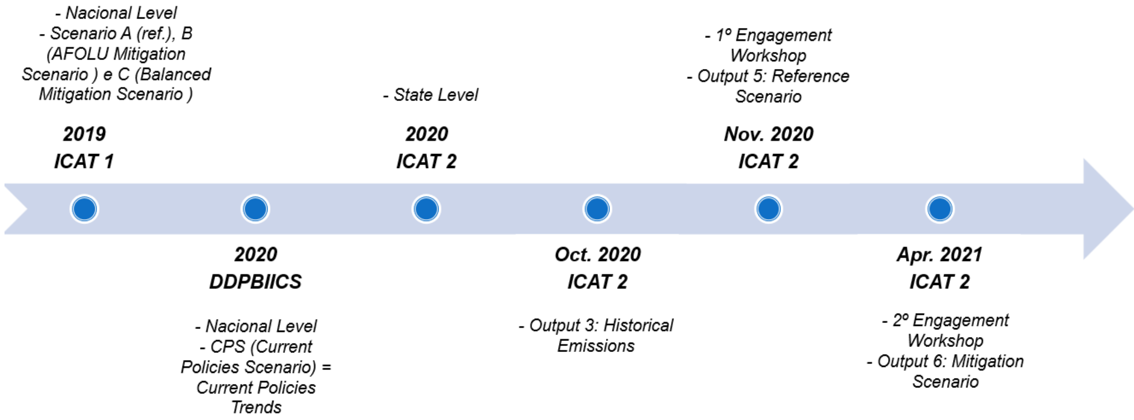


Figure 1. Project Timeline

The ICAT 1 project methodology starts with estimating a baseline scenario (Scenario A – reference scenario) to represent the current emission trends in the country up to 2030, considering the pre-NDC commitments and policies and the current mitigation actions supporting the NDC commitment. Then, the quantified mitigation actions required to meet the NDC targets are grouped into two other scenarios (Scenarios B and C), with emissions estimated up to 2030. They respect the economy-wide targets for 2025 and 2030, representing different combinations of sectoral mitigation actions to achieve the NDC goals. The three scenarios are described below:

Scenario A (Real Path Scenario) is based on current GHG emission trends, including all the policies and measures to cope with the Brazilian NAMAs and NDC commitments. This scenario represents the most likely emissions level the country would achieve if the implementation of the mitigation measures follows the current path.

Scenario B (AFOLU Scenario) reaches the mitigation targets for 2025 and 2030 as in the NDC commitment and includes several mitigation actions proposed by the Brazilian Forum on Climate Change, emphasizing the AFOLU sector.

Scenario C (Balanced Scenario) also reaches the mitigation targets for 2025 and 2030 as in the NDC commitment and includes another set of mitigation actions proposed by the Forum, with a substantial reduction of emissions from other sectors than AFOLU.

3. Mitigation measures used in the national study – ICAT 1 – Brazil – Scenario C

3.1 AFOLU – Agriculture, Forestry and Other Land Use

3.1.1 Land Use Change and Forestry (LULUCF)

- Reduction of deforestation

The annual rate of deforestation until 2020 was estimated based on the targets of the governmental policies for the Amazon and Cerrado biomes, established in both NAMA and NDC. For 2020-2030, the ambition was to reduce 57% in deforestation in the Amazon biome, according to the Brazilian Forum on Climate Change (FBMC).

- Carbon Sinks in Protected Areas (Conservation Units and Indigenous Lands)

Protected areas (Conservation Units and Indigenous Lands) in 2020 would be constant over time and the same size of the current area under this category that reached 269.0 Mha in 2017. In 2020-2030, we assumed an increase of 18.0 Mha, as suggested by the FBMC. According to the Brazilian Forest Service, this area is equivalent to 25% of the forest areas with no property rights assignment (http://www.florestal.gov.br). The protected area by 2030 would then be 287.1 Mha in Scenario C.

- Restoration of Native Forest

Native forest to be restored covering all biomes (Amazonia, Atlantic Forest, Caatinga, Cerrado, Pantanal and Pampa) would be 3.0 Mha until 2030. This target would contribute to the recovery of forest liabilities to cope with the new Forest Code, estimated by Soares Filho in 9.3 Mha (2013).

- Conservation of secondary forest

In Scenario C, removals provided by secondary forests were assumed to be proportional to the emissions from deforestation and other land use changes.

- Increase in commercial planted forest area (commercial tree)

The commercial planted forest area (Eucalyptus and Pinus) is estimated according to the wood demand until 2030 simulated in the other sectors.

- Increase in forest-livestock integration systems (agroforestry)

The area under the forest-livestock integration system by 2030 is 4.4 Mha. This value considered an annual increment of 0.96 Mha/year in 2010-2015.

- Restoration of degraded pasture

In Scenario C, carbon storage from the annual increment of 0.78 Mha/year is simulated for 2016-2030, amounting to 15.6 Mha of restored pasture in 2030.

3.1.2 Agriculture

- Increased zero-tillage cropping systems.

The agricultural area under the zero-tillage system was estimated considering the grain area production in 2005-2015 (IBGE, 2016), the GDP annual growth rate adopted, historical data about areas under zero-tillage from 2005 to 2012, published by FEBRAPDP (2012), and the target established in the ABC Plan (Brazil, 2010) for 2020 (an increase of 8 million ha relatively to 2010).

The assumption was that 39 Mha would be under zero-tillage techniques in 2020. Between 2020-2030 the assumption was zero-tillage in 100% of the expanded soybean area, totaling 45 Mha by 2030.

- Increased use of Biological Nitrogen Fixation (BNF)

The agricultural area under Biological Nitrogen Fixation was estimated considering the production area of grains in the period 2005-2015 (IBGE, 2016), the GDP annual growth rate estimates, the historical data of soybean areas under BNF (2005-2015), and the target established in the ABC Plan (Brazil, 2010) by 2020 (an increase of 5.5 Mha relatively to 2010). The assumption was that 33 Mha would be under BNF in 2020 (an increase of 9.3 Mha compared to 2010). Between 2020 and 2030, the assumption was that 100% of the expanded soybean area would be under BNF, amounting to 38.5 Mha by 2030.

- Manure Management

The amount of animal waste treated until 2030 was estimated considering historical data of the annual populations (number of cattle, swine, and other animal categories) and the GDP yearly growth rate. The percentage of waste treated would be the same as in 2015 by 2030.

- Intensification of livestock productivity

The Intensification of livestock productivity considered an increase of 20% in herd productivity from 2020 on, the restoration of 15.6 Mha pastureland, management of pasture areas, genetic improvement, and reduction of the slaughter age from 37 to 27 months (Strassburg, 2014).

3.2 Transport

Scenario C has an emphasis on policies that encourage active transportation, as well as alternatives for more efficient and low-carbon energy consumption.

The scenario also considered an increment of the vehicles' occupancy rate in passenger transport. For private transportation (automobiles and light commercial vehicles), there is greater participation of alternative vehicles (hybrids and electric) from 2025, being no longer a niche marketplace. In addition, the project considered the effective participation of the travel-sharing segment as ride-hailing, ride-sharing, and car sharing (primarily electric).

Modal split considers the completion on time of all works of the *PAC* and *Avançar* programs[2]. There are more integrating policies in urban passenger transport (buses integration using exclusive lanes and subways), more investment in exclusive lanes for public transport, and active transport measures. Moreover, there is a greater qualification of the bus fleet (adoption of advanced international standards). For automobiles and light commercial vehicles, the

[2] PAC (Growth Acceleration Program) and *Avançar* are national programs encompassing economic policies to accelerate the Brazilian economic growth, with priorities in infrastructure investment.

project assumed a reduction in the average age of vehicles and a more intense scrapping rate due to partnerships with automakers and dealers for the immediate scrapping of old vehicles with lines of credit for the acquisition of new ones.

There is a gradual adoption of the international trend toward electrification (IEA, 2018), with incentives for resale and production, except for batteries, of light and heavy vehicles (buses). In addition, there is more effective participation of sustainable programs for freight transport (e.g., PLVB) and passengers (e.g., EEMU). Nonetheless, there are more incentives to adopt modes with lower carbon intensity (tC/TJ) and energy intensity (TJ/t.km or TJ/pass.km) in the transportation matrix. Along these lines, the share of water transport (especially cabotage) increases in the transport matrix due to the higher demand from tax incentives and a reduction in the segment's bureaucracy. Rail capacity is also enhanced.

There are gradual gains in energy efficiency up to 12% (by 2025) and 18% (by 2030) for cars and light commercial vehicles from the Rota 2030 program. Regarding the *RenovaBio* program, we consider biokerosene in air transportation from 2025 and biomethane in road transportation until 2030. Furthermore, the supply of ethanol is close to the scenario of the average growth scenario of the study "Ethanol Supply Scenarios and Otto Cycle Demand 2018-2030" (EPE, 2018), representing 47 billion litres.

Table 1. Targets and assumptions considered in Scenario C – ICAT 1 Project

FBMC (NDC/NAMA)	Assumptions
Optimizing and diversifying freight transport	Adaptation of the railway network, increasing the capacity and reusing underused lines.
	Adjust concessions or renewal contracts for railways in the scope of the Investment Partnership Program (PPI), to ensure greater integration between the lines.
	Expansion of rail and water networks with the completion of ongoing programs (PAC and Avançar).
	Tax differentiation for inland navigation and cabotage.
Expansion of public transportation, active mobility and optimization of private motorized transport	Demand captured from private transport to BRT, VLT, subway and urban trains by the conclusion on time of all ongoing works (PAC and Avançar).
	Qualification of the bus fleet (stimulating the electrification) and expansion of exclusive bus lanes.
	Measures to increase all aspects of active transport (76.10^9 p.km)
	Integrating policies in urban passenger transport
	Effective participation of the vehicle and ride sharing segment (Carsharing, Carpooling and Ridesharing)
Energy efficiency gains for the fossil fuel fleet, considering passengers and freight transport	Rota 2030 Program (18% of gains in energy efficiency)
	Lower carbon intensity (tC/TJ) and energy intensity (TJ/t.km or TJ/pass.km) in the transportation matrix.
	Regular efficiency gains for other segments (emphasis on PLVB for freight, and EEMU for passengers).
Fostering aviation biokerosene and greater efficiency in air transport	biokerosene in the air transport mode from 2025, with the implementation of the RenovaBio, reaching the blend of 5% (B5) in 2030.
Expansion of alternative vehicles fleet and the supply of biofuels	RenovaBio, increasing the supply of ethanol to 47 billion liters; Market share of flexible-fuel vehicles at 60%.
	Participation of electric vehicles in the fleet of 5% for light vehicles; 10% motorcycles; 12.5% urban buses and 2% trucks.
	Biodiesel Blend at 17% (B17)
	Replacement of 10% of the demand for NGV (1.215 10^3 toe in 2030) by biogas (to be consumed in the states of Rio de Janeiro and São Paulo).

Source: ICAT 1 – Report 2

3.3 Industry

The macroeconomic modelling simulated the future activity level of each industrial branch. It includes the increase in the demand for HFC and SF_6 gases.

The mitigation measures that aim at reducing fuel consumption in each industrial segment are in Table 2. In general, three measures reduce this consumption: (i) optimization of combustion; (ii) heat recovery systems; (iii) steam recovery systems.

Table 2. Energy intensity reduction by industrial subsector between 2015 and 2030 (%) – ICAT 1 Project

Industrial branch	Mitigation measure	Energy intensity reduction (toe/t product) in 2015-2030
		Scenario C
Cement	Optimization of combustion	6.0%
	Heat recovery systems	9.0%
Iron and steel	Optimization of combustion	14%
Iron alloy	Heat recovery systems	14.0%
Non-ferrous metals	Optimization of combustion and Heat recovery systems	9.0%
Pulp and paper	Optimization of combustion and Steam recovery systems	8.0%
Mining and pelleting	Optimization of combustion	14.0%
Chemical	Optimization of combustion	7.0%
	Heat recovery systems	8.0%
Food and beverage	Optimization of combustion	5.0%
	Steam recovery systems	7.0%
Textile	Optimization of combustion	5.0%
	Heat recovery systems	5.0%
Ceramic	Optimization of combustion	4.0%
	Heat recovery systems	7.0%
Other industry	Optimization of combustion	5.0%
	Heat recovery systems	7.0%

Source: ICAT 1 – Report 2

Scenario C considers that there would be a replacement of current fossil fuels by natural gas and by renewable biomass. Gains in the share of these fuels in each industrial segment between 2015 and 2030 are in

Table 3. Replacement of fossil fuels by natural gas and by renewable biomass in Scenario C (%) – ICAT 1 Project

Industrial Branch	Substitution of other fossil fuels for natural gas	Substitution of fossil fuels for renewable biomass
Cement	1.5%	-
Iron and Steel	-	7%
Iron alloys	-	2%
Mining and pelleting	5%	-
Chemical	4%	-
Non-ferrous and other metals	5%	7%
Pulp and paper	4%	2%
Textile	1.5%	
Ceramic	2%	3%

Source: ICAT 1 – Report 2

For specific processes and product use, Table 4 presents the mitigation. In cement production, additives could reduce GHG emissions due to the lower clinker/cement ratio. Regarding product use, like fluorinated greenhouse gases, the replacement or leakage control of gases and the end-of-life recollection could lead to substantial emission reductions.

Table 4. Mitigation measures and potential in IPPU between 2015 and 2030 (%) – ICAT 1 Project

Segment	Mitigation Measure	Emission reduction between 2015 and 2030
		Scenario C
Cement	Add additives (reduction of clinker/cement ratio)	17%
HFCs	Replacement for low GWP refrigerant	55%
	Leakage control and end-of-life recollection	40%
SF_6	Leakage control and end-of-life recollection	50%
PFCs	Optimization and process control	20%

Source: ICAT 1 – Report 2

3.4 Other sectors of energy use

In this sector, no measures were considered.

3.5 Energy supply

In Scenario C, the primary assumption was that no additional fossil fuel power capacity would be added, besides those that won energy auctions until 2017. Efforts aim to foster a higher penetration of renewable sources, like photovoltaics, wind power, sugarcane bagasse, and firewood thermal power plant.

Scenario C includes significant efforts to reduce emissions from the energy sector. The activity level is the same in Oil, LNG, and gas production and reaches 2.69 M bpd in 2030.

Mitigation efforts in the E&P segment for flare reduction are based on the flare levels in the United Kingdom. Stewart (2014), assessing more than 200 UK offshore oil fields, "found that 3% of produced AG was flared or vented at offshore fields. This value drops to 2% when we include only fields developed after 1998. Of the 99 fields developed after 1998, a large range of mean flaring/venting percentages (0-90%) exists at individual fields, indicating that several fields flare high fractions of the AG produced".

Based on this study results, Scenario C assumed that 2.0%, the current value in practice in the UK, would be a viable target for Brazil by 2030. We set the values for the intermediate years by interpolation. Therefore, the mitigation efforts in Scenario C to the E&P segment would then limit flaring and venting to 3.2% in 2020, 2.6% in 2025, and 2.0 in 2030.

As mentioned, in respect to refining, emissions in the refinery segment result from leakages from piping connectors, valves, compressors, and pumps. According to EPA (2018), valves and connectors account for more than 90% of emissions from leaking equipment, with valves being the most significant source.

Therefore, potential mitigation actions are improvement of leak detection and repair (LDAR) programs; improvement of block valves packing; optimization of the valve stuffing box and stem finishes; installation of a second valve on cap or plug on open-ended lines; use of low emission type control valves; upgrade of pump seals; use of low emission quarter-turn valves; 126 and use of lof leakless technology (bellow valves; canned and magnetic drive pumps). Still, according to EPA, fugitive emissions in the US were reduced from 50-90% with LDAR.

Refineries in Europe are under phase III of the EU emissions trading system (EU ETS) since 2013. Based on the 2010 cap, 1.74% is reduced annually, limiting the number of EUAs available to 21% below the 2005 level by 2020. Opportunities to reduce emissions in 2050 are in energy efficiency actions: refinery process efficiency (e.g., catalyst improvements), use of low carbon energy sources (reduction of liquid fuel, increase gas and electricity grid), and CO_2 capture (CONCAWE, 2018).

Although CO_2 capture is not operational yet, Brazilian refineries should assess this option, along with energy efficiency measures and changes in energy sources. Other mitigation alternatives are improving flare efficiency and reducing venting and leakages. Flare efficiency can be improved with correct steam volume and by improving the seal in the compressor. Leak monitoring and repair could be improved with LDAR or SMART LDAR procedures. Studies with these options are summarized below.

Robinson et al. (2007) tested the SMART LDAR, another leak gas detection technology. This technology consists of a portable Infrared camera that scans components more quickly and produces images of gas leaks in real-time. The study concluded that the camera could detect emissions from piping components with leak rates as low as 2 gr/hr. The faster scanning rate allows operators to get better returns on repair efforts because it is easier to identify large leaks. Vidal (2006) studied the same technology for two Brazilian refineries and concluded that results were satisfied only in large leaks. The advantage is the faster response to identify large leaks and repair the components.

Some flaring reduction options are also reported in IPIECA (2012), like reducing the amount of material sent to the flare, processes operation improvement by reducing emergency flaring episodes and installing flare gas recovery systems to recycle the hydrocarbons back into the processing system.

Comodi, Renzi & Rossi (2016) investigated methods to improve energy efficiency in an Italian oil refinery with ejector and liquid ring compressor technologies, and the amount of flare gas that can be recovered yearly corresponds to 6600 t CO_2e.

Silva et al. (2016) studied the optimal steam flow rate used in flares in a large refinery in Brazil by monitoring hydrocarbon emissions using an infrared camera. Results show that the flares were not working on the 98% efficiency, as specified by manufacturers, with the steam 127 flow being higher than the optimal. Results show that the optimal steam would be 44% and 78% smaller than the current flow and that adjusting the steam flow would increase combustion efficiency, reducing costs and black smoke.

Based on these studies, we assume that Petrobras can reduce leaks in the refining segment. Petrobras CDP inventory (2017) reported a reduction of 374,157 t CO_2e (AR4 GWP) or 0.5 Mt CO_2e (AR5 GWP) in fugitive emission due to leakages monitoring and reduction and improvements in management losses of gas flare in refineries in 2016.

According to Scenario C, refineries can save the same amount of fugitive emissions from leakage, venting, and flaring reported in 2016 every five years, resulting in the annual mitigation of 0.5 Mt CO_2e (AR5 GWP) in 2020, 2025, and 2030.

3.6 Waste

3.6.1 Solid waste

According to FBMC, the following mitigation measures could reduce about 20.8 Mt CO_2e in 2030 compared to the emissions in Scenario A (reference scenario) in the same year. These measures are:

- Expansion of the collection/use of methane from unmanaged dumps managed landfills: implementation of methane recovery infrastructure.
- Increase of the composting volume of organic waste segregated at source: largescale waste systems with food, urban pruning leaves, and branches, etc., producing an organic compost for soil carbon fixation (this isolated action has a little-perceived potential, but joined with the previous one it can reach a mitigation potential by 8 Mt CO_2e.
- Conversion of methane from landfills into biogenic CO_2, in flares: considerable mitigation potential in managed and controlled dumps where it is not possible to reuse, and
- Reverse logistic programs, reduction at source, and selective collection of waste with federal support to local and regional programs associated with environmental education programs of broad reach and participation of different school levels.

Therefore, in scenario C, the simulations consider the penetration of the mitigation measures suggested. The collection and treatment levels were maintained but with more outstanding efforts in emissions reduction. For example, the annual increase of 10% in methane recovery for flaring from 2021 until it stabilizes at 80% is adopted in all metropolitan regions and large cities in Scenario C. The numbers presented in Table 5 translate the set of following assumptions adopted to build Scenario C. The following assumptions are considered:

- MSW and ISW (II-A) disposal in landfill: from 46.1% in 2005 to 75% in 2030, an increase of 62.7% in the landfill rate;
- Methane recovery in landfills for:

  - destruction in flairs (95% efficiency): from 70% in 2021 down to 0% in 2028 in capitals and metropolitan areas;
  - destruction in flairs (95% efficiency): from 75% in 2021 down to 40% in 2028 in big cities (over 500,000 inhabitants);
  - electricity generation: from 0% in 2020 up to 80% in 2028 with a 10% annual increase in capitals and metropolitan areas;
  - electricity generation: from 0% in 2020 up to 40% in 2028 with 5% annual increase in big cities (over 500,000 inhabitants);

- replacement of natural gas used in vehicular fleet: from 2.5% of the total methane generated in 2025 up to 3.5% in 2030, following the demand envisaged to the states of São Paulo and Rio de Janeiro, as simulations in the transportation section;

- Composting: increases in the total collected waste from 1.0% in 2005 to 2.0% in 2030; and
- Recycling of paper, cardboard and cellulose: increase from 5.4% in 2005 to 12.0% in 2030.

Table 5. Solid waste activity levels by subsector between 2005 and 2030 in Scenario C (Mt and %) – ICAT 1 Project

Activity Level		2005		2010		2015		2016		2017		2020		2025		2030	
		Mt	%	Mt	%	Mt	%	Mt	%	Mt	%	Mt	%	Mt	%	Mt	%
MSW and ISW(II-A) generation		63.3	100.0	71.2	100.0	79.8	100.0	78.2	100.0	80.6	100.0	85.0	100.0	92.3	100.0	99.7	100.0
MSW and ISW(II-A) collected for disposal sites		52.9	83.5	63.4	89.0	72.5	90.8	71.4	91.2	73.1	90.7	76.8	89.9	82.0	88.8	86.9	84.9
Disposal Sites	Unmanaged Shallow	14.1	26.7	11.5	18.1	12.5	17.2	12.4	17.4	11.4	15.6	11.2	14.6	11.0	13.4	10.8	12.5
	Unmanaged deep	14.4	27.2	15.4	24.3	17.5	24.1	17.3	24.0	16.7	22.8	16.2	21.1	14.5	17.7	10.9	12.5
	Managed (landfills)	24.4	46.1	36.5	57.6	42.6	58.7	41.7	58.4	45.0	61.6	49.4	64.2	56.5	68.9	65.2	75.0
Not collected (uncategorized)		6.4	10.0	3.3	4.7	1.7	2.2	1.1	1.5	1.5	1.9	1.3	1.6	1.2	1.3	1.1	1.1
Aerobic composting		0.6	1.0	0.4	0.6	0.3	0.4	0.3	0.4	0.3	0.4	0.2	0.3	1.0	1.2	1.9	2.0
Recycling		3.4	5.4	4.1	5.7	5.3	6.6	5.4	7.0	5.7	7.1	6.5	7.7	8.0	8.7	9.7	12.0

Source: ICAT 1 – Report 2

3.6.2 Wastewater

In scenario C, mitigation measures were considered from 2018 to 2030, maintaining the level of collection and treatment and complying on a larger scale with the PNSB[3], with more significant efforts than in the Reference Scenario in reducing emissions, for example, with an increase in the methane recovery for flare burning, from 2021 to stabilize by 80% in anaerobic plants. The numbers presented in Table 6 translate the set of following assumptions adopted to build Scenario C:

- Wastewater treatment in plants: 50.8% of the sewage generated in 2030;
- Treatment in anaerobic plants: Displacement of 5% of treatment from septic tanks to anaerobic plants up to 26.5% in 2030;
- Destruction of biomethane in flares of anaerobic plants: increases from 60% to 80% from 2021 to 2030 (flare efficiency rate of 55%);
- Domestic sewage treatment in septic and rudimentary tanks decreases from 21% to 16% in 2030, due to the displacement of 5% for anaerobic treatment plants;

[3] The National Basic Sanitation Plan comprises four integrated components: drinking water supply, sanitary sewage, solid waste collection and management, and urban rainwater drainage and management.

- Methane destruction in industrial plants of the capitals, metropolitan regions, large cities (> 500 thousand inhabitants), and medium-size (> 100 thousand inhabitants) to 46.9% of the biomethane produced in 2030 (55% efficiency).

Table 6. Wastewater activity levels between 2005 and 2030 in Scenario C (Mt and %) – ICAT 1 Project

Activity Level	2005		2010		2015		2016		2017		2020		2025		2030	
	Mt BOD	%	Mt BOD	%	Mt BOD	%	Mt BOD	%	Mt BOD	%	Mt BOD	%	Mt BOD	%	Mt BOD	%
Wastewater generation	3.0	100	3.2	100	3.4	100	3.4	100	3.5	100	3.5	100	3.7	100	3.8	100
Sewage treatment plant	0.5	16.7	0.9	27.5	1.4	39.9	1.4	40.5	1.4	41	1.5	42.4	1.6	44.3	1.7	50.8
Emission-free processes	0.1	2.3	0.1	1.8	0	1.5	0	1.5	0	1.4	0	1.3	0	1.1	0	1
Sludge activated	0.2	6.6	0.4	11.8	0.5	14.4	0.5	14.7	0.5	15	0.6	15.7	0.6	16.7	0.7	17.5
Anaerobic Treatments	0.1	3.8	0.3	9.2	0.6	18.2	0.6	18.5	0.6	18.8	0.7	19.6	0.8	20.7	1	26.5
facultative lagoons	0.1	3.4	0.1	3.4	0.1	3.5	0.1	3.5	0.1	3.5	0.1	3.5	0.1	3.5	0.1	3.5
Other treatments, unspecified	0.0	0.5	0	1.3	0.1	2.4	0.1	2.4	0.1	2.4	0.1	2.4	0.1	2.4	0.1	2.4
Septic tank	0.3	10.5	0.3	10.8	0.4	12.2	0.4	12.5	0.4	12.9	0.5	13.1	0.5	13.8	0.5	13.1
Rudimentary tank	0.5	16.4	0.4	13.7	0.4	11	0.4	10.5	0.3	10	0.3	8.3	0.2	5.6	0.1	2.9
Launch in water bodies	1.7	56.4	1.5	48	1.2	36.8	1.2	36.5	1.2	36.2	1.3	36.1	1.3	36.2	1.2	33.1

Source: ICAT 1 – Report 2

4. Emission Scenarios for the State of Rio de Janeiro

This section focuses on the state of Rio de Janeiro, describing its historical emissions and assessing its emission trends through the Reference and Mitigation Scenarios.

4.1 Results of Sectoral Projections

4.1.1 AFOLU – Agriculture, Forestry and Other Land Use

The agriculture, forestry and other land use (AFOLU) sector describes the GHG emissions from two distinct subsectors: LULUCF (Land use, land use change, and forestry) and agriculture. Emissions and removals related to forest and other land use are covered under LULUCF. Agriculture includes emissions from crops (rice cultivation, prescribed burning of savannas and grassland, and soils) and livestock (enteric fermentation, manure management).

a. Land Use Change and Forest (LULUCF)

Both Reference and Mitigation Scenarios present a considerable reduction in GHG emissions from LULUCF in the State during the analyzed period (2005-2030). This reduction is mainly due to deforestation reduction and the increase of protected areas. Land use emissions started to be negative in 2010 with this carbon removal and remain negative throughout the analyzed period. In the projected period (2025-2030), emissions show a smoother reduction.

During 2005-2025 and 2005-2030, LULUCF emissions of the Reference Scenario reduced 105%. On the other hand, LULUCF emissions of the Mitigation Scenario decreased 106%, as detailed in Table 7.

Table 7. Table 7. Emissions from LULUCF – State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
LULUCF (net emissions)	6.3	-0.2	-0.4	-0.3	-0.3	-0.4	-0.3	-0.4	-105%	-106%	-105%	-106%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

b. Agriculture

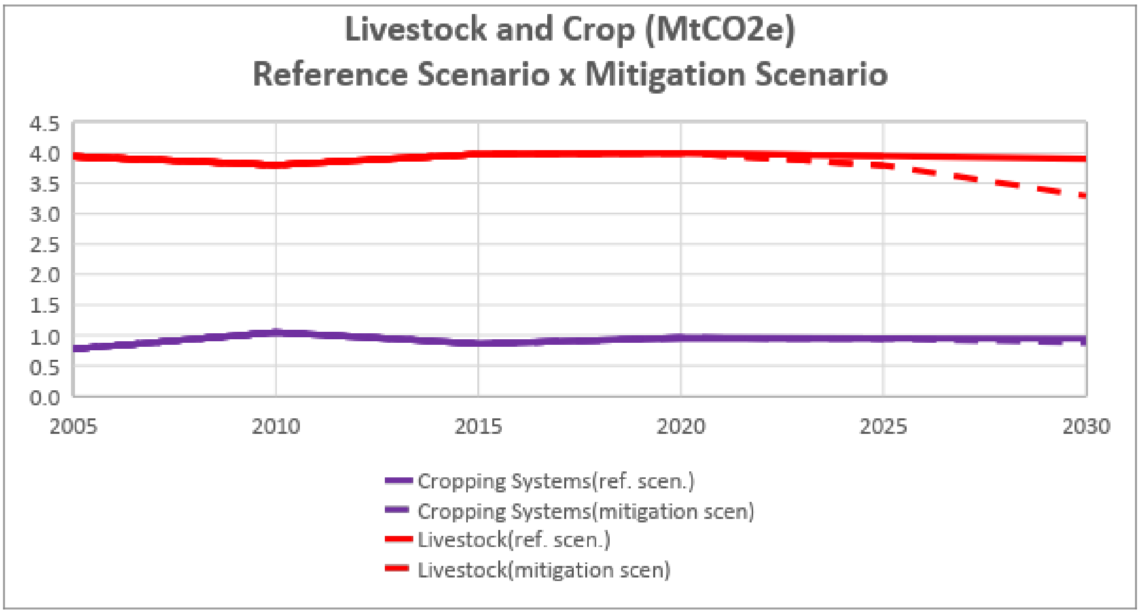
Regarding emissions during the entire analyzed period, agriculture subsector emissions in the Reference Scenario remained constant from 2005 to 2025 and increases 3% from 2005 to 2030. In the Mitigation Scenario, agriculture subsector emissions increase 1% from 2005 to 2025 and reduced 12% from 2005 to 2030. So, the adoption of mitigation measures leads to a significant reduction in emissions by 2030 compared to the current policy trend.

Livestock emissions remain the primary source of emissions of the agriculture sector in both Scenarios. However, it presents a higher reduction in emissions than crops in the Mitigation Scenario, as detailed in Table 8 and Figure 2.

Table 8. Agriculture emissions by subsector – State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Agriculture	**4.7**	**4.9**	**4.8**	**5.0**	**4.9**	**4.7**	**4.8**	**4.2**	**4%**	**1%**	**3%**	**-12%**
Livestock	3.9	3.8	4.0	4.0	3.9	3.8	3.9	3.3	0%	-4%	-1%	-16%
Crop	0.8	1.1	0.9	1.0	1.0	0.9	0.9	0.9	23%	22%	22%	13%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 2. Agriculture emissions by subsector – State of Rio de Janeiro (Mt CO_2e)

Crop

Crops are the second-largest source of emissions in the agriculture sector, and the activities associated with agricultural soil are the main emission source in this subsector.

Regarding crop emissions, the Reference Scenario increased 23% from 2005 to 2025 and 22% from 2005 to 2030. On the other hand, in the Mitigation Scenario, crop emissions increased 22% from 2005 to 2025 and 13% from 2005 to 2030 (Table 9).

Table 9. Crop emissions by subsector – State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Cropping Systems	0.8	1.1	0.9	1.0	1.0	0.9	0.9	0.9	23%	22%	22%	13%
Agricultural Soils	0.6	1.0	0.8	0.9	0.9	0.9	0.9	0.8	39%	37%	38%	26%
Rice Cultivation	0.039	0.014	0.001	0.006	0.006	0.006	0.005	0.005	-86%	-86%	-87%	-87%
Burning of Agricultural Residues	0.088	0.062	0.045	0.046	0.045	0.053	0.045	0.056	-48%	-40%	-49%	-36%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Livestock

Livestock is the main emission source in the agriculture subsector led by enteric fermentation. Regarding emissions during the entire analyzed period, livestock emissions in the Reference Scenario remained constant from 2005 to 2025 and increased 3% from 2005 to 2030. In the Mitigation Scenario, livestock emissions decreased 1% from 2005 to 2025 and 16% from 2005 to 2030 (Table 10).

Table 10. Livestock emissions by subsector – State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Agriculture	**4.7**	**4.9**	**4.8**	**5.0**	**4.9**	**4.7**	**4.8**	**4.2**	**4%**	**1%**	**3%**	**-12%**
Livestock	3.9	3.8	4.0	4.0	3.9	3.8	3.9	3.3	0%	-4%	-1%	-16%
Enteric Fermentation	3.7	3.6	3.7	3.7	3.7	3.5	3.6	3.0	-1%	-5%	-2%	-18%
Manure management	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	17%	17%	17%	11%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

AFOLU consolidated results

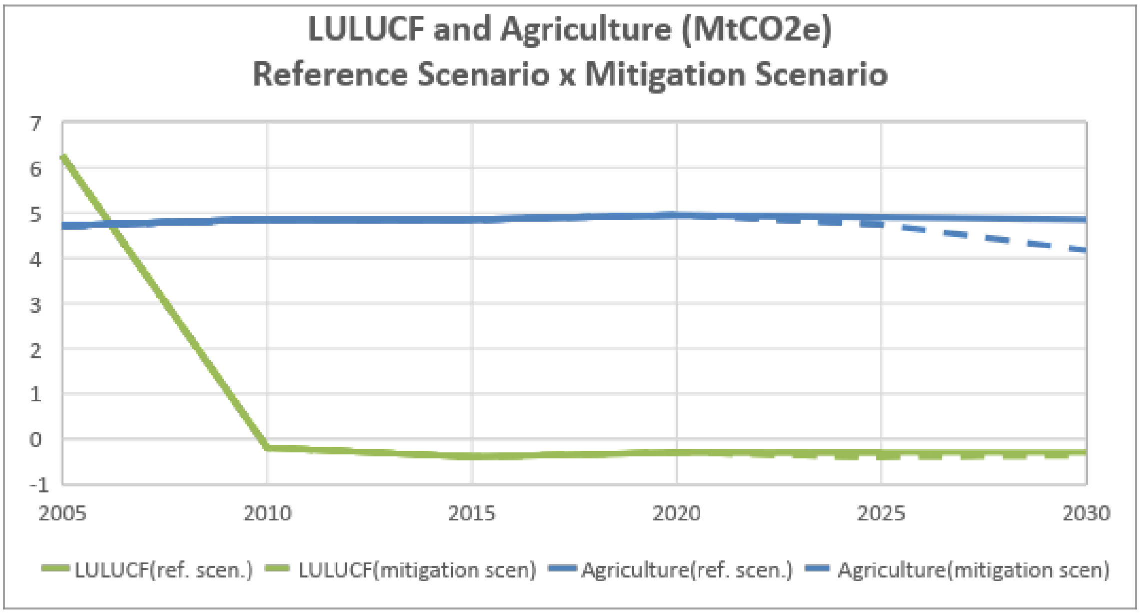
AFOLU emissions in the Reference Scenario decrease 58% from 2005 to 2025 and 59% from 2005 to 2030. In the Mitigation Scenario, AFOLU emissions fell 60% from 2005 to 2025 and 65% from 2005 to 2030 (Table 11 and Figure 3). This decrease is due to the reduction of deforestation rates, increased protected areas during 2005-2010, and the adoption of less carbon-intensive agricultural activities, mainly in the Mitigation Scenario.

Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures leads to a reduction in emissions of 16% (Figure 4).

Table 11. Emissions from Agriculture, forestry and other land use (AFOLU) – State of Rio de Janeiro (Mt CO_2e and %)

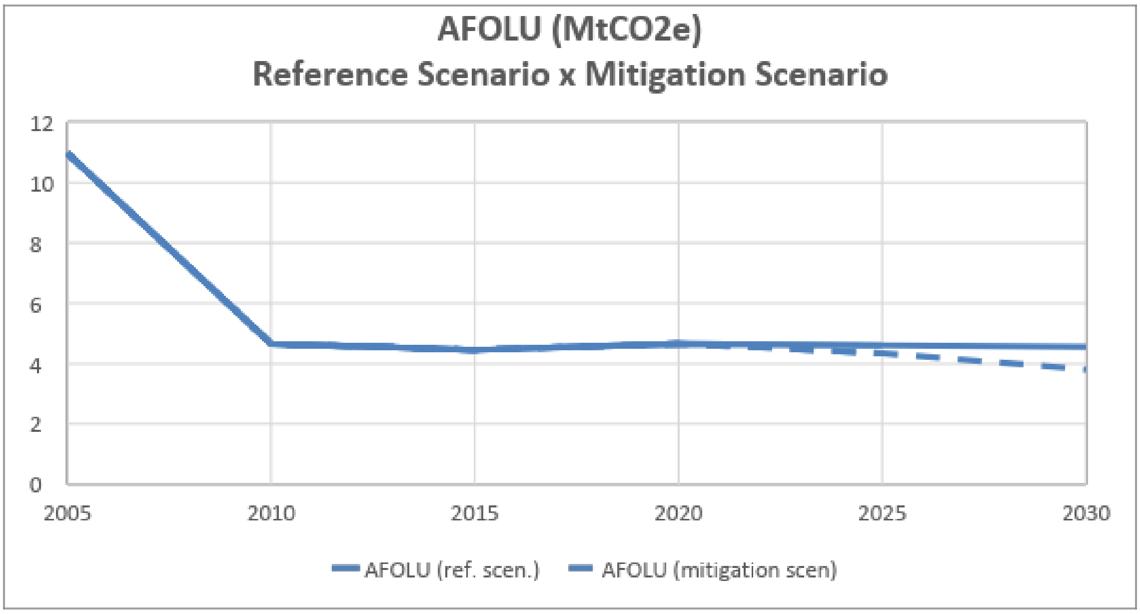
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
AFOLU	**11.0**	**4.7**	**4.4**	**4.7**	**4.6**	**4.3**	**4.6**	**3.8**	**-58%**	**-60%**	**-59%**	**-65%**
LULUCF(net emissions)	6.3	-0.2	-0.4	-0.3	-0.3	-0.4	-0.3	-0.4	-105%	-106%	-105%	-106%
Agriculture	4.7	4.9	4.8	5.0	4.9	4.7	4.8	4.2	4%	1%	3%	-12%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 3. Emissions from Agriculture and LULUCF – State of Rio de Janeiro (Mt CO_2e)



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 4. Emissions from Agriculture, forestry and other land use (AFOLU) – State of Rio de Janeiro (Mt CO_2e)

4.1.2 Transport

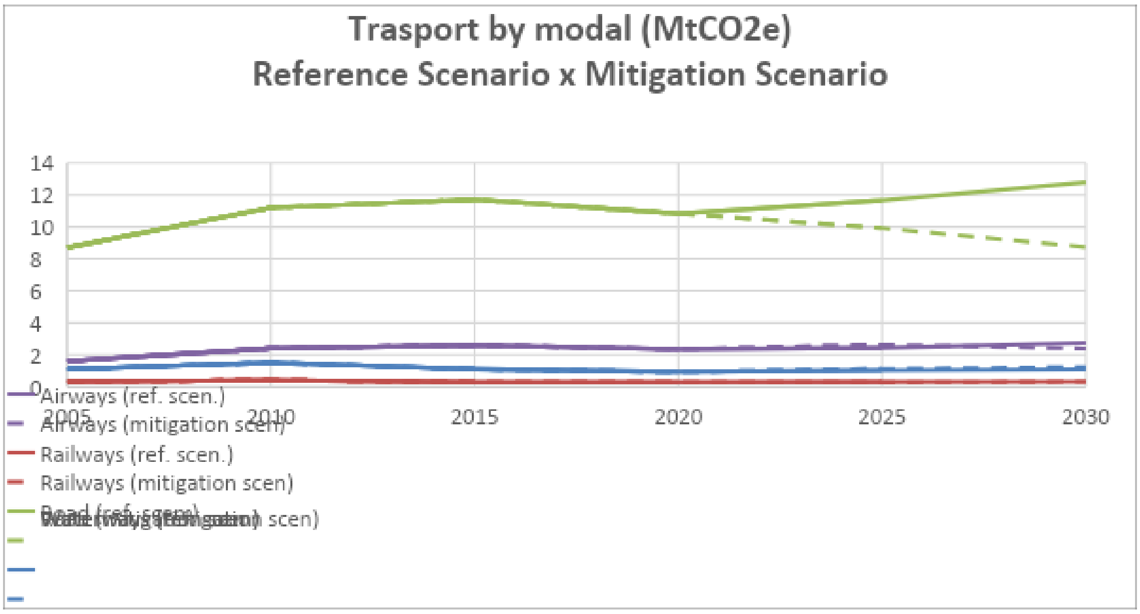
Transport emissions in the Reference Scenario increased 31% from 2005 to 2025 and 19% from 2005 to 2030. In the Mitigation Scenario, transport emissions increased 44% from 2005 to 2025 and 8% from 2005 to 2030 (Table 12 and Figure 6). Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures leads to a reduction in emissions of 25%.

The primary source of emissions of the transport sector is road transport, and most of these emissions come from diesel oil, used mainly by cargo and mass transportation. However, comparing the Reference Scenario with the Mitigation Scenario, the road mode has the most significant mitigation potential. On the other hand, other modes present a slight variation (Figure 5).

Table 12. Transport emissions by modes – State of Rio de Janeiro (Mt CO_2e and %)

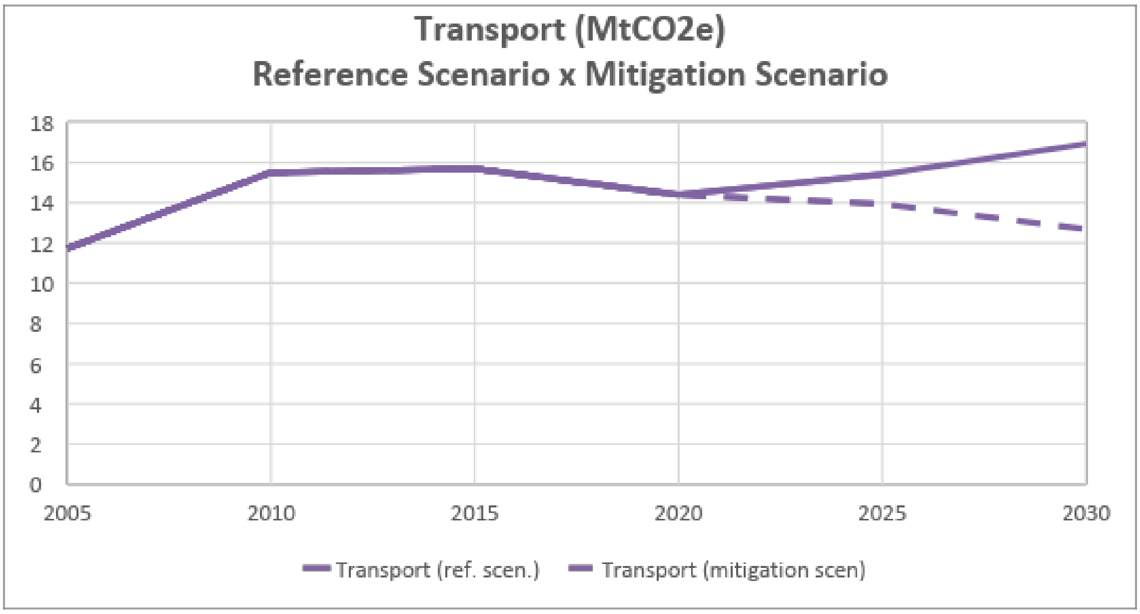
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Transport	12	16	16	14	15	14	17	13	31%	19%	44%	8%
Road	9	11	12	11	12	10	13	9	34%	14%	47%	0%
Rail	0.32	0.41	0.29	0.29	0.30	0.27	0.33	0.32	-6%	-14%	2%	-1%
Air	1.6	2.4	2.6	2.3	2.4	2.6	2.7	2.4	52%	64%	71%	50%
Water	1.1	1.5	1.1	0.9	1.0	1.1	1.1	1.2	-6%	1%	-1%	13%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 5. Transport emissions by modes – State of Rio de Janeiro (Mt CO_2e)



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 6. Emissions from the transport sector – State of Rio de Janeiro (Mt CO_2e)

4.1.3 Industry

Industry emissions include both industrial processes and product Use (IPPU) and industrial energy use. However, the main source of emissions is IPPU. In the Reference Scenario, IPPU emissions increased 48% from 2005 to 2025 and 16% from 2005 to 2030. In the Mitigation Scenario, IPPU emissions increased 16% from 2005 to 2025 and 18% from 2005 to 2030.

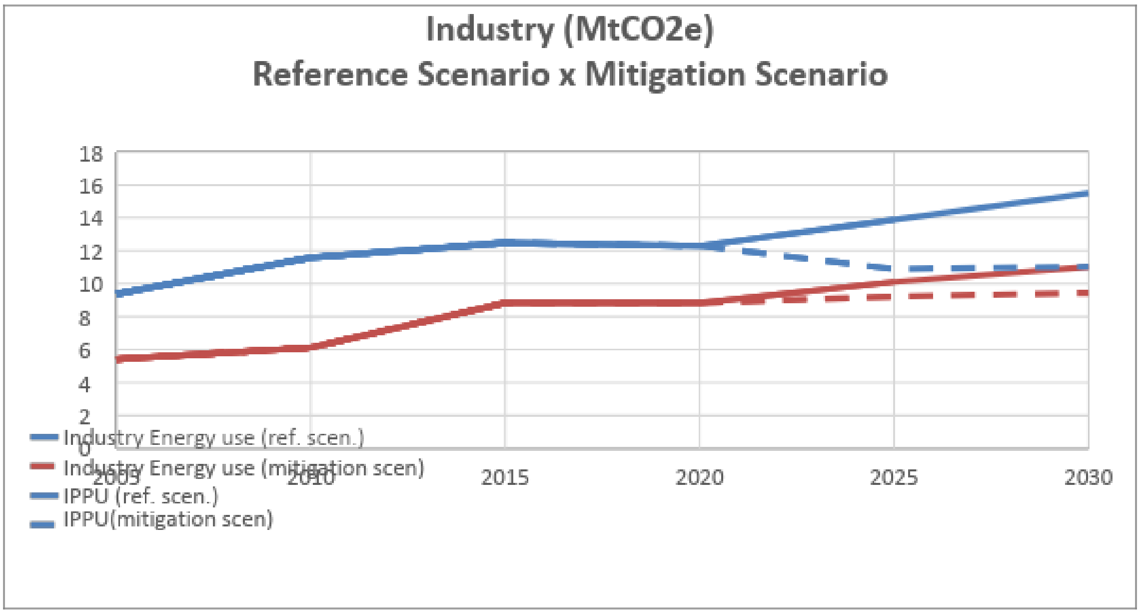
On the other hand, energy emissions presented a higher increase during the analyzed period for both Scenarios. In the Mitigation Scenario, energy emissions increased 86% % from 2005 to 2025 and 103% from 2005 to 2030. In the Mitigation Scenario, Energy emissions increased 70% from 2005 to 2025 and 74% from 2005 to 2030.

Total Industry emissions in the Reference Scenario increased 62% from 2005 to 2025 and 79% from 2005 to 2030. In the Mitigation Scenario, Industry emissions increased 36% from 2005 to 2025 and 38% from 2005 to 2030 (Table 13 and Figure 7). Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures leads to a reduction in emissions of 23% (Figure 8).

Table 13. Emissions from the industry sector – energy use and industrial processes and product use (IPPU) – State of Rio de Janeiro (Mt CO_2e and %)

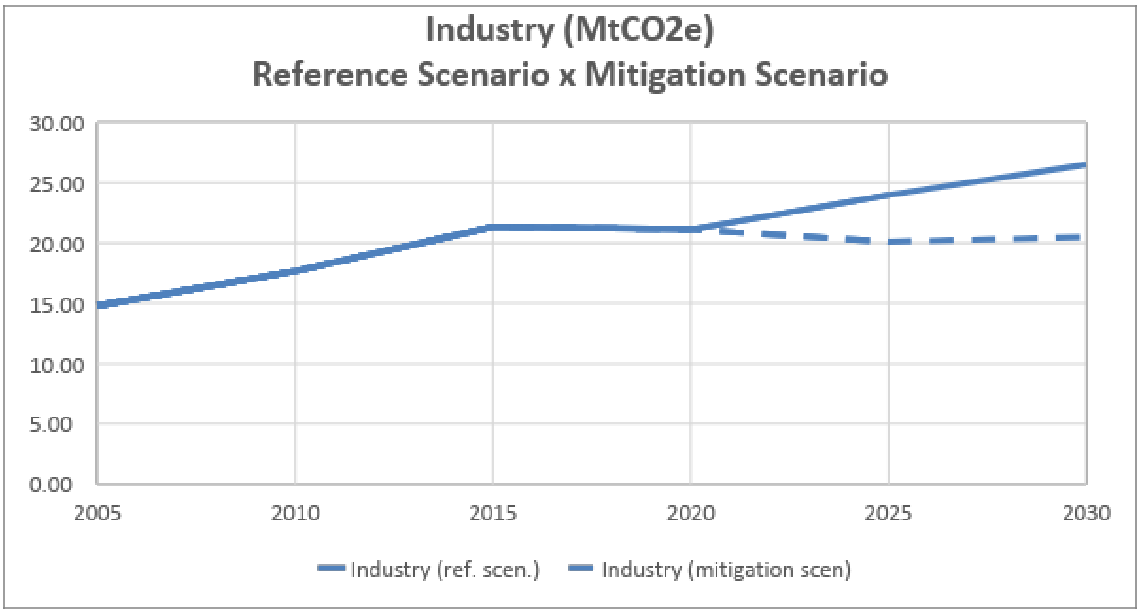
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e						%					
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Industry (Energy)	5	6	9	9	10	9	11	9	86%	70%	103%	74%
Industrial Processes and Product Use	9	12	12	12	14	11	15	11	48%	16%	65%	18%
Industry (IPPU and energy)	**15**	**18**	**21**	**21**	**24**	**20**	**27**	**20**	**62%**	**36%**	**79%**	**38%**
Cement	1.1	1.8	1.2	1.1	1.3	1.3	1.5	1.3	15%	11%	29%	15%
Iron and steel	9	12	16	15	18	15	19	16	94%	68%	114%	73%
Non-Ferrous Metals and Other	0.53	0.11	0.11	0.10	0.11	0.10	0.12	0.11	-80%	-81%	-78%	-80%
Paper and Cellulose	0.10	0.11	0.10	0.10	0.11	0.10	0.13	0.11	14%	-2%	28%	10%
Chemical	1.96	1.52	0.91	0.89	1.00	0.93	1.10	0.94	-49%	-53%	-44%	-52%
Food and beverage	0.41	0.40	0.36	0.36	0.40	0.37	0.44	0.40	-3%	-10%	7%	-2%
Rest of industry	1.6	1.8	2.8	3.1	3.4	2.1	3.8	1.9	120%	32%	143%	21%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 7. Industry emissions by subsector- energy use and industrial processes and product use (IPPU) – State of Rio de Janeiro (Mt CO_2e)



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 8. Emissions from the industry sector – State of Rio de Janeiro (Mt CO_2e)

4.1.4 Other sectors of energy use

The Other sectors of energy use include the residential, commercial, public, and agriculture sectors. The residential sector is the largest emitter, followed by the commercial, public, and agriculture sectors. The agriculture sector was the only one that reduced emissions during the analyzed period.

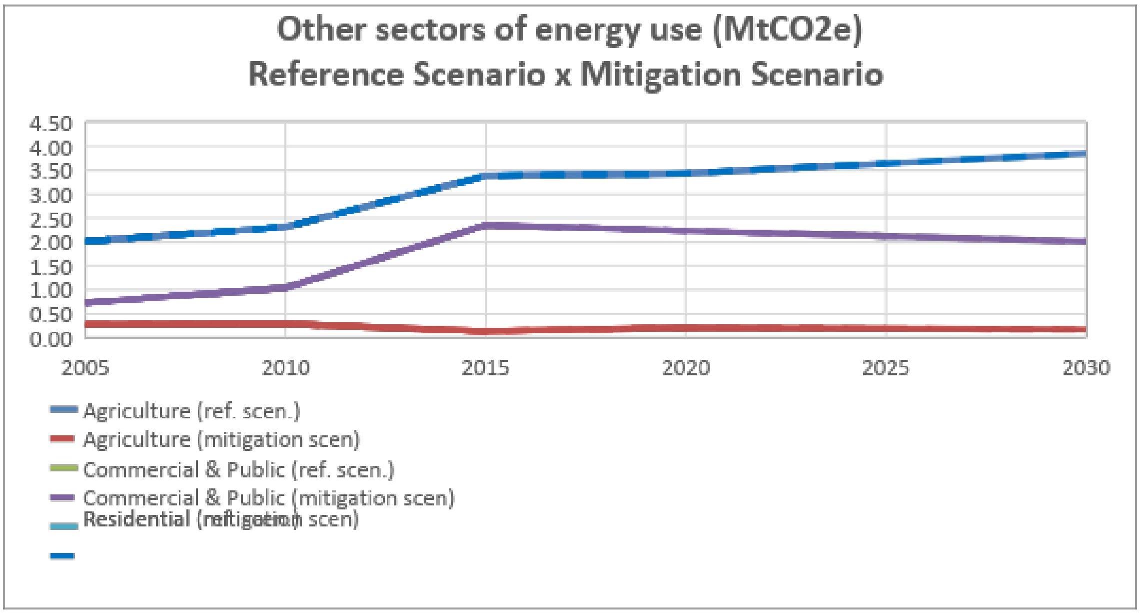
The Reference and Mitigation Scenarios are the same in these sectors since additional mitigation measures were not considered in the Mitigation Scenario. Emissions from these sectors increased 98% from 2005 to 2025 and 100% from 2005 to 2030.

Residential emissions increased 81% % from 2005 to 2025 and 91% from 2005 to 2030. Commercial and Public emissions increased 190% % from 2005 to 2025 and 175% from 2005 to 2030. Agriculture emissions decreased 29% % from 2005 to 2025 and 35% from 2005 to 2030 (Table 14 and Figure 9).

Table 14. Emissions from Other sectors of energy use – State of Rio de Janeiro (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e						%					
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Other sectors of energy use	3	4	6	6	6	6	6	6	98%	98%	100 %	100 %
Residential	2	2	3	3	4	4	4	4	81%	81%	91%	91%
Commercial & Public	1	1	2	2	2	2	2	2	190 %	190 %	175 %	175 %
Agriculture	0.27	0.29	0.13	0.21	0.19	0.19	0.18	0.18	-29%	-29%	-35%	-35%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 9. Emissions from Other sectors of energy use – State of Rio de Janeiro (Mt CO_2e)

4.1.5 Energy supply

The energy sector comprises the fuel combustion in the transformation centers and the sector's self-production. Fugitive emissions from the oil and gas sector are also considered. The noticeable increase in emissions occurred during 2005 and 2015; then, there was a reduction in emissions followed by an increase (Table 15, Figure 10 and Figure 11).

In the Reference Scenario, Energy supply emissions increased 108% from 2005 to 2025 and 121% from 2005 to 2030. The Mitigation Scenario increased 100% from 2005 to 2025 and 102% from 2005 to 2030. Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures leads to a reduction in emissions of 9%.

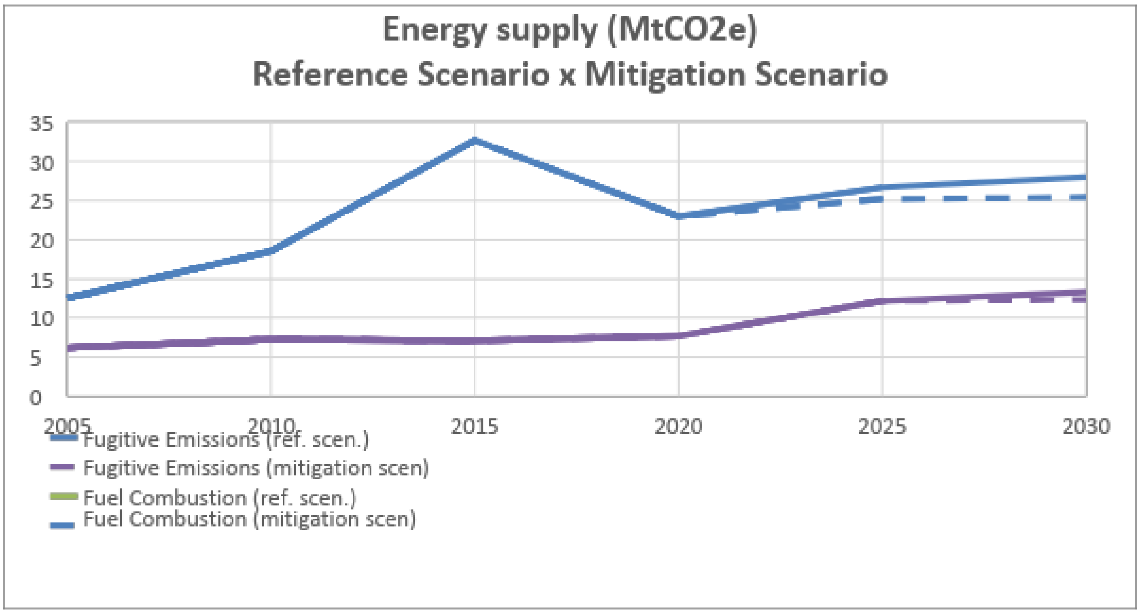
Fuel combustion is the main energy supply sector's emissions, mainly because of the transformation centers. In the Reference Scenario, fuel combustion emissions increased 113% % from 2005 to 2025 and 123% from 2005 to 2030. The Mitigation Scenario increased 101% from 2005 to 2025 and 103% from 2005 to 2030.

Regarding fugitive emissions, E&P is the primary source of emissions. In the Reference Scenario, fugitive emissions increased 97% % from 2005 to 2025 and 115% from 2005 to 2030. The Mitigation Scenario increased 97% from 2005 to 2025 and 100% from 2005 to 2030.

Table 15. Energy supply emissions by sector – State of Rio de Janeiro in the period 2005-2030 (Mt CO_2e and %)

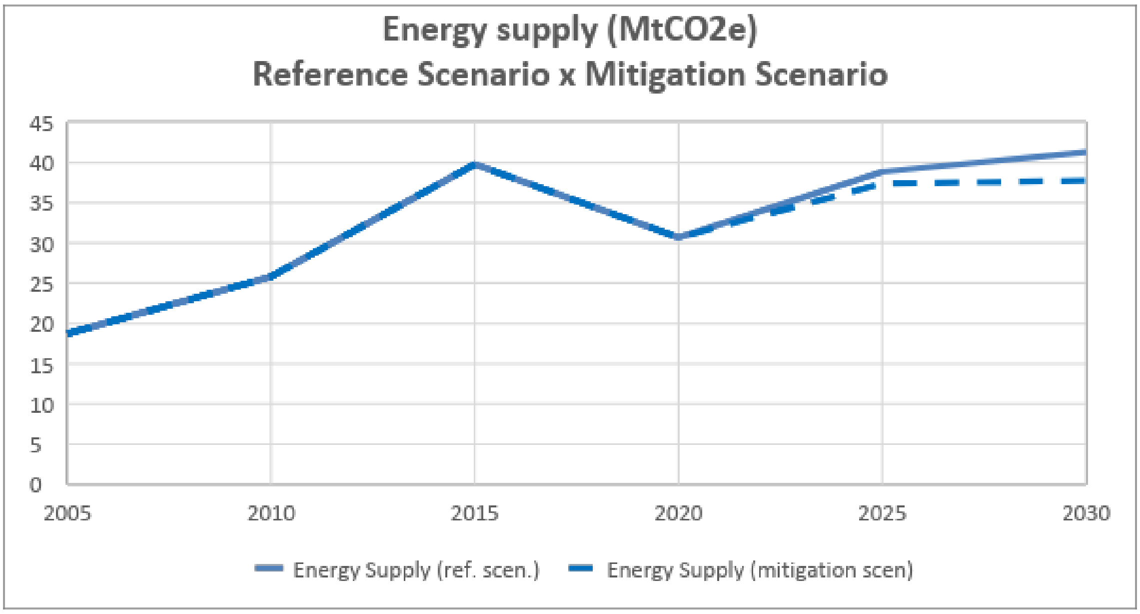
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref	Mitig	Ref	Mitig	Ref	Mitig	Ref	Mitig
Energy supply (total)	19	26	40	31	39	37	41	38	108%	100%	121%	102%
Energy supply (Fuel combustion)	13	19	33	23	27	25	28	25	113%	101%	123%	103%
Energy Sector Consumption	5	6	11	7	8	8	9	8	64%	58%	72%	57%
Transformation Centers	8	12	22	16	19	17	19	18	146%	129%	157%	133%
Power Plants	6	11	21	15	17	16	18	16	184%	166%	199%	172%
Coke production	1.6	1.6	1.4	1.4	1.7	1.6	1.7	1.6	6%	-3%	6%	-5%
Charcoal Production	0.002	0.001	0.004	0.003	0.003	0.003	0.003	0.004	40%	40%	75%	110%
Energy supply (Fugitive Emissions)	6	7	7	8	12	12	13	12	97%	97%	115%	100%
E&P	6	7	6	7	11	11	12	11	99%	99%	117%	100%
Oil Refining	0.039	0.036	0.034	0.034	0.039	0.035	0.044	0.040	1%	-9%	13%	2%
Fuel transport	0.6	0.6	0.6	0.7	1.1	1.1	1.2	1.2	87%	87%	105%	105%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 10. Energy supply emissions by sector – State of Rio de Janeiro in the period 2005-2030 (Mt CO_2e)



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 11. Energy supply emissions – State of Rio de Janeiro in the period 2005-2030 (Mt CO_2e)

4.1.6 Waste

Waste emissions include both solid waste and wastewater. Waste emissions main increase occurred between 2005 and 2015, followed by a softer increase. (Table 16, Figure 12 and Figure 13).

In the Reference Scenario, waste emissions increased 142% from 2005 to 2025 and 154% from 2005 to 2030. The Mitigation Scenario increased 123% from 2005 to 2025 and 142% from 2005 to 2030. Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures leads to a reduction in emissions of 9%.

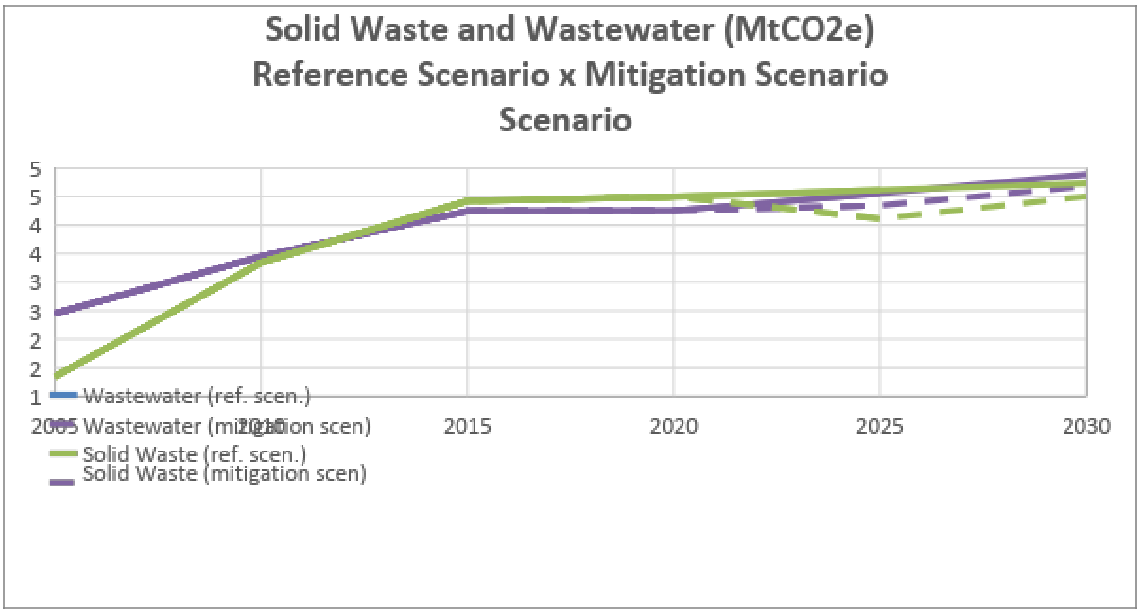
Wastewater is the main source of Emissions from the waste sector, mainly because of industrial wastewater. In the Reference Scenario, wastewater emissions increased 86% % from 2005 to 2025 and 99% from 2005 to 2030. The Mitigation Scenario increased 77% from 2005 to 2025 and 91% from 2005 to 2030.

Regarding solid waste emissions, urban solid waste is the main source of emissions. In the Reference Scenario, solid waste emissions increased 244% % from 2005 to 2025 and 253% from 2005 to 2030. The Mitigation Scenario increased 207% from 2005 to 2025 and 236% from 2005 to 2030.

Table 16. Emissions from the waste sector – State of Rio de Janeiro (Mt CO_2e and %)

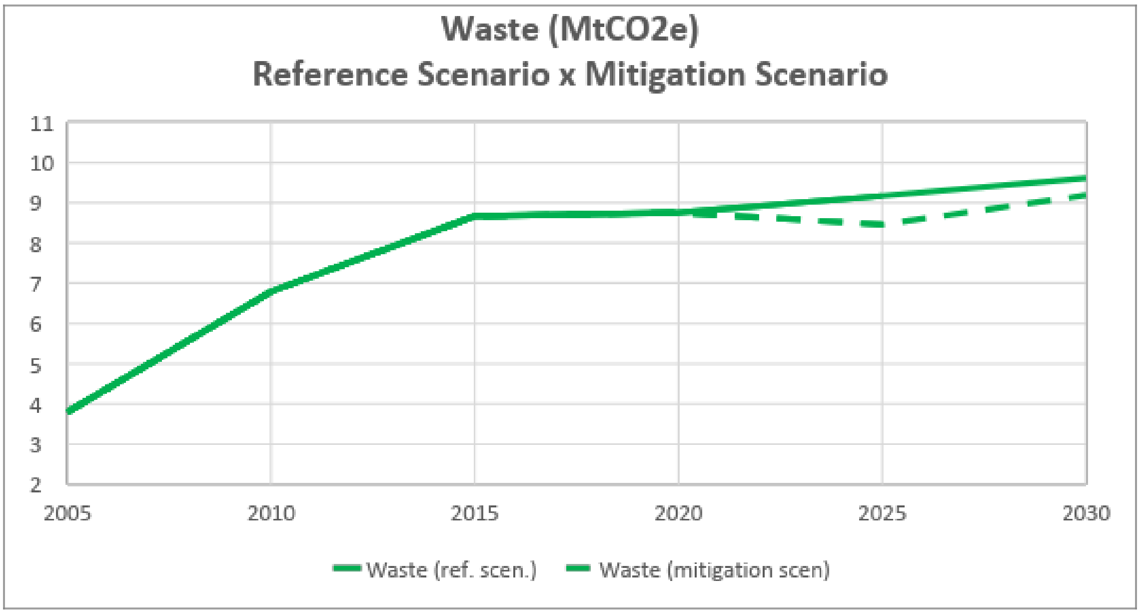
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Waste	3.8	6.8	8.7	8.8	9.2	8.5	9.6	9.2	142%	123%	154%	142%
Solid Waste	1.3	3.3	4.4	4.5	4.6	4.1	4.7	4.5	244%	207%	253%	236%
Urban Solid Wastes	1.3	3.1	3.8	3.9	4.0	3.0	4.0	2.9	196%	123%	199%	118%
Others	0.0	0.2	0.6	0.6	0.6	1.1	0.7	1.6	10%	91%	22%	169%
Wastewater Treatment and Discharge	2	3	4	4	5	4	5	5	86%	77%	99%	91%
Domestic Wastewater	0.9	1.3	1.7	1.7	1.7	1.6	1.7	1.7	99%	88%	101%	91%
Industrial Wastewater	1.6	2.2	2.6	2.5	2.8	2.7	3.1	3.0	79%	71%	99%	91%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 12. Waste emissions by subsector – State of Rio de Janeiro (Mt CO_2e)



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 13. Emissions from the waste sector – State of Rio de Janeiro (Mt CO_2e)

4.2 Consolidation of Scenarios – State of Rio de Janeiro

Total emissions from the State of Rio de Janeiro reached 103 Mt CO_2e in 2030 in the Reference Scenario and 88 Mt CO_2e in the Mitigation Scenario. Therefore, the Reference Scenario increases 56% and the Mitigation Scenario 33% from 2005 until 2030.

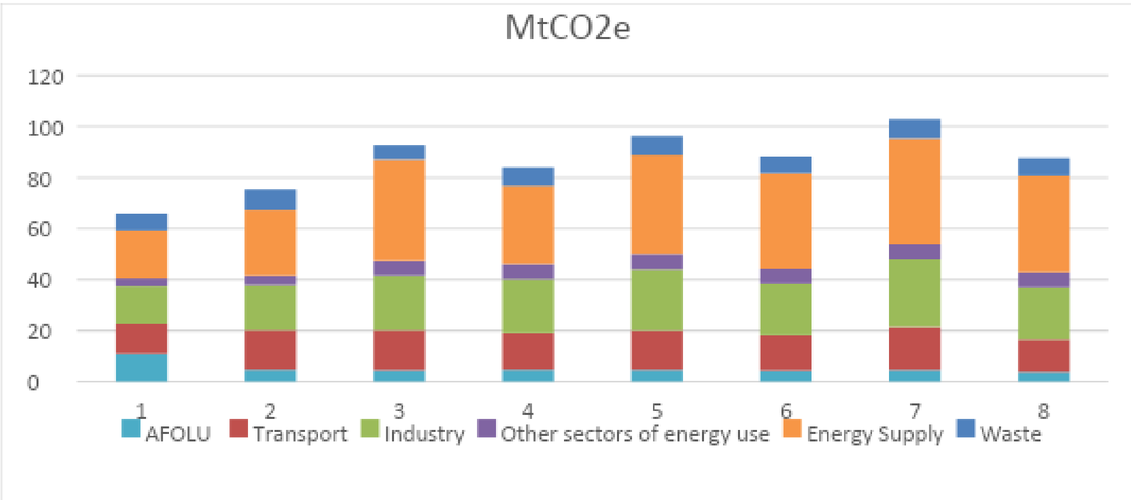
In 2030, the main source of emissions is the energy supply sector, followed by industry, transport, waste, other sectors of energy use, and AFOLU. AFOLU is the less emitting sector because of deforestation reduction and carbon removals by increasing protected areas.

The sector with the most significant potential for increasing emissions, considering 2005 until 2030 and the selected mitigation measures, is the Energy supply sector. Conversely, the sector with the most considerable potential for reducing emissions is AFOLU. (Table 17 and Figure 14).

Table 17. Rio de Janeiro State emissions by sector in the period 2005-2030 (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	$MtCO_2e$								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
AFOLU	11	5	4	5	5	4	5	4	-1%	-7%	-2%	-18%
Transport	12	16	16	14	15	14	17	13	31%	19%	44%	8%
Industry	15	18	21	21	24	20	27	20	62%	36%	79%	38%
Other sectors of energy use	3	4	6	6	6	6	6	6	98%	98%	100%	100%
Energy supply	19	26	40	31	39	37	41	38	108%	100%	121%	102%
Waste	7	8	5	7	7	6	8	7	11%	-2%	14%	4%
Total	66	75	93	84	96	88	103	88	46%	34%	56%	33%

Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.



Note: Historical emission data from 2005 to 2015 and projections from 2016 to 2030.

Figure 14. Rio de Janeiro State emissions by sector in the period 2005-2030 (Mt CO_2e and %)

5. Emission Scenarios for the State of Minas Gerais

This section focuses on the state of Minas Gerais, describing its historical emissions and assessing its emission trends through the Reference and Mitigation Scenarios.

5.1 Results of Sectorial Projections

5.1.1 AFOLU – Agriculture, Forestry and Other Land Use

The agriculture, forestry and other land use (AFOLU) sector describes the GHG emissions from two distinct subsectors: LULUCF (land use, land use change, and forestry) and Agriculture. Emissions and removals related to forest and other land use are covered under LULUCF. Agriculture includes emissions from crops (agricultural soils, rice cultivation, burning of agricultural residues and liming) and livestock (enteric fermentation and manure management).

a. LULUCF

Both Reference and Mitigation Scenarios present a considerable increase in GHG emissions from LULUCF in the State during the analyzed period (2005-2030). This emissions increase is mainly due to deforestation, while the carbon removals from protected areas remain almost constant.

During 2005-2025 and 2005-2030, LULUCF emissions of the Reference Scenario increased 60%. LULUCF emissions of the Mitigation Scenario increased 60% in 2005-2025 and 59% from 2005 to 2030 (Table 18). LULUCF emissions increase as Brazil's deforestation emissions have generally increased. In the ICAT 1 project, no additional mitigation measure was considered for the Cerrado, Atlantic Forest, and Caatinga biomes for the Mitigation Scenario (LULUCF Gross Emissions remain 32 Mt CO_2e in 2030, both scenarios).

Table 18. Table 18. LULUCF emissions by subsector – State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e						%					
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
LULUCF (net emissions)	18	18	14	29	29	29	29	29	60%	60%	60%	59%
LULUCF Gross Emissions	21	21	17	32	32	32	32	32	52%	52%	52%	52%
LULUCF Removals	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.9	0%	0%	0%	5%

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

b. Agriculture

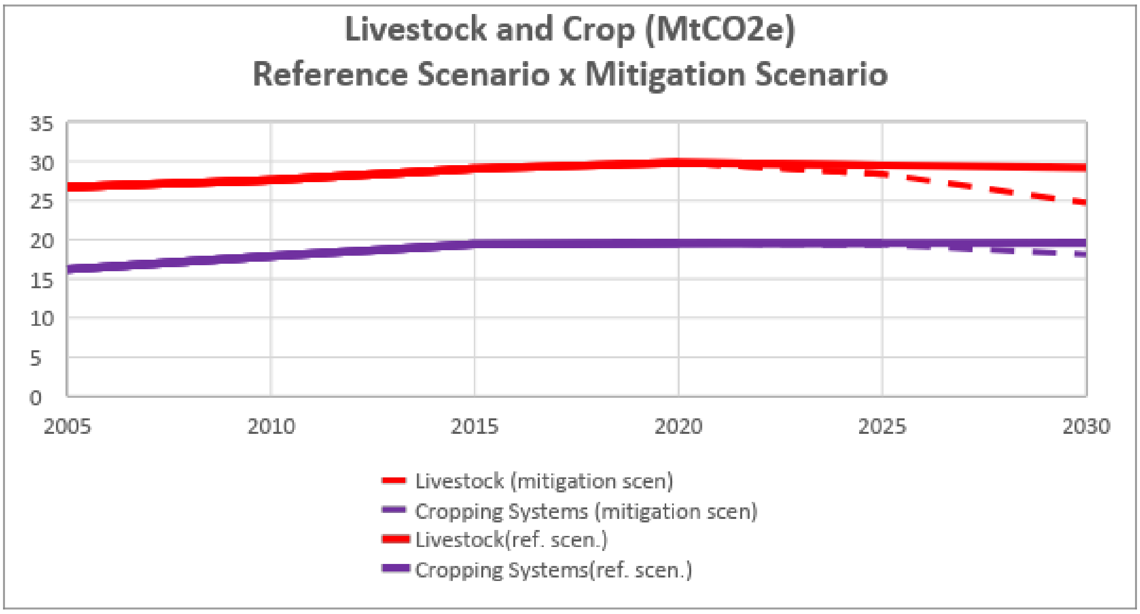
GHG agricultural emissions include emissions from crops and livestock. Regarding emissions during the entire analyzed period, agriculture subsector emissions in the Reference Scenario increased 14% from 2005 to 2030, while in the Mitigation Scenario, emissions remain constant in the same period. So, adopting less carbon-intensive agricultural activities leads to a significant reduction in emissions by 2030, compared to the current policy trend.

Livestock emissions remain the primary source of emissions of the agriculture sector in both Scenarios. However, it presents a higher reduction in emissions than crops in the Mitigation Scenario, as detailed in Table 19 and Figure 15.

Table 19. Agriculture emissions by subsector – State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e						%					
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Agriculture	43	46	49	49	49	48	49	43	14%	11%	14%	0%
Livestock	27	28	29	30	30	28	29	25	11%	6%	9%	-8%
Cropping Systems	16	18	19	20	20	19	20	18	21%	20%	21%	12%

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 15. Agriculture emissions by subsector – State of Minas Gerais (Mt CO_2e)

Crop

Crop emissions include emissions from agricultural soils, rice cultivation, burning of agricultural residues, and liming. Crops are the second most significant source of emissions in the agricultural sector, and activities associated with agricultural soils are the main source of emissions in this subsector. Although rice cultivation and the burning of agricultural residues had a significant percentage reduction in emissions in the period, the values of these emissions are low.

Regarding emissions during the entire analyzed period, crop's emissions in the Reference Scenario increased 21% from 2005 to 2025 and the same percentage from 2005 to 2030. In the Mitigation Scenario, crop's emissions increased 20% from 2005 to 2025 and 12% from 2005 to 2030 (Table 20).

Table 20. Crop emissions by subsector – State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e						%					
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Crop	**16**	**18**	**19**	**20**	**20**	**19**	**20**	**18**	**21%**	**20%**	**21%**	**12%**
Agricultural Soils	14.6	16.0	17.4	17.5	17.4	17.1	17.3	15.8	19%	17%	19%	8%
Rice Cultivation	0.32	0.13	0.06	0.05	0.05	0.05	0.04	0.04	-86%	-86%	-86%	-86%
Burning of Agricultural Residues	0.29	0.14	0.11	0.09	0.09	0.10	0.09	0.11	-69%	-64%	-69%	-62%
Liming	0.99	1.63	1.89	1.91	2.02	2.08	2.12	2.19	104%	110%	114%	121%

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Livestock

Livestock is the main emission source in the agriculture subsector led by enteric fermentation. However, livestock has the most significant mitigation potential with an 8% reduction from 2005 to 2030 in the mitigation scenario due to the intensification of livestock productivity with the management of pasture areas, genetic improvement, and reduction of the slaughter age.

Regarding emissions during the entire analyzed period, livestock emissions in the Reference Scenario increased 11% from 2005 to 2025 and 9% from 2005 to 2030. On the other hand, in the Mitigation Scenario, Livestock emissions rose 6% from 2005 to 2025 and decreased 8% from 2005 to 2030 (Table 21).

Table 21. Livestock emissions by subsector – State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e						%					
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Livestock	**27**	**28**	**29**	**30**	**30**	**28**	**29**	**25**	**11%**	**6%**	**9%**	**-8%**
Enteric Fermentation	25	25	27	27	27	26	26	22	7%	3%	6%	-11 %
Manure management	1.9	2.2	2.4	2.9	2.9	2.9	2.9	2.7	50%	50%	50%	43%

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

AFOLU consolidated results

AFOLU emissions in the Reference Scenario increased 28% from 2005 to 2025 and 27% from 2005 to 2030. In the Mitigation Scenario, AFOLU emissions increased 26% from 2005 to 2025 and 17% from 2005 to 2030 (Table 22 and Figure 16). The difference in emissions between the scenarios is due to the mitigation measures adopted in the Mitigation Scenario, mainly in the agriculture sector, such as the intensification of livestock productivity (Figure 16).

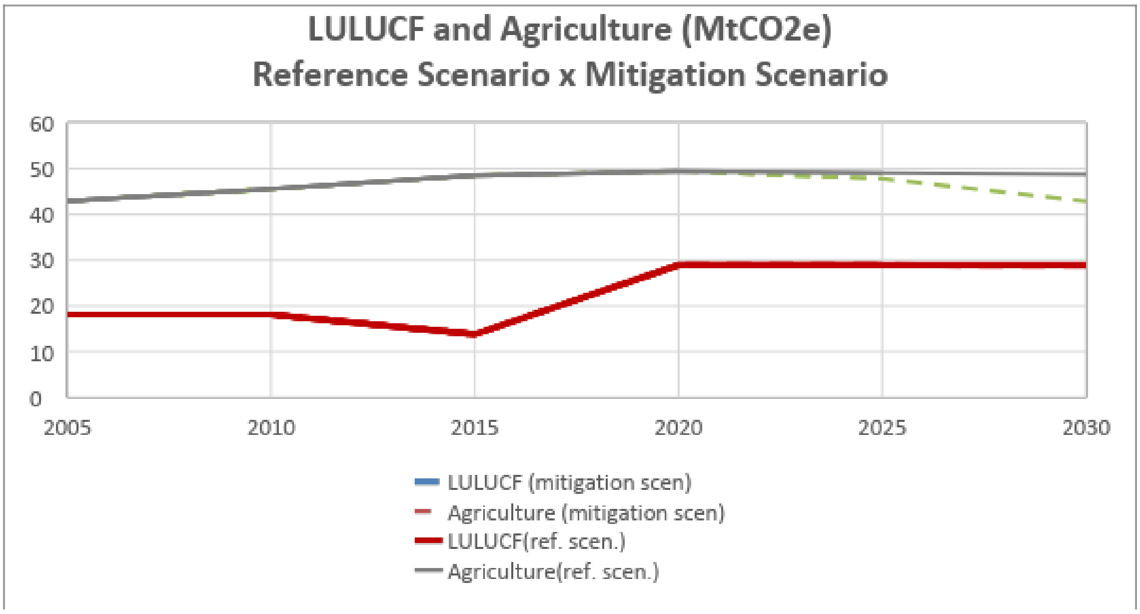
Comparing emissions from both Scenarios in 2030 and adopting all the proposed mitigation measures package for the AFOLU sector, it is possible to decrease emissions by 8% (Figure 17).

Table 22. Emissions from Agriculture, forestry and other land use (AFOLU) – State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e						%					
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
AFOLU	61	64	62	78	78	77	78	72	28%	26%	27%	17%
LULUCF (net emissions)	18	18	14	29	29	29	29	29	60%	60%	60%	59%

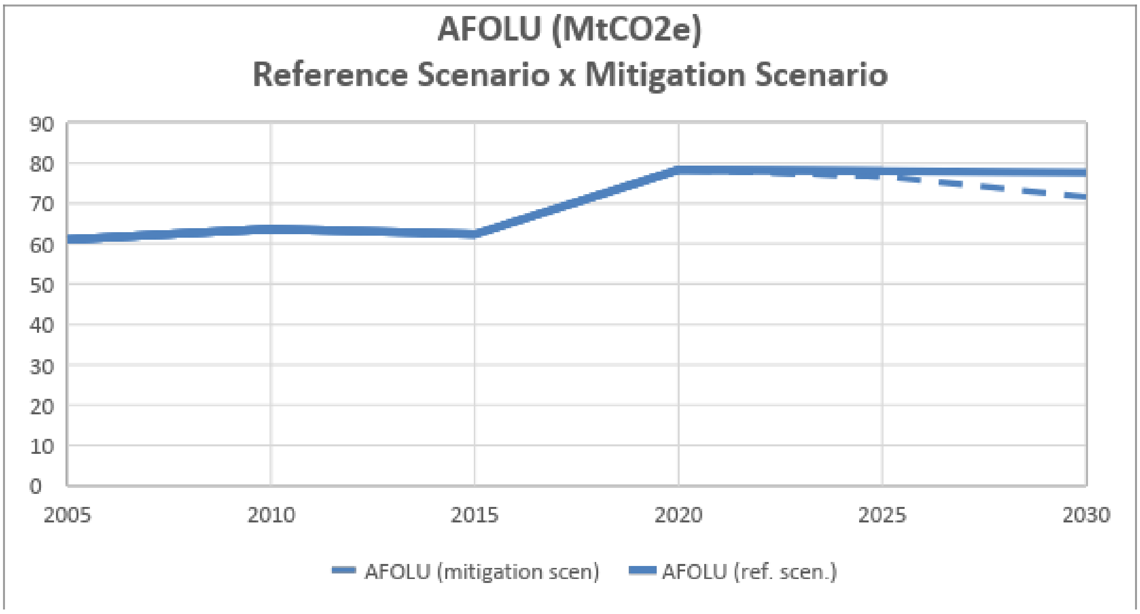
Agriculture	43	46	49	49	49	48	49	43	14%	11%	14%	0%

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 16. Emissions from agriculture, forestry and other land use (AFOLU) by subsector – State of Minas Gerais (Mt CO_2e)



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 17. Emissions from Agriculture, forestry and other land use (AFOLU) – State of Minas Gerais (Mt CO_2e)

5.1.2 Transport

Transport emissions in the Reference Scenario increased 53% from 2005 to 2025 and 67% from 2005 to 2030. In the Mitigation Scenario, transport emissions increased 32% from 2005 to 2025 and 17% from 2005 to 2030 (Table 23).

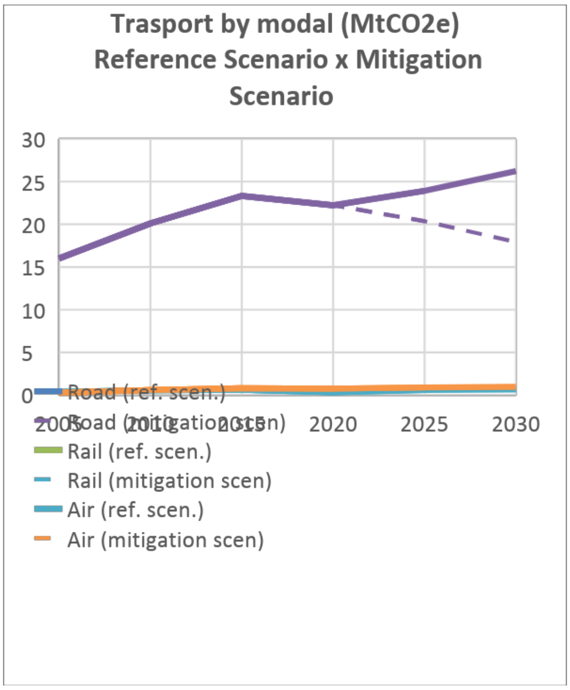
Road transport is the primary source of emissions of the transport sector modes from the State of Minas Gerais. On the other hand, comparing the Reference Scenario with the Mitigation Scenario, the road mode has the most significant mitigation potential (Figure 18). The road mitigation package includes the growth in biofuels supply, energy efficiency gains, the expansion of the electric vehicle fleet, and greater use of public transport.

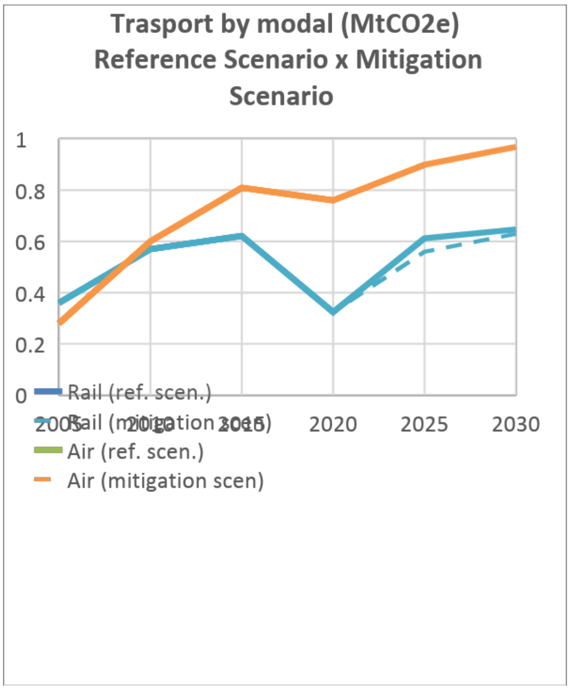
In both scenarios, air transport is the modal that emissions increase the most, with a variation of 246% in the Reference Scenario and 203% in the Mitigation Scenario in the entire period. Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures leads to a reduction in emissions of 30% (Figure 19).

Table 23. Transport emissions by modes – State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Transport	17	21	25	23	25	22	28	19	53%	32%	67%	17%
Road	16	20	23	22	24	20	26	18	50%	27%	64%	12%
Rail	0.36	0.57	0.62	0.32	0.61	0.56	0.65	0.63	70%	55%	80%	75%
Air	0.3	0.6	0.8	0.8	0.9	1.0	1.0	0.8	221%	248%	246%	203%

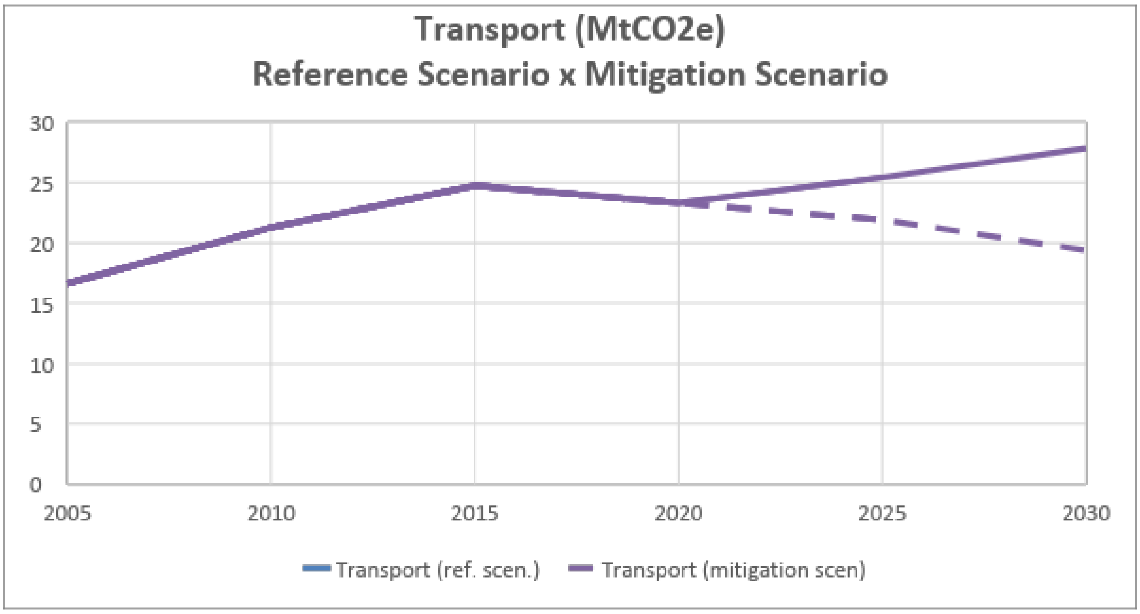
Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.





Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 18. Transport emissions by modes – State of Minas Gerais (Mt CO_2e)



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 19. Emissions from the transport sector – State of Minas Gerais (Mt CO_2e)

5.1.3 Industry

Industry emissions include both Industrial Processes and Product Use (IPPU) and Energy Use. Total industry emissions in the Reference Scenario increased 15% from 2005 to 2025 and 28% from 2005 to 2030. In the Mitigation Scenario, industry emissions increased 5% from 2005 to 2025 and 10% from 2005 to 2030.

IPPU is the primary emissions source (Table 24 and Figure 20) and comprehends three subsectors: minerals, metals, and chemicals. In the Reference Scenario, IPPU emissions increased 10% from 2005 to 2025 and 22% from 2005 to 2030, while the Mitigation Scenario increased 1% in the first and 5% in the second period.

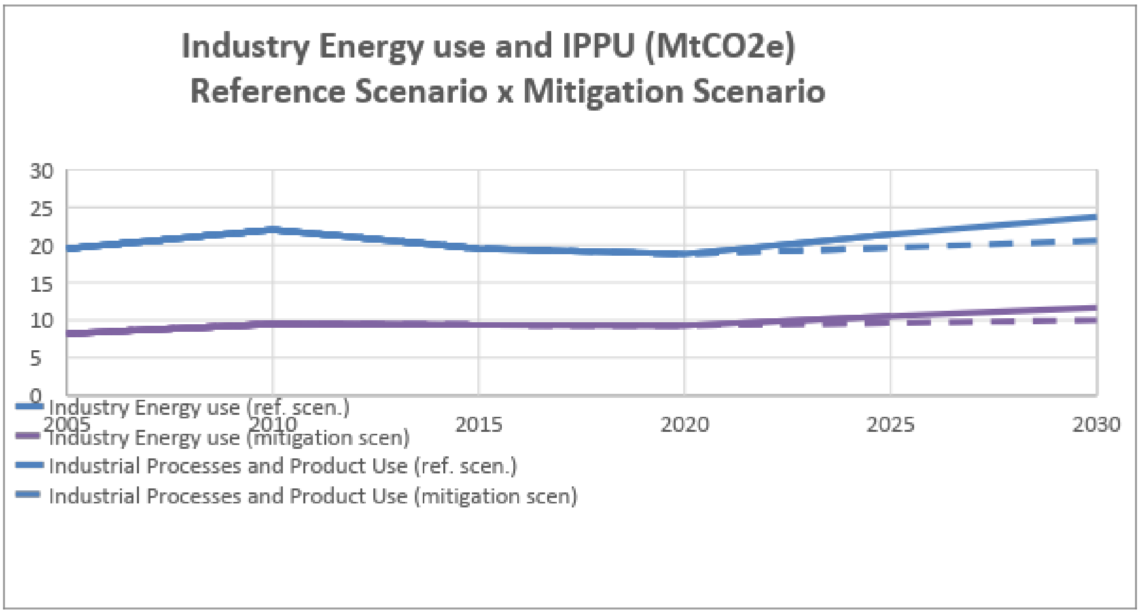
Industrial energy use is desegregated in seven industrial subsectors plus "Other Industries". Cement is the main emission source from energy use and has the most significant increase in emissions from 2005 to 2030 in both scenarios. On the other hand, some industries reduced emissions during 2005-2030 (decreasing order): pig iron and steel; iron-alloys; pulp & paper; non-ferrous/other metallurgical.

Comparing emissions from both Scenarios in 2030, adopting the proposed mitigation measures, such as energy intensity reduction, leak control, process control, and replacement of fossil fuels by natural gas and renewable biomass, leads to a reduction in emissions of 14% (Figure 21).

Table 24. Emissions from the industry sector – energy use and industrial processes and product use (IPPU) – State of Minas Gerais (Mt CO_2e and %)

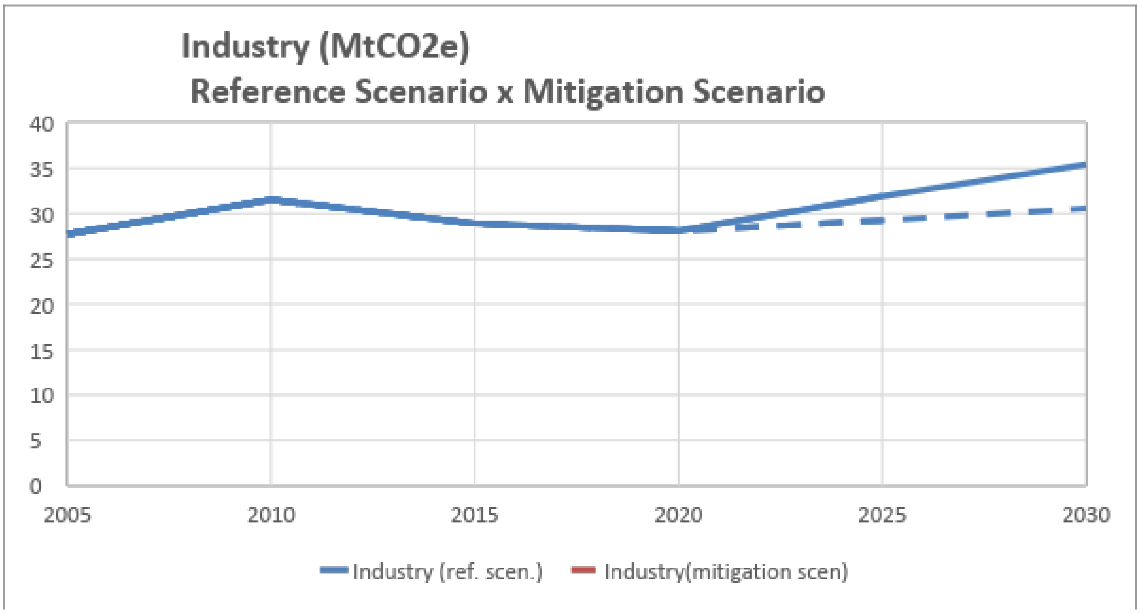
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Total Industry (Energy + IPPU)	28	32	29	28	32	29	35	31	15%	5%	28%	10%
Industry Energy use	8	9	9	9	11	10	12	10	28%	17%	42%	22%
Cement	1.7	3.2	3.6	3.4	3.8	3.6	4.3	3.6	131%	117%	158%	117%
Pig iron and steel	2.3	1.8	1.5	1.5	1.7	1.6	1.9	1.6	-25%	-32%	-18%	-30%
Iron-Alloys	0.1	0.1	0.05	0.05	0.1	0.0	0.1	0.1	-50%	-75%	-45%	-45%
Non-Ferrous/Other Metallurgical	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.4	5%	-7%	15%	-2%
Chemical	0.4	0.5	0.6	0.6	0.6	0.6	0.7	0.6	44%	34%	59%	37%
Food and Beverage	0.6	0.7	0.7	0.7	0.8	0.7	0.9	0.8	42%	32%	57%	44%
Pulp & Paper	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	-7%	-20%	4%	-11%
Other Industries	2.4	2.6	2.2	2.4	2.7	2.4	3.0	2.6	14%	2%	27%	9%
Industrial Processes and Product Use	20	22	20	19	21	20	24	21	10%	1%	22%	5%
Minerals	6	9	9	8	9	9	10	9	49%	45%	67%	53%
Metals	13	13	11	11	12	11	13	11	-9%	-20%	1%	-17%
Chemical	0.01	0.01	0.01	0.01	0.012	0.011	0.014	0.012	24%	14%	38%	16%

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 20. Emissions from industry – energy use and industrial processes and product use (IPPU) – State of Minas Gerais (Mt CO_2e)



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 21. Emissions from the industry sector – State of Minas Gerais (Mt CO_2e)

5.1.4 Other sectors of energy use

The Other sectors of energy use include: residential, commercial, public, and agriculture. The residential sector is the largest emitter, followed by agriculture and commercial & public subsectors. The agriculture sector was the only one that increased emissions during the analyzed period.

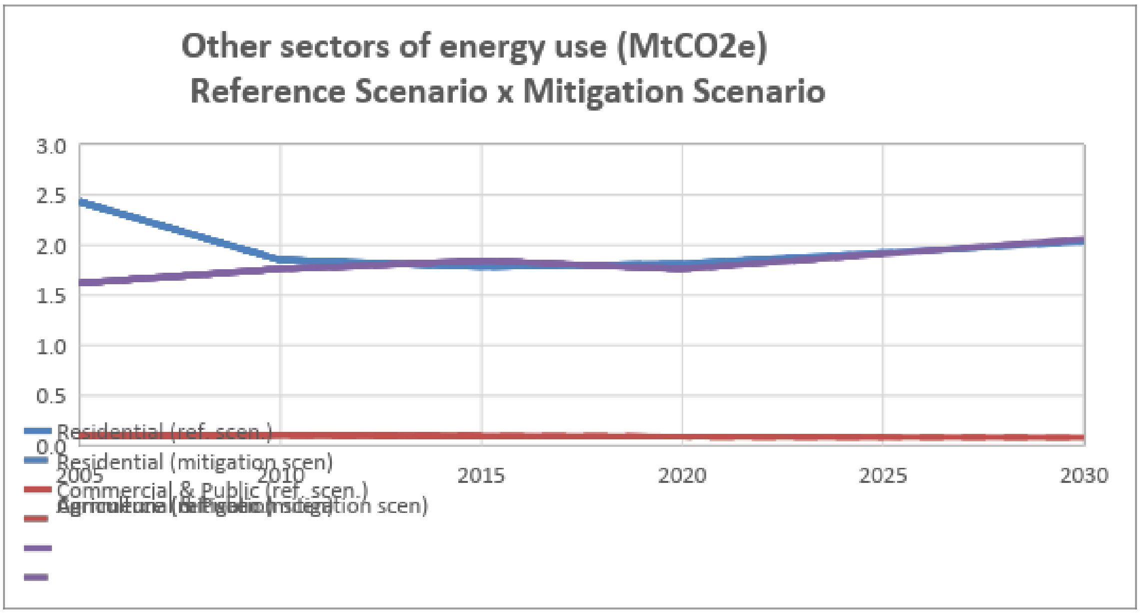
The Reference and Mitigation Scenarios are the same in these sectors since additional mitigation measures were not considered. Emissions from these sectors decreased 6% from 2005 to 2025 and increased 1% from 2005 to 2030.

Residential emissions decreased 21% from 2005 to 2025 and 16% from 2005 to 2030. Commercial and Public emissions decreased 13% from 2005 to 2025 and 17% from 2005 to 2030. Agriculture emissions increased 18% from 2005 to 2025 and 27% from 2005 to 2030 (Table 25 and Figure 22).

Table 25. Emissions from other sectors of energy use – State of Minas Gerais (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e						%					
Scenario					Ref	Mitig	Ref	Mitig	Ref	Mitig	Ref	Mitig
Other sectors of energy use	**4.2**	**3.7**	**3.7**	**3.7**	**3.9**	**3.9**	**4.2**	**4.2**	**-6%**	**-6%**	**1%**	**1%**
Residential	2.4	1.9	1.8	1.8	1.9	1.9	2.0	2.0	-21%	-21%	-16%	-16%
Commercial & Public	0.100	0.110	0.097	0.092	0.087	0.087	0.083	0.083	-13%	-13%	-17%	-17%
Agriculture	1.62	1.76	1.84	1.76	1.91	1.91	2.06	2.06	18%	18%	27%	27%

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 22. Emissions from Other sectors of energy use – State of Minas Gerais (Mt CO_2e)

5.1.5 Energy supply

The energy sector emissions comprise the fuel combustion in the transformation centers (power plants and charcoal production) and in the sector’s own consumption to produce energy. In the Reference Scenario, Energy supply emissions decrease 22% from 2005 to 2025 and 17% from 2005 to 2030. In the Mitigation Scenario, emissions fall 25% from 2005 to 2025 and 17% from 2005 to 2030 (Table 26 and Figure 23).

Comparing emissions from both Scenarios in 2030 and considering all mitigation measures for the energy supply sector, there is no difference between the two scenarios (Figure 24). In the Mitigation Scenario, the demand for charcoal – a renewable energy source – increases, so the production emissions. The rise in charcoal production emissions offsets the reduction in emissions from power plants.

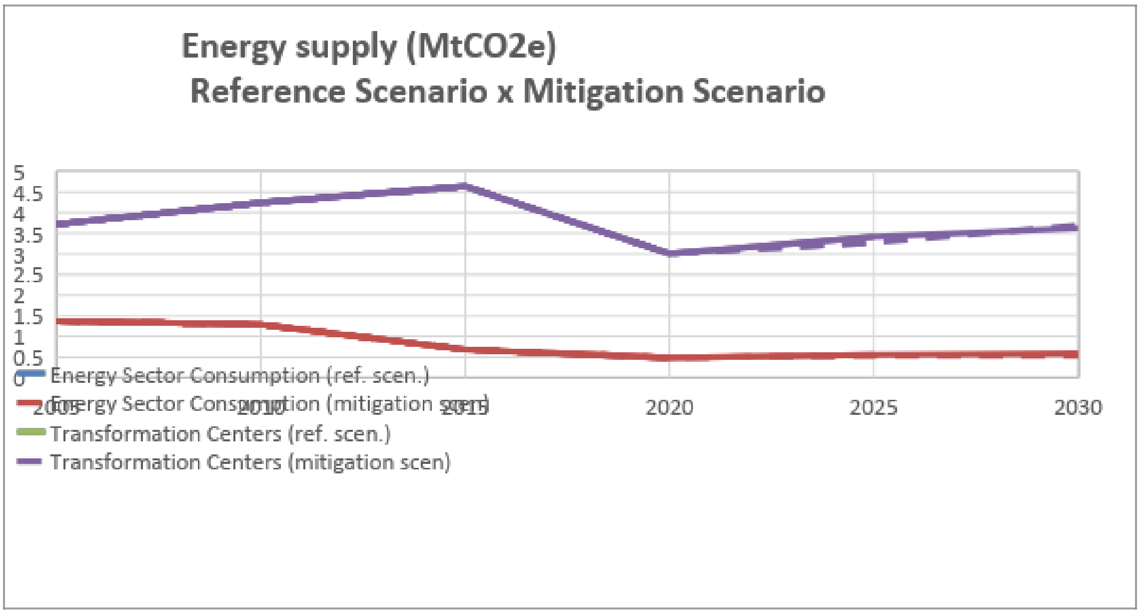
Transformation centers are the main source of emissions of the energy supply sector. In the Reference Scenario, transformation centers emissions decreased 8% from 2005 to 2025 and 3% from 2005 to 2030. The Mitigation Scenario decreased 12% from 2005 to 2025 and 1% from 2005 to 2030.

Regarding energy sector consumption emissions, in the Reference Scenario, emissions decreased 22% from 2005 to 2025 and 17% from 2005 to 2030. The Mitigation Scenario decreased 25% from 2005 to 2025 and 17% from 2005 to 2030.

Table 26. Energy supply emissions by sector – State of Minas Gerais (Mt CO_2e and %)

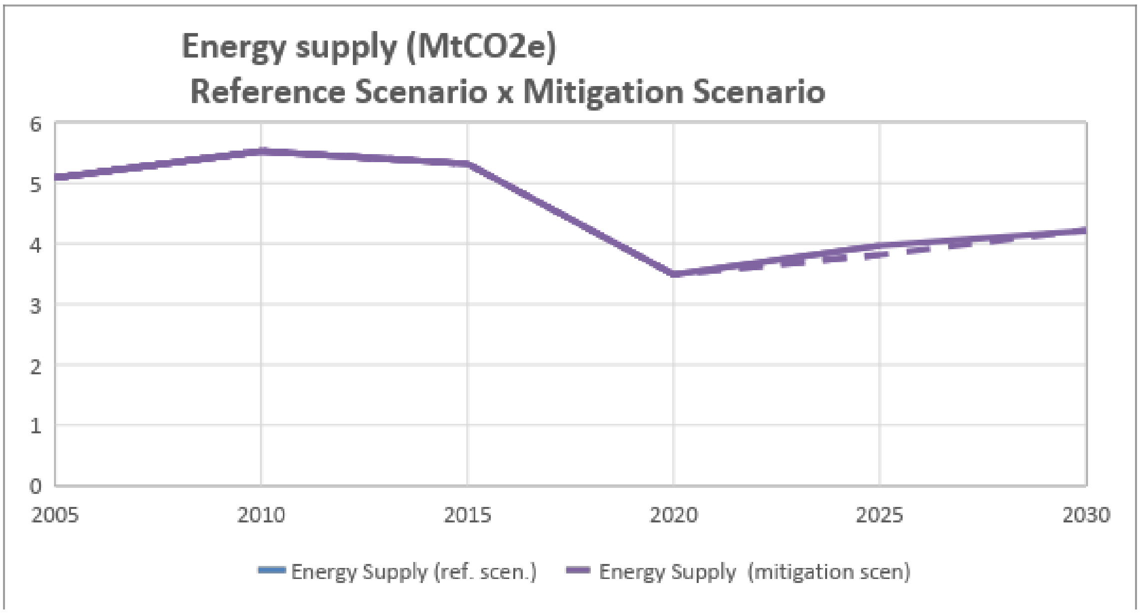
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e							%				
Scenario					Ref	Mitig	Ref	Mitig	Ref	Mitig	Ref	Mitig
Energy supply (Fuel Combustion)	**5.1**	**5.5**	**5.3**	**3.5**	**4.0**	**3.8**	**4.2**	**4.2**	**-22%**	**-25%**	**-17%**	**-17%**
Energy Sector Consumption	1.37	1.29	0.68	0.48	0.56	0.54	0.59	0.53	-59%	-61%	-57%	-61%
Transformation Centers	3.7	4.2	4.6	3.0	3.4	3.3	3.6	3.7	-8%	-12%	-3%	-1%
Power Plants	1.6	2.3	2.6	1.9	2.2	2.0	2.3	2.1	35%	27%	42%	29%
Charcoal Production	2.1	1.9	2.0	1.1	1.3	1.3	1.4	1.6	-41%	-41%	-36%	-23%

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 23. Energy supply emissions by sector – State of Minas Gerais (Mt CO_2e)



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 24. Energy supply emissions – State of Minas Gerais in the period 2005-2030 (Mt CO_2e)

5.1.6 Waste

The waste sector emissions are divided into two main subsectors: solid waste and wastewater. In the Reference Scenario, waste emissions increased 142% from 2005 to 2025 and 154% from 2005 to 2030. The Mitigation Scenario increased 123% from 2005 to 2025 and 142% from 2005 to 2030 (Table 27). There is a significant increase in waste emissions due to improved collection and treatment of urban solid waste and wastewater.

Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures leads to a reduction in emissions of 5% (Figure 26). The Mitigation Scenario considers more ambitious mitigation measures, with a higher percentage of biogas recovery in sanitation systems. Methane from wastewater treatment plants and landfills is captured and destroyed in flairs or used for electricity generation and fuel for the vehicular fleet running on natural gas.

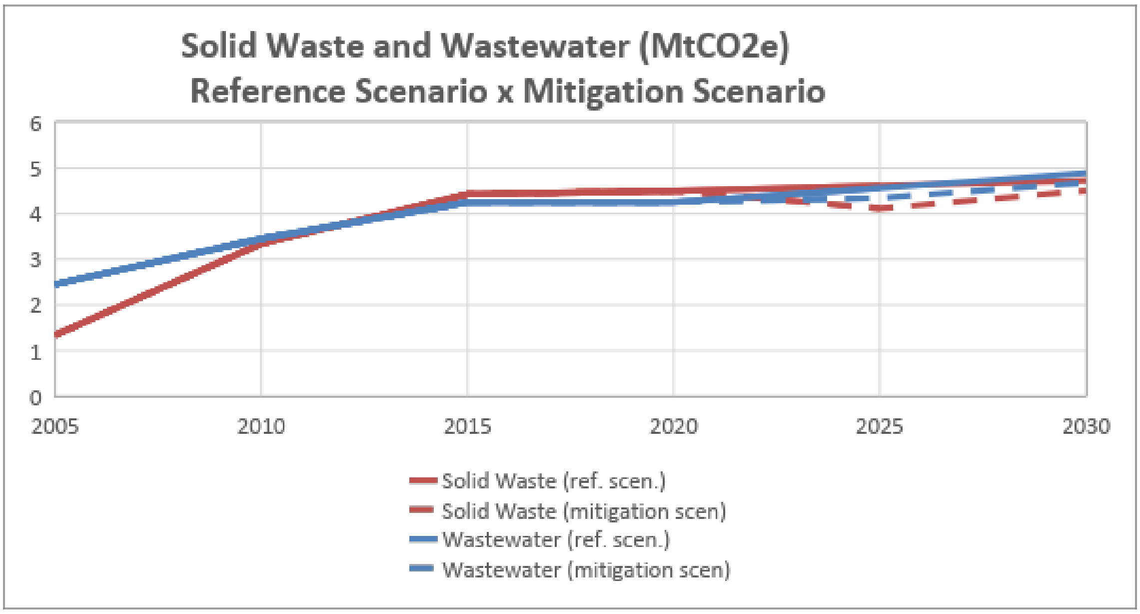
From 2005 to 2030, wastewater and solid waste emissions have almost the same weight in total Emissions from the waste sector (Figure 25). However, there is a substantial increase in the solid waste subsector emissions (253% in the Reference Scenario and 236% in the Mitigation Scenario). In the Reference Scenario, wastewater emissions increased by 86% from 2005 to 2025 and 99% from 2005 to 2030. In the Mitigation Scenario, they increased 77% from 2005 to 2025 and 91% from 2005 to 2030

Regarding solid waste emissions, urban solid waste is the main source. The Reference Scenario increased 244 % from 2005 to 2025 and 253% from 2005 to 2030. On the other hand, the Mitigation Scenario increased 207% from 2005 to 2025 and 236% from 2005 to 2030. Therefore, urban solid waste has the most significant mitigation potential comparing scenarios in 2030: 1.1 $MtCO_2e$/year.

Table 27. Emissions from the waste sector – State of Minas Gerais (Mt CO_2e and %)

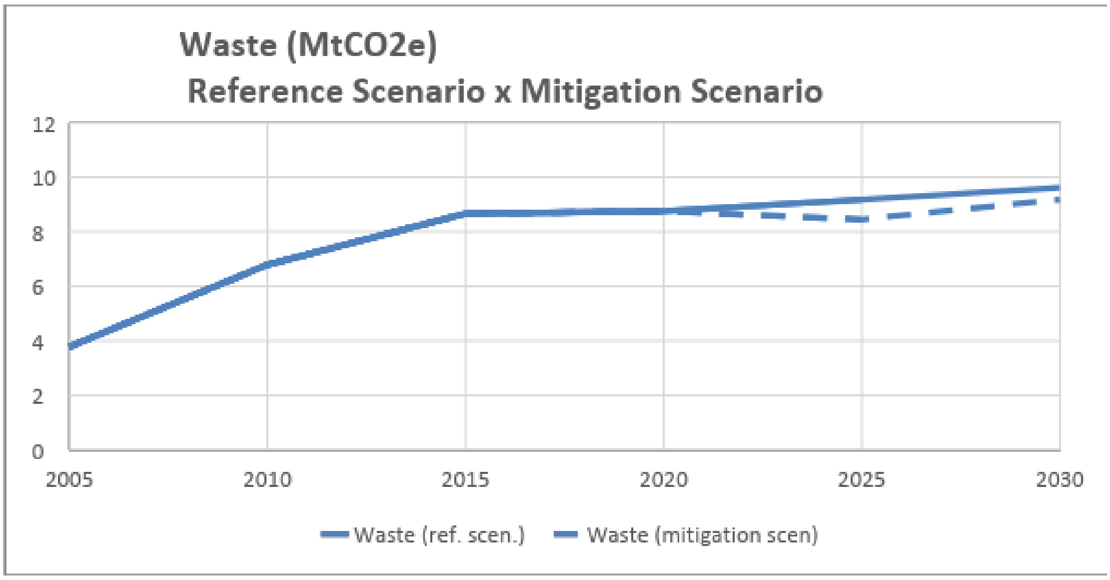
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e							%				
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Waste	**3.8**	**6.8**	**8.7**	**8.8**	**9.2**	**8.5**	**9.6**	**9.2**	**142%**	**123%**	**154%**	**142%**
Solid Waste	1.3	3.3	4.4	4.5	4.6	4.1	4.7	4.5	244%	207%	253%	236%
Urban Solid Wastes	1.3	3.1	3.8	3.9	4.0	3.0	4.0	2.9	196%	123%	199%	118%
Other solid waste	0.0	0.2	0.6	0.6	0.6	1.1	0.7	1.6	208%	435%	241%	653%
Wastewater Treatment and Discharge	2.5	3.5	4.2	4.3	4.6	4.3	4.9	4.7	86%	77%	99%	91%
Domestic Wastewater	0.87	1.29	1.67	1.71	1.73	1.64	1.75	1.66	99%	88%	101%	91%
Industrial Wastewater	1.6	2.2	2.6	2.5	2.8	2.7	3.1	3.0	79%	71%	99%	91%

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 25. Waste emissions by subsector – State of Minas Gerais (Mt CO_2e)



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 26. Emissions from the waste sector – State of Minas Gerais (Mt CO_2e)

5.2 Consolidation of Scenarios – State of Minas Gerais

In 2019, the state of Minas Gerais published the Minas Gerais Integrated Development Plan (PMDI), which sets out strategic objectives and guidelines that extend to short and medium-term plans and articulates the actions and programs formulated by government agencies. The estimates of avoided GHG emissions resulting from these actions and programs were not included in the scenarios due to differences in methodological approaches. However, they are included in Annex I to provide an order of magnitude of the corresponding GHG emissions mitigation potential.

The consolidated emissions from Minas Gerais reached 159 MtCO_2e in 2030 in the Reference Scenario and 139 Mt CO_2e in the Mitigation Scenario (Table 28 and Figure 27), increasing 34% in the Reference Scenario and 18% in the Mitigation Scenario from 2005 to 2030.

In 2030, the primary source of emissions is the AFOLU sector, followed by industry, transport, waste, energy supply, and other energy use sectors. In AFOLU, agriculture is the most emitting subsector, with livestock as the main source of emissions in both Scenarios.

Waste is the sector that emissions grew the most from 2005 to 2030. There is a significant increase in waste emissions due to improved collection and treatment of urban solid waste and wastewater—an emissions increase associated with the expansion of basic sanitation services. Even in the Mitigation Scenario, with the adoptions of mitigation measures, emissions grow despite the penetration of more ambitious mitigation measures to destroy a more significant biogas accumulation in landfills and wastewater treatment plants.

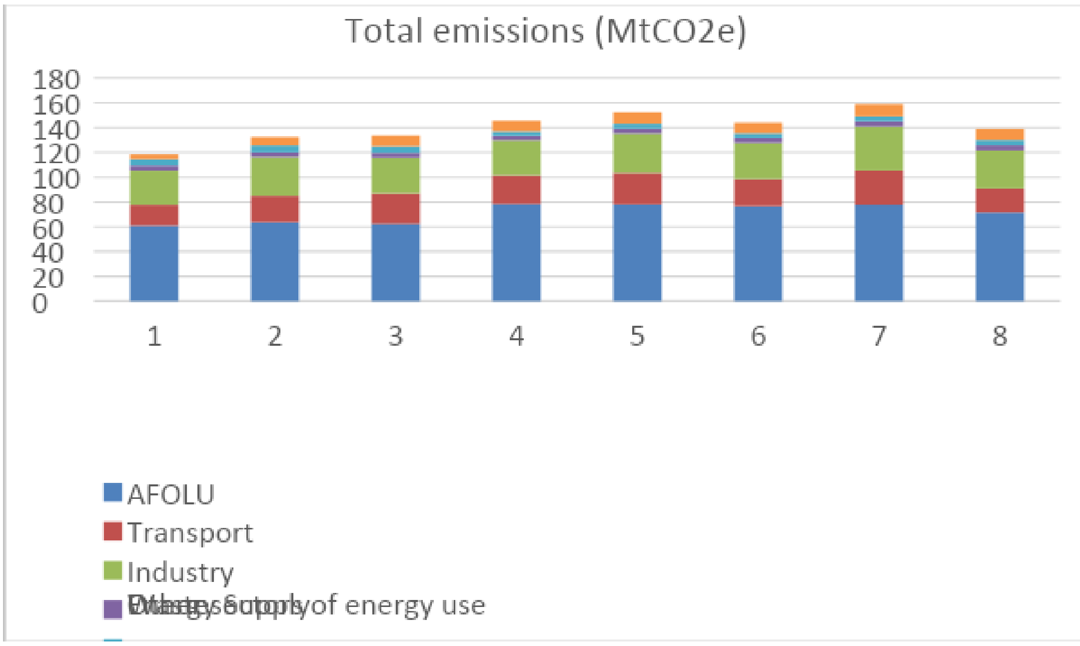
In both scenarios, from 2005 to 2030, emissions increase in all sectors, except in the Energy supply sector that reduces 17%. Even in the Mitigation Scenario, between 2005 and 2030, Minas Gerais will need an additional effort to help Brazil meet the Paris Agreement's goals. In the Mitigation Scenario, emissions grow 142% in Waste, 17% in transport, 13% in AFOLU, and 10% in industry.

In 2025 and 2030, it is possible to see in Figure 27 the impact of the mitigation measures considered in the Mitigation Scenario in each sector, reducing the total State emissions compared to the Reference Scenario. In 2030, total mitigation (the Reference Scenario emissions minus the Mitigation Scenario emissions) in transport has the most significant potential with an 8 $MtCO_2e$/year emission reduction. AFOLU comes second with 6 MtCO2e/year and Industry third with 5 MtCO2e/year. The Waste sector also presented some mitigation potential (reduction of 0.4 MtCO2e/year between the two scenarios); however, the expansion of essential sanitation services resulted in a significant emission increase.

Table 28. Minas Gerais State emissions by sector in the period 2005-2030 ($MtCO_2e$ and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	$MtCO_2e$						%					
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
AFOLU	61	64	62	78	78	77	78	72	23%	21%	22%	13%
Transport	17	21	25	23	25	22	28	19	53%	32%	67%	17%
Industry	28	32	29	28	32	29	35	31	15%	5%	28%	10%
Other sectors of energy use	4.2	3.7	3.7	3.7	3.9	3.9	4.2	4.2	-6%	-6%	1%	1%
Energy supply	5.1	5.5	5.3	3.5	4.0	3.8	4.2	4.2	-22%	-25%	-17%	-17%
Waste	3.8	6.8	8.7	8.8	9.2	8.5	9.6	9.2	142%	123%	154%	142%
Total	**118**	**132**	**134**	**146**	**152**	**144**	**159**	**139**	**29%**	**22%**	**34%**	**18%**

Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.



Note: Historical emission data from 2005 to 2014 and projections from 2015 to 2030.

Figure 27. Minas Gerais State emissions by sector in the period 2005-2030 (Mt CO_2e and %)

6. Emission Scenarios for the State of Amazonas

This section focuses on the state of Amazonas, describing its historical emissions and assessing its emission trends through the Reference and Mitigation Scenarios.

6.1 Results of Sectorial Projections

6.1.1 AFOLU

The agriculture, forestry and other land use (AFOLU) sector describes the GHG emissions from two distinct subsectors: LULUCF (land use, land use change, and forestry) and agriculture. Emissions and removals related to forest and other land use are covered under LULUCF. Agriculture includes emissions from crops (agricultural soils, burning of agricultural residues and carbon in soil) and livestock (enteric fermentation, manure management).

a. LULUCF

The land use, land-use change and forestry (LULUCF) subsector includes emissions from deforestation and forest residues and carbon removals in secondary forests and protected areas. The last is the most relevant. In LULUCF, total gross emissions are the sum of deforestation and forest residue emissions and varied widely over the years. LULUCF net emissions are the LULUCF total gross emissions (with emphasis on deforestation) discounted by the removals (mainly from protected areas and indigenous lands). LULUCF removals are the sum of secondary forests and protected areas.

Both Reference and Mitigation Scenarios present a reduction in LULUCF net emissions during the analysed period (2005-2030). Net LULUCF emissions remain negative throughout the period (2005-2030) in both Scenarios, as removals are bigger than emissions. However, emissions from deforestation and other land use changes increased significantly in the Reference Scenario. Therefore, the reduction in the whole period (2005-2030) is mainly due to carbon removals. In the Mitigation scenario, the reduction is mainly due to deforestation reduction and increased protected areas and indigenous land. The removals consider the natural carbon sequestration in protected areas (conservation units and indigenous lands).

Between 2005-2025, LULUCF net emissions in the Reference Scenario reduced 3% and from 2005 to 2030 reduced 2%, while in the Mitigation Scenario reduced 134% (2005-2025) and 147% (2005-2030), as detailed in Table 29.

Table 29. LULUCF emissions by subsector – State of Amazonas (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig	Ref	Mitig	Ref	Mitig	Ref	Mitig
LULUCF (net emissions)	**-37**	**-74**	**-66**	**-38**	**-38**	**-86**	**-38**	**-91**	**-3%**	**-134%**	**-2%**	**-147%**
Gross Emissions	60	45	54	88	88	41	88	40	46%	-32%	46%	-34%
Deforestation and other land use changes	58	44	52	85	85	37	85	36	46%	-36%	46%	-37%
Liming and forest residues	2	2	2	3	3	3	3	3	49%	54%	49%	54%
Removals	-97	-119	-121	-126	-126	-127	-126	-131	-29%	-31%	-29%	-35%
Recovery of Degraded Pasturelands	-1.0	-1.0	-0.1	-0.1	-0.1	-0.2	0.0	0.0	87%	82%	100%	100%
Livestock-Forest Systems	-0.01	-0.01	-0.02	-0.02	-0.02	-0.03	-0.03	-0.04	-140%	-220%	-180%	-273%
Protected Areas and Indigenous Lands	-94	-108	-110	-115	-115	-119	-115	-123	-22%	-27%	-22%	-31%
Secondary forests	-3	-10	-10	-11	-11	-8	-11	-8	-326%	-203%	-326%	-203%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

b. Agriculture

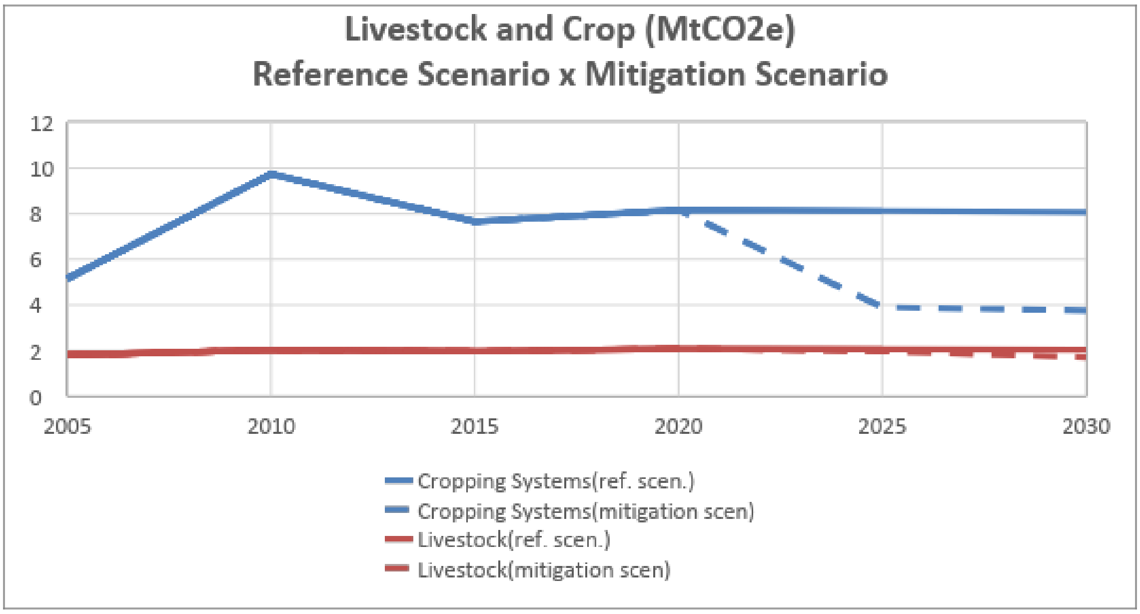
GHG agricultural emissions include emissions from crops and livestock. In the entire analyzed period, agriculture subsector emissions in the Reference Scenario increased 45% from 2005 to 2030, while in the Mitigation Scenario, they decreased 22% in the same period. So, adopting mitigation measures and less carbon-intensive agricultural activities leads to a significant reduction in emissions by 2030, compared to the current policy trend.

Crops remain the main source of emissions of the agriculture sector in both Scenarios. However, it presents a higher reduction in emissions than livestock in the Mitigation Scenario, as detailed in Table 30 and Figure 28.

Table 30. Agriculture emissions by subsector – State of Amazonas (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig	Ref.	Mitig	Ref.	Mitig.	Ref.	Mitig
Agriculture	**7**	**12**	**10**	**10**	**10**	**6**	**10**	**5**	**46%**	**-16%**	**45%**	**-22%**
Livestock	1.8	2.0	2.0	2.1	2.1	2.0	2.0	1.7	14%	9%	12%	-6%
Cropping Systems	5	10	8	8	8	4	8	4	58%	-24%	57%	-27%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 28. Agriculture emissions by subsector – State of Amazonas (Mt CO_2e)

Crop

Crop emissions are those from agricultural soils, burning of agricultural residues, and variation in soil carbon stock. Crops are the primary source of emissions in the agricultural sector, and activities associated with soil carbon are the main source of emissions in this subsector. However, crops also have the most significant mitigation potential with a 27% reduction from 2005 to 2030 in the Mitigation Scenario due to improved agricultural practices, such as increased forest-livestock integration systems (agroforestry).

During the entire period analyzed, crop emissions in the Reference Scenario increased by 58% from 2005 to 2025 and 57% from 2005 to 2030. However, in the Mitigation Scenario, these emissions were reduced by 24% from 2005 to 2025 and 27% from 2005 to 2030 (Table 31).

Table 31. Crop emissions by subsector – State of Amazonas (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Crop	5	10	8	8	8	4	8	4	58%	-24%	57%	-27%
Agricultural Soils	0.5	0.6	0.5	0.6	0.6	0.6	0.6	0.5	13%	12%	13%	3%
Burning of Agricultural Residues	0.0050	0.0050	0.0030	0.0037	0.0036	0.0042	0.0036	0.0045	-27%	-15%	-28%	-10%
Carbon in Soil	5	9	7	8	8	3	7	3	62%	-28%	62%	-30%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Livestock

Livestock is the second-largest emission source in the agriculture subsector, led by enteric fermentation. In the entire analyzed period, livestock emissions in the Reference Scenario increased 14% from 2005 to 2025 and 12% from 2005 to 2030. On the other hand, the Mitigation Scenario increased 9% from 2005 to 2025 and decreased 6% from 2005 to 2030 (Table 32).

Table 32. Livestock emissions by subsector – State of Amazonas (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					**Ref.**	**Mitig**	**Ref.**	**Mitig**	**Ref.**	**Mitig.**	**Ref.**	**Mitig.**
Livestock	1.8	2.0	2.0	2.1	2.1	2.0	2.0	1.7	14%	9%	12%	-6%
Enteric Fermentation	1.7	2.0	1.9	2.0	2.0	1.9	2.0	1.6	14%	9%	13%	-6%
Manure management	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	1%	1%	1%	-4%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

AFOLU consolidated results

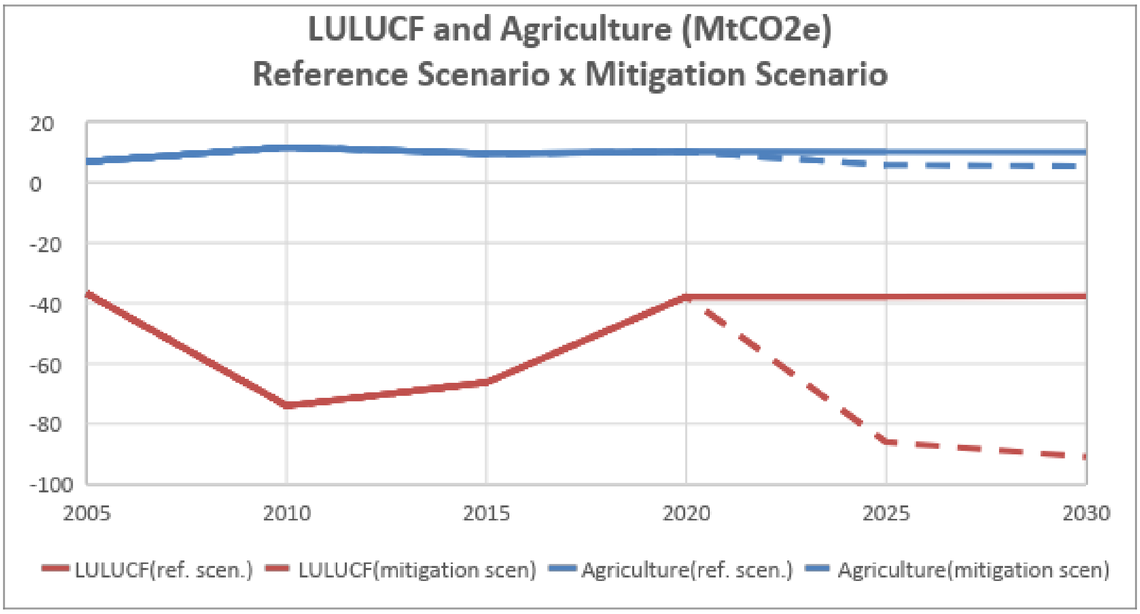
AFOLU emissions in the Reference Scenario increased 7% from 2005 to 2025 and 8% from 2005 to 2030. On the contrary, in the Mitigation Scenario, AFOLU emissions decreased 168% from 2005 to 2025 and 186% from 2005 to 2030 (Table 33). The big difference in emissions between the scenarios is in the LULUCF sector, due to reducing deforestation rates and increasing protected areas (Figure 29).

Comparing emissions from both scenarios in 2030, adopting all the proposed mitigation measures for the AFOLU sector, it is possible to increase the removals by 209%. In other words, the Mitigation Scenario has 209% more carbon removals than the Reference Scenario in 2030 (Figure 30) .

Table 33. Emissions from Agriculture, forestry and other land use (AFOLU) – State of Amazonas (Mt CO_2e and %)

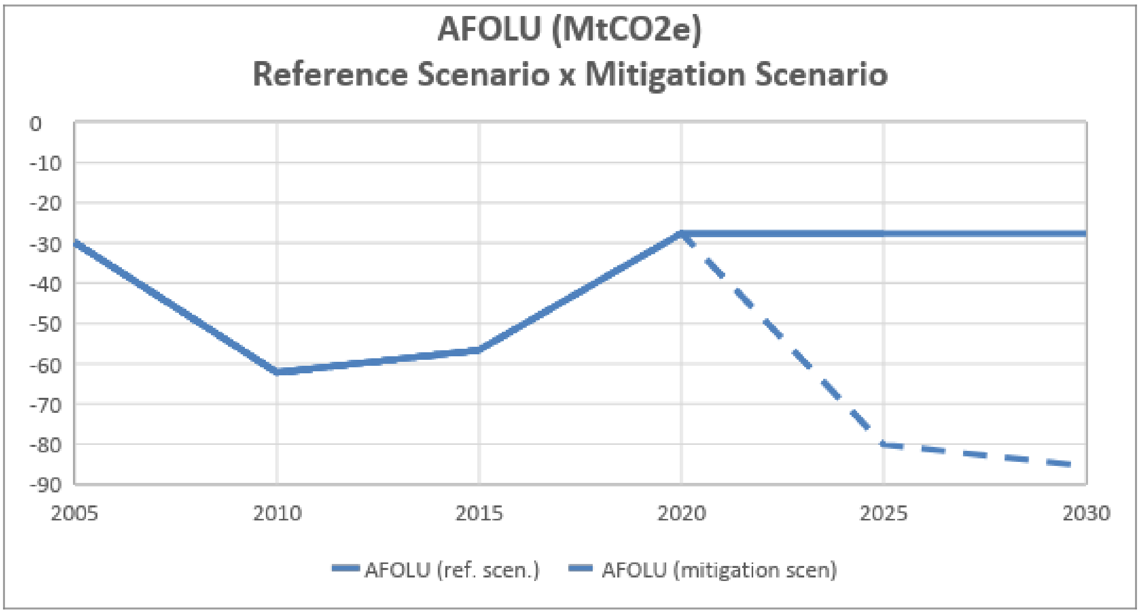
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
AFOLU	**-30**	**-62**	**-57**	**-28**	**-28**	**-80**	**-28**	**-85**	**7%**	**-168%**	**8%**	**-186%**
LULUCF (net emissions)	-37	-74	-66	-38	-38	-86	-38	-91	-3%	-134%	-2%	-147%
Agriculture	7	12	10	10	10	6	10	5	46%	-16%	45%	-22%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 29. Emissions from Agriculture, forestry and other land use (AFOLU) Subsectors – State of Amazonas (Mt CO_2e)



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 30. Emissions from Agriculture, forestry and other land use (AFOLU) – State of Amazonas (Mt CO_2e)

6.1.2 Transport

Transport emissions in the Reference Scenario increased 96% from 2005 to 2025 and 113% from 2005 to 2030. In the Mitigation Scenario, transport emissions increased 76% from 2005 to 2025 and 59% from 2005 to 2030 (Table 34).

Road transport is the main source of emissions of the transport sector in the State of Amazonas. On the other hand, comparing the Reference Scenario with the Mitigation Scenario, the road mode has the largest mitigation potential (Figure 31). The road mitigation package includes an increase in biofuels demand, energy efficiency gains, the expansion of the electric vehicle fleet, and greater use of public transport.

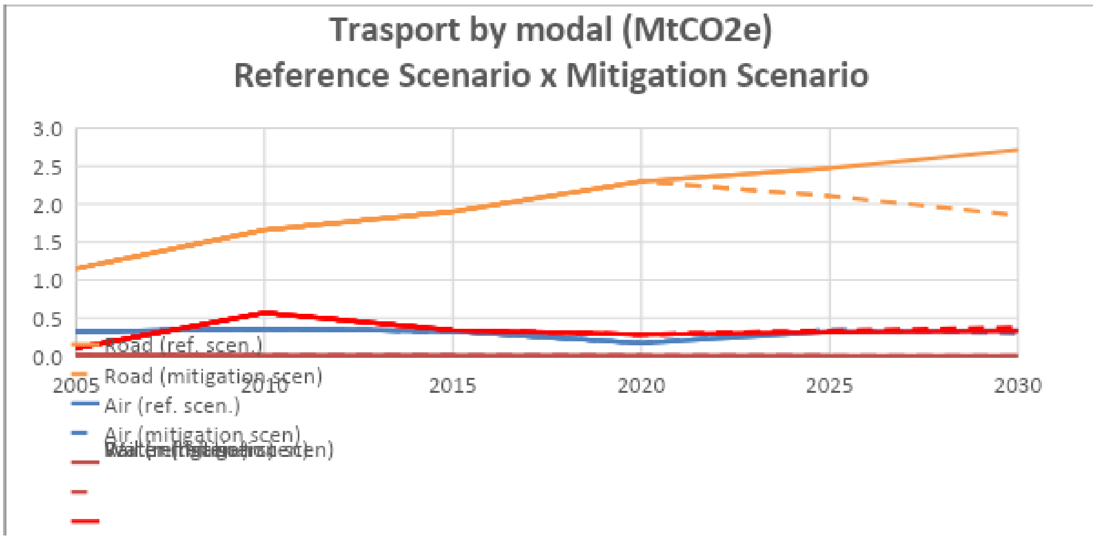
In both scenarios, water is the transport mode in which emissions increased the most, with a variation of 212% in the Reference Scenario and 256% in the Mitigation Scenario, in the entire period. These emissions are low, but its share (mainly cabotage) increases in the transport matrix due to the more significant tax incentives and the reduction of bureaucracy in the segment.

Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures leads to a reduction in emissions of 25% (Figure 32)

Table 34. Transport emissions by modes – State of Amazonas (Mt CO_2e and %)

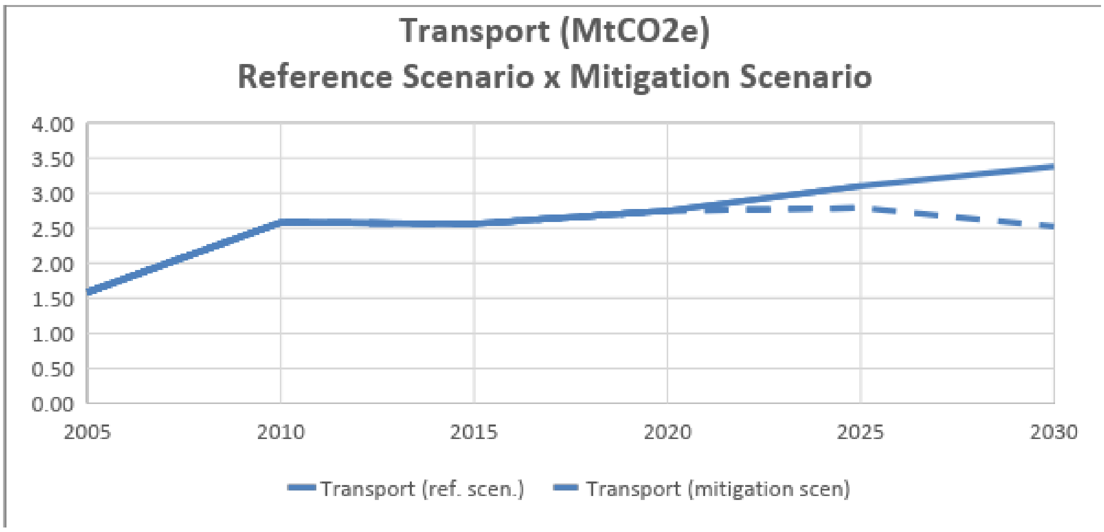
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Transport	1.6	2.6	2.6	2.7	3.1	2.8	3.4	2.5	96%	76%	113%	59%
Road	1.2	1.7	1.9	2.3	2.5	2.1	2.7	1.9	115%	83%	136%	61%
Rail	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-100%	-100%	-100%	-100%
Air	0.32	0.36	0.32	0.17	0.32	0.35	0.34	0.30	0%	8%	5%	-8%
Water	0.11	0.57	0.34	0.28	0.31	0.34	0.33	0.37	196%	220%	212%	256%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 31. Transport emissions by modes – State of Amazonas (Mt CO_2e)



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 32. Emissions from the transport sector – State of Amazonas (Mt CO_2e)

6.1.3 Industry

Industry emissions include IPPU and industrial energy use. IPPU emissions data are only available for the cement industry, but IPPU is the main source of emissions (Table 35). In the Reference Scenario, IPPU emissions were reduced by 33% from 2005 to 2025 and 25% from 2005 to 2030, while in the Mitigation Scenario, IPPU emissions were reduced by 35% from 2005 to 2025 and 31% from 2005 to 2030.

Emissions from industrial energy use are disaggregated into six industrial sub-sectors plus “other industries”, which is the main source of emissions from industrial energy use. Energy emissions showed the most significant percentage reduction during the period analyzed for both Scenarios. Emissions from energy use were reduced by 60% from 2005 to 2025 and 56% from 2005 to 2030 in the Reference Scenario. In the Mitigation Scenario, this reduction reached 64% from 2005 to 2025 and 62% from 2005 to 2030.

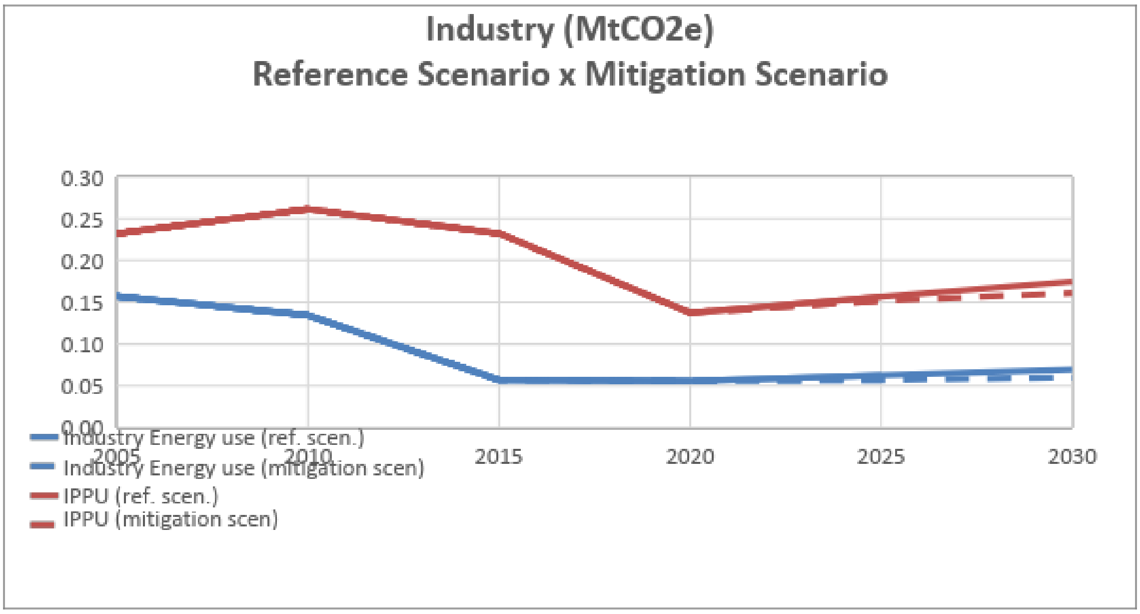
Total industry emissions in the Reference Scenario were reduced by 44% from 2005 to 2025 and 37% from 2005 to 2030. In the Mitigation Scenario, industry emissions fell by 46% from 2005 to 2025 and 43% from 2005 to 2030 (Figure 33)

Comparing emissions from both scenarios in 2030, adopting the proposed mitigation measures, such as energy intensity reduction, leakage control, process control, and replacement of fossil fuels by natural gas and renewable biomass, led to a reduction in emissions by 10% (Figure 34).

Table 35. Emissions from the industry sector – energy use and Industrial Processes and Product Use (IPPU) – State of Amazonas (Mt CO_2e and %)

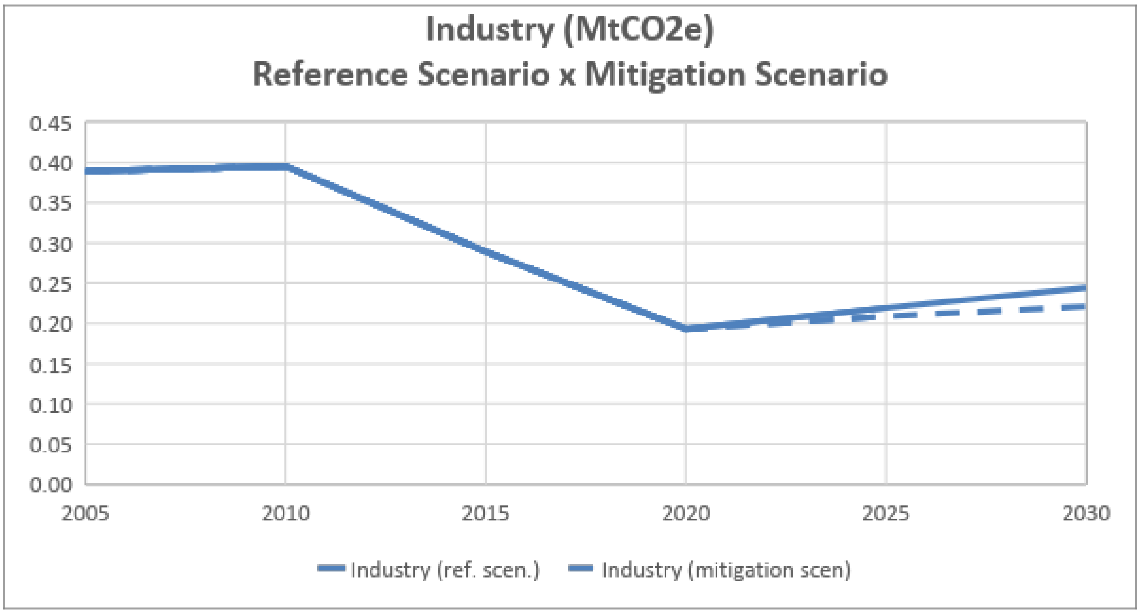
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig	Ref.	Mitig	Ref.	Mitig	Ref.	Mitig
Total Industry (Energy + IPPU)	0.39	0.40	0.29	0.19	0.22	0.21	0.24	0.22	-44%	-46%	-37%	-43%
Industry (Energy)	0.157	0.134	0.057	0.056	0.063	0.057	0.070	0.060	-60%	-64%	-56%	-62%
Cement	0.000	0.002	0.001	0.002	0.003	0.002	0.003	0.002	31%[1]	23%[1]	47%[1]	24%[1]
Pig iron and steel	0.005	-	-	-	-	-	-	-	-	-	-	-
Non-Ferrous/Other Metallurgical	0.012	0.019	0.000	0.002	0.002	0.002	0.002	0.002	-81%	-83%	-79%	-82%
Chemical	0.009	0.011	0.014	0.020	0.023	0.021	0.025	0.022	154%	135%	180%	140%
Food and Beverage	0.026	0.032	0.011	0.007	0.008	0.008	0.009	0.008	-67%	-69%	-63%	-67%
Pulp & Paper	0.029	0.015	0.007	-	-	-	-	-	-	-	-	-
Other Industries	0.076	0.055	0.024	0.024	0.027	0.024	0.029	0.025	-65%	-69%	-61%	-67%
Industrial Processes and Product Use	0.23	0.26	0.23	0.14	0.16	0.15	0.17	0.16	-33%	-35%	-25%	-31%
Mineral Industry	0.23	0.26	0.23	0.14	0.16	0.15	0.17	0.16	-33%	-35%	-25%	-31%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 33. Industry emissions by subsector- energy use and industrial processes and product use (IPPU) – State of Amazonas (Mt CO_2e)



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 34. Emissions from the industry sector – State of Amazonas (Mt CO_2e)

6.1.4 Other sectors of energy use

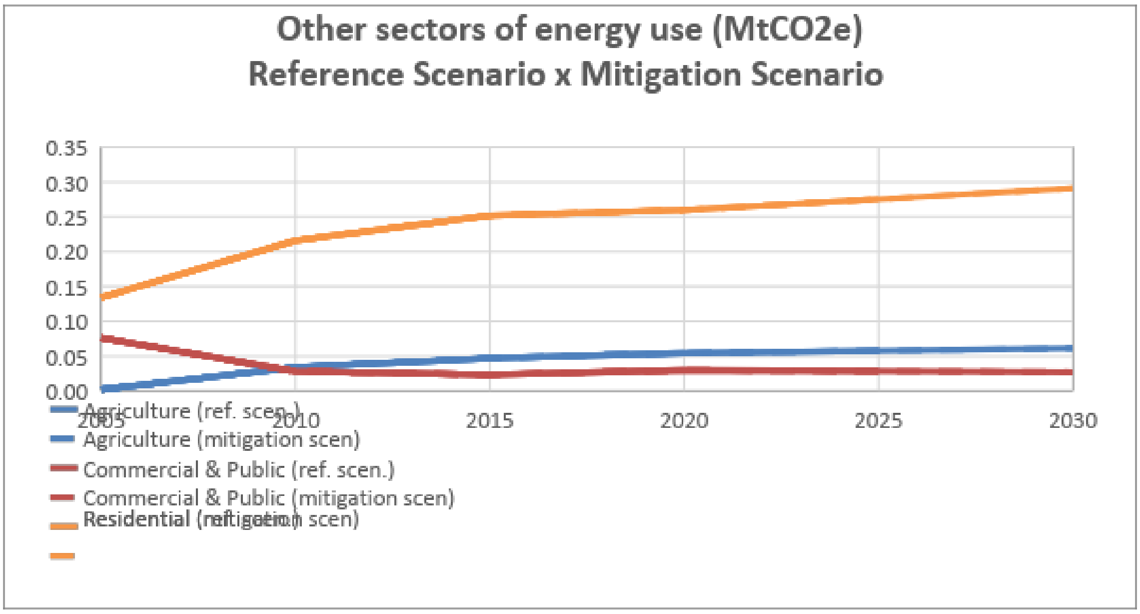
The other energy use sectors account for agriculture, public, commercial, and residential energy use. Emissions in the Reference and Mitigation Scenario increased 70% from 2005 to 2025 and 79% from 2005 to 2030 (Table 36). No specific mitigation measures were considered in the Mitigation Scenario in this sector.

From 2005 to 2030, estimated emissions follow the same trend, with residential being the main emission source. However, the agriculture subsector has a substantial increase in emissions from energy use in the same period. On the other hand, commercial and public subsector was the only one that reduced emissions during the analyzed period. The other energy consumption sectors have the lowest percentage of emissions from the entire state of Amazonas.

Table 36. Emissions from Other sectors of energy use – State of Amazonas (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Other sectors of energy use	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	70%	70%	79%	79%
Residential	0.13	0.22	0.25	0.26	0.28	0.28	0.29	0.29	105%	105%	117%	117%
Commercial & Public	0.076	0.028	0.023	0.030	0.028	0.028	0.027	0.027	-63%	-63%	-65%	-65%
Agriculture	0.002	0.034	0.047	0.054	0.058	0.058	0.061	0.061	2783%	2783%	2947%	2947%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 35. Other sectors of energy use emissions by subsector – State of Amazonas (Mt CO_2e)

6.1.5 Energy supply

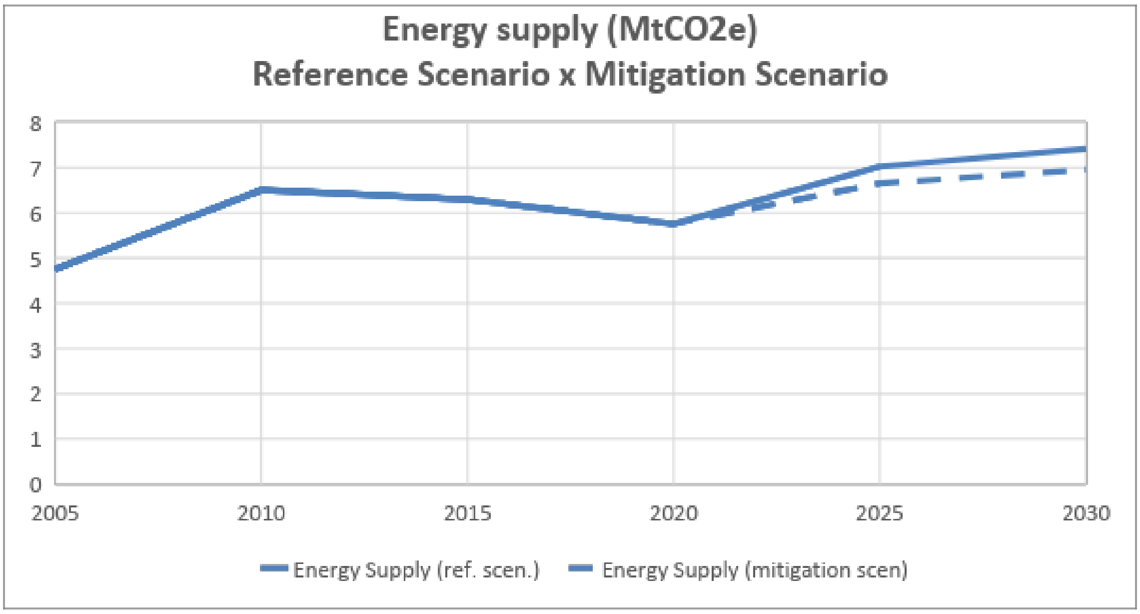
The energy sector emissions comprise the fuel combustion in the transformation centers and the energy sector's own consumption emissions. In the Reference Scenario, Energy supply emissions increased 48 % from 2005 to 2025 and 56% from 2005 to 2030. The Mitigation Scenario increased 40% from 2005 to 2025 and 46% from 2005 to 2030 (Table 37 e Figure 36). Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures leads to a reduction in emissions of 6%. The main assumption is that no additional fossil fuel power capacity would be added, besides those that won energy auctions until 2017. Furthermore, efforts would be made to foster a higher penetration of renewable sources.

Fuel combustion in transformation centers is the primary source of emissions of the Energy supply sector, mainly because of the electricity generation (public utility). In the Reference Scenario, transformation centers emissions increased 47 % from 2005 to 2025 and 56% from 2005 to 2030. The Mitigation Scenario increased 38% from 2005 to 2025 and 45% from 2005 to 2030.

Table 37. Energy supply emissions by sector – State of Amazonas (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig	Ref.	Mitig	Ref.	Mitig	Ref.	Mitig
Energy supply (Fuel Combustion)	**4.8**	**6.5**	**6.3**	**5.8**	**7.0**	**6.7**	**7.4**	**7**	**48%**	**40%**	**56%**	**46%**
Energy Sector Consumption	0.7	0.6	0.7	0.7	1.1	1.1	1.1	1.1	50%	50%	55%	55%
Transformation Centers	4.0	5.9	5.6	5.0	5.9	5.6	6.3	5.8	47%	38%	56%	45%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 36. Energy supply emissions – State of Amazonas (Mt CO_2e)

6.1.6 Waste

Waste emissions include both solid waste and wastewater. In the Reference Scenario, waste emissions increased 53 % from 2005 to 2025 and 56% from 2005 to 2030. In the Mitigation Scenario, emissions increased 31% from 2005 to 2025 and 32% from 2005 to 2030 (Table 38 and Figure 37

Comparing emissions from both Scenarios in 2030, the adoption of the proposed mitigation measures led to a reduction in emissions of 16% (Figure 38). The Mitigation scenario considers the penetration of the mitigation measures suggested in ICAT 1, such as higher percentage of waste disposal in landfills, capture, and recovery of methane for destruction in flairs, electricity generation, or replacement of natural gas used in the vehicular fleet in wastewater treatment in plants and landfills.

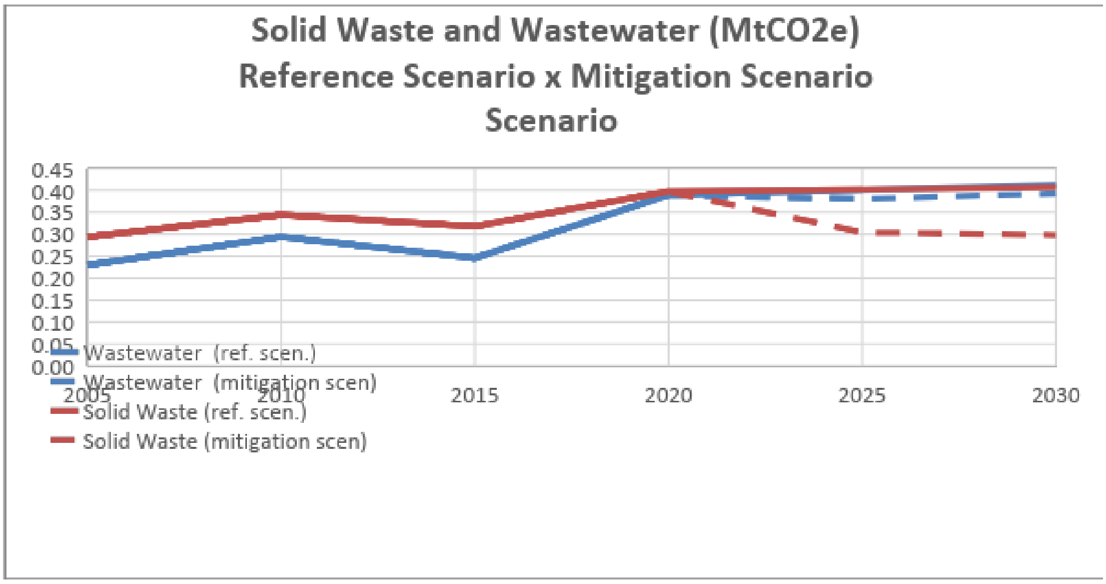
From 2005 to 2030, wastewater and solid waste emissions have almost the same share in Emissions from the waste sector. However, there is a substantial increase in emissions from the wastewater sector, mainly in the industrial subsector. In 2025 and 2030, compared to 2005, emissions grew 323% and 370% in the Reference Scenario and 305% and 352% in the Mitigation Scenario.

Regarding solid waste emissions, urban solid waste is the main source. The Reference Scenario increased 37 % from 2005 to 2025 and 39% from 2005 to 2030. The Mitigation Scenario increased 3% from 2005 to 2025 and 1% from 2005 to 2030. Solid waste has the most significant difference in emission values between the scenarios.

Table 38. Emissions from the waste sector – State of Amazonas (Mt CO_2e and %)

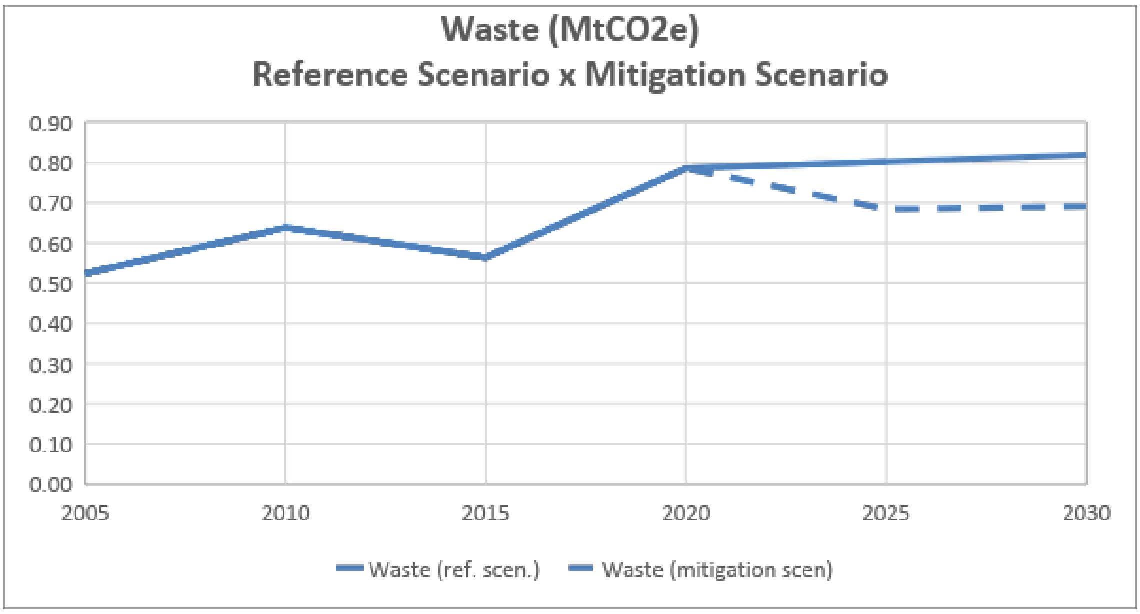
Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	Mt CO_2e								%			
Scenario					Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.	Ref.	Mitig.
Waste	**0.5**	**0.6**	**0.6**	**0.8**	**0.8**	**0.7**	**0.8**	**0.7**	**53%**	**31%**	**56%**	**32%**
Solid Waste	0.3	0.3	0.3	0.4	0.4	0.3	0.4	0.3	37%	3%	38%	1%
Urban Solid Wastes	0.3	0.3	0.3	0.4	0.4	0.3	0.4	0.3	37%	3%	39%	1%
Others	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.003	7%	87%	19%	163%
Wastewater Treatment and Discharge	0.2	0.3	0.2	0.4	0.4	0.4	0.4	0.4	74%	65%	79%	71%
Domestic Wastewater	0.2	0.3	0.2	0.3	0.3	0.3	0.3	0.3	53%	45%	55%	47%
Industrial Wastewater	0.02	0.04	0.02	0.07	0.08	0.07	0.08	0.08	323%	305%	370%	352%

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 37. Waste emissions by subsector – State of Amazonas (Mt CO_2e)



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 38. Emissions from the waste sector – State of Amazonas (Mt CO_2e)

6.2 Consolidation of Scenarios – State of Amazonas

Total emissions from the State of Amazonas reached -15 Mt CO_2e in 2030 in the Reference Scenario and -75 Mt CO_2e in the Mitigation Scenario (Table 39). It represents an increase of 31% in the Reference Scenario net emissions. In other words, there was a reduction in removals from -22 $MtCO_2e$ in 2005 to -15 Mt CO_2e in 2030. In the Mitigation Scenario, there is a reduction of 233% in net emissions from 2005 to 2030, with more carbon removals in 2030 than in 2005.

In 2030, the main source of emissions is the AFOLU sector, followed by energy supply, transport, waste, industry, and other energy use sectors. AFOLU is the most emitting sector due to deforestation and other land use changes. However, it is also the sector with the most carbon removals with increased protected areas and indigenous lands.

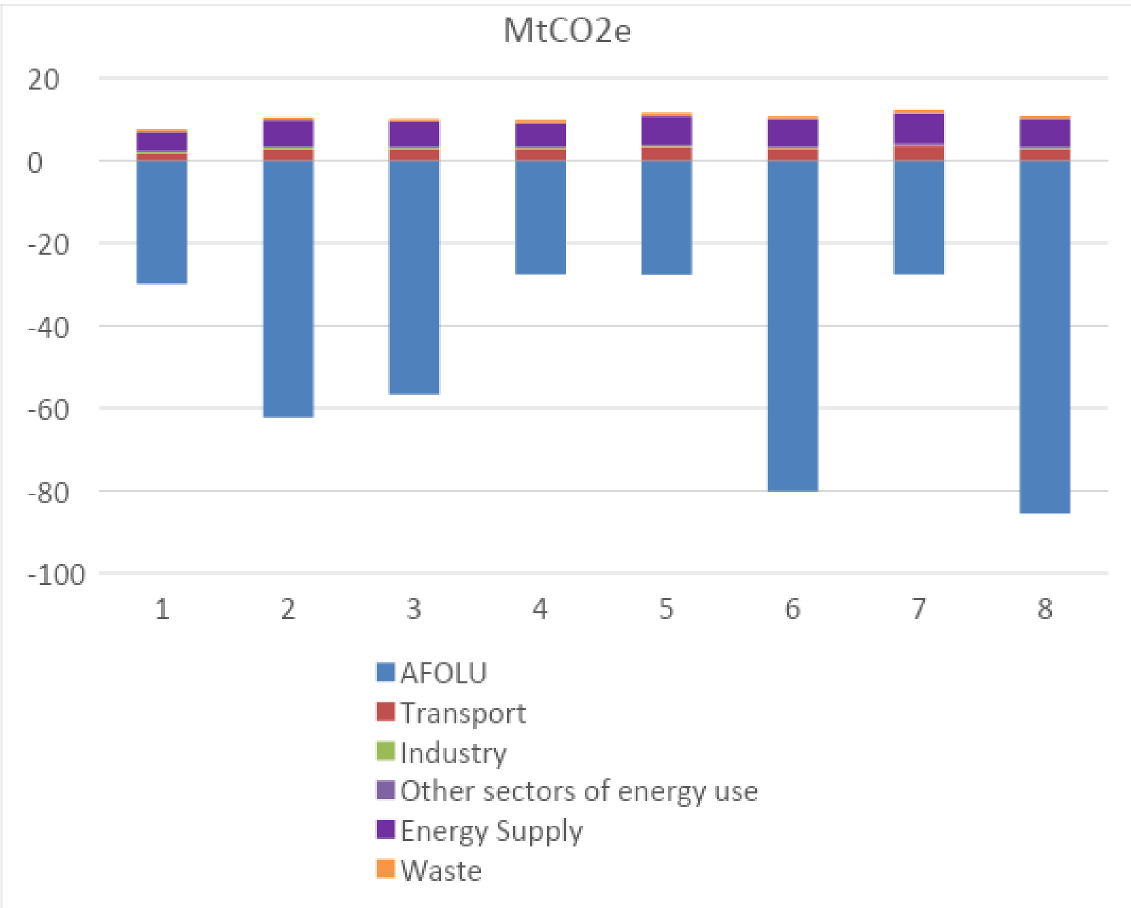
Transport and Other energy use are the sectors that grew the most in emissions from 2005 to 2030. From 2005 to 2030 in the Mitigation Scenario, AFOLU and industry have reduced emissions. In the Reference Scenario, only the industry sector reduces emissions (AFOLU in the Reference Scenario reduces removals; this sector has lower negative net emissions).

In 2025 and 2030, it is possible to see in Figure 39 the impact of the mitigation measures considered in each sector, reducing the total emissions from the state of Amazonas. In 2030, regarding the results of mitigating GHG emissions (the Reference Scenario emissions minus the Mitigation Scenario emissions), AFOLU has the most significant impact of measures with a 58 $MtCO_2e$/year increase in removals between the two scenarios, followed by transport with 0.5$MtCO_2e$ / year and Energy supply with a reduction of 0.5 $MtCO_2e$/year.

Table 39. Amazonas State emissions by sector in the period 2005-2030 (Mt CO_2e and %)

Emission Sources	2005	2010	2015	2020	2025		2030		2005-2025		2005-2030	
	$MtCO_2e$								%			
Scenario					Ref.	Mitig	Ref.	Mitig	Ref	Mitig	Ref.	Mitig.
AFOLU	-30	-62	-57	-28	-28	-80	-28	-85	56%	-29%	56%	-37%
Transport	1.6	2.6	2.6	2.7	3.1	2.8	3.4	2.5	96%	76%	113%	59%
Industry	0.4	0.4	0.3	0.19	0.22	0.21	0.24	0.22	-44%	-46%	-37%	-43%
Other sectors of energy use	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	70%	70%	79%	79%
Energy supply	4.8	6.5	6.3	5.8	7.0	6.7	7.4	7.0	48%	40%	56%	46%
Waste	0.5	0.6	0.6	0.8	0.8	0.7	0.8	0.7	53%	31%	56%	32%
Total	**-22**	**-52**	**-47**	**-18**	**-16**	**-69**	**-15**	**-75**	**28%**	**-210%**	**31%**	**-233%**

Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.



Note: Historical emission data from 2005 to 2018 and projections from 2019 to 2030.

Figure 39. Amazonas State emissions by sector in the period 2005-2030 (Mt CO_2e and %)

7. Conclusion

The Brazilian Nationally Determined Contribution (NDC), presented in 2015, had an economy-wide goal of 37% GHG emission reduction in 2025 and an intended 43% reduction in 2030, compared to 2005 as the base year. In its annex "for clarification purposes," it is specified that these goals would translate into an aggregate limit of 1.3 Gt CO2e in 2025 and 1.2 $GtCO_2e$ in 2030 (GWP-100, IPCC AR5) – based on the 2005 Brazil emission level (2.1 $GtCO_2e$) of the Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC).

The new Brazilian 1st NDC, submitted to the UNFCCC in 2020, keeps the economy-wide goal of 37% GHG emission reduction in 2025 and confirms the 43% reduction in 2030 compared to 2005. However, it uses the base year value from the Third National Communication, which emissions amounted to 2.8 $GtCO_2e$ in 2005. These goals translate into an aggregate limit of 1.8 $GtCO_2e$ in 2025 and 1.6 $GtCO_2e$ in 2030 (GWP-100, IPCC AR5).

In the years to come, the absolute levels of emission targets for 2025 and 2030 will have to be changed again to 1.5 and 1.4 $GtCO_2e$ /year, to reflect the new figure of 2.4 $GtCO_2e$ /year for 2005 presented in the Brazilian Fourth National Communication recently submitted to the UNFCCC.

Table 40. GHG net emissions in Brazil, 2005-2015 and Targets for 2025 and 2030 in billions of tons of carbon dioxide equivalent ($GtCO_2e$)

GHG Brazilian Emissions	2005	2010	2015	2025	2030
NDC (2015)	**2.1**			**1.3**	**1.2**
New 1st NDC (2020)	**2.8**			**1.8**	**1.6**
Fourth National Communication of Brazil (2021)	**2.4**	1.2	1.5	**1.5**	**1.4**
%	**100%**			**2005 Value -37%**	**2005 Value -43%**

Sources: Brazil (2015); Brazil (2016); Brazil (2021)

Brazilian NDC mitigation targets are economy-wide, and there is no specific target for subnational instances. Therefore, individual states do not need to comply with any national mitigation target so far. However, in the reference scenario, total net emissions for the three states increase rather than decrease from 2005 to 2025 and 2030. Even in Amazonas, where total net emissions are negative, this contribution to meet Brazilian NDC targets has slightly decreased.

This report identified the potential of the additional policies and measures identified in the ICAT 1 project to foster mitigation actions in the three selected states and therefore go beyond the current mitigation actions reflected in the Reference Scenario. The Mitigation Scenario emissions from Rio de Janeiro and Minas Gerais states still increase emissions in 2025 and 2030 comparing to 2005. On the other hand, the State of Amazonas, where total net emissions are negative, can contribute to the Brazilian NDC targets. Amazonas has enormous potential for reducing emissions with additional policies and measures, mainly in then the AFOLU sector-removals increased even more in the State in the Mitigation Scenario.

Figure 40 below, presents how the emissions in the states of Rio de Janeiro, Minas Gerais and Amazonas unfold in both scenarios, comparing to the NDC targets.

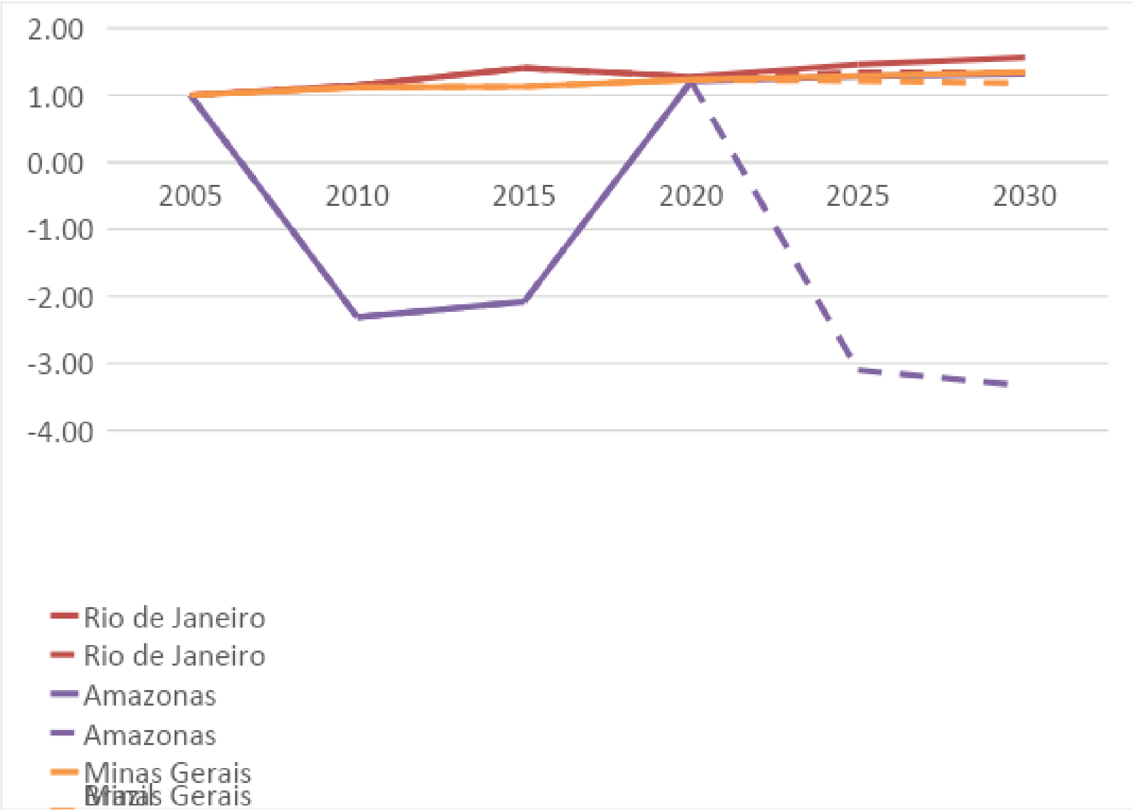


Figure 40. States pathways compared to Brazilian NDC targets

ANNEX I – Mitigation actions provided for in the Minas Gerais Integrated Development Plan (PMDI)

The following estimates are not included in the scenarios due to differences in methodological approaches. Moreover, they are only rough numbers and serve to give a dimension to the measure's mitigation potential.

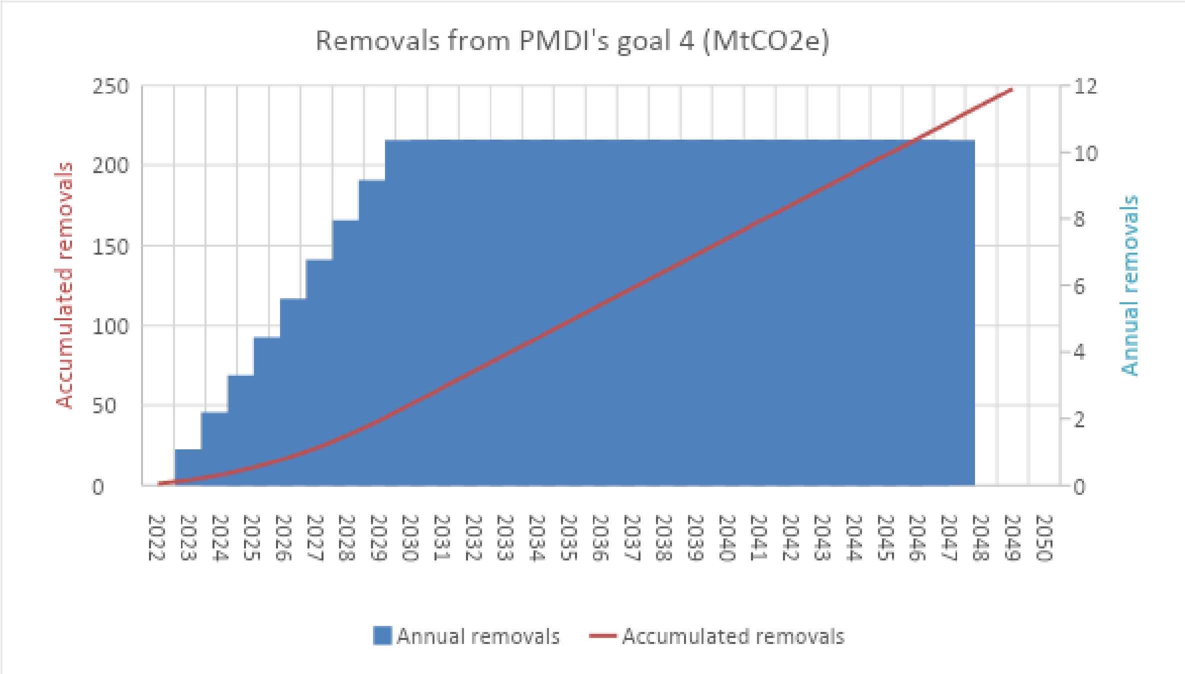
1) Carbon Removals Potential

In 2019, the state of Minas Gerais published the Minas Gerais Integrated Development Plan (PMDI), which sets out strategic objectives and guidelines that extend to short and medium-term plans and articulates the actions and programs formulated by government agencies. PMDI determines ten strategic objectives to be implemented, among them objective 4: "Protect, recover and promote the sustainable use of Ecosystems." One of the evaluated indexes is the "Ratio between restored/conserved areas and suppressed areas." This proportion is set at 1.03 in 2022, 1.09 in 2026, and 1.15 in 2030.

Considering that the projected annual emissions levels from deforestation for the state reflect roughly the annual vegetation suppressed areas, we can estimate a proxy for the potential carbon removals that the adoption of these policies can generate for the state.

To carry out the carbon removal estimates, we used some simplifying hypotheses, namely: "conserved/restored areas" are treated as reforested areas; as the species and their mitigation potential in the Plan are not mentioned, the mitigation estimate considered that the average carbon to be removed in one hectare corresponds to the average carbon emitted in the inventory; as in reforestation trees growth occurs over 30 years, for each annually emitted carbon, it would take 30 years to remove the same carbon amount; removals are considered a linear function; the values over the years are unknown, so the goals defined for 2022, 2026 and 2030 were taken as a basis, and the intermediate years are interpolated values; reforestation would take place until 2030, and estimated removals are presented until 2050.

The results show that achieving PMDI's goal 4 leads to increasing annual carbon removal, stabilizing at 10.4 MtCO2 removed annually in 2030, as shown in Figure 41. he cumulative carbon removal potential is 50.89 MtCO_2 from 2022 to 2030. Removal potential between 2022 and 2050 is even higher, reaching 258.28 MtCO_2e.



Source: Authors estimates based on Governo do Estado de Minas Gerais, 2019

Figure 41. Estimates of carbon removals with PMDI objective 4.

2) Sol de Minas Project and Photovoltaic Power Generation

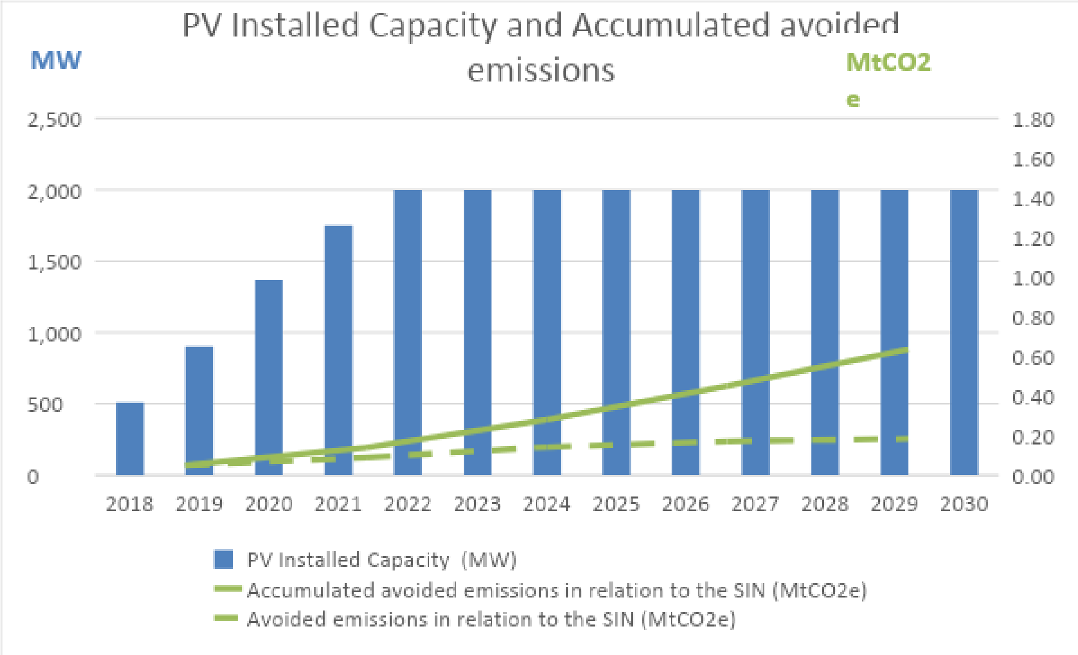
The Project Sol de Minas is part of the Minas Gerais Government strategic planning. The main objective is to leverage the state's leading role in the photovoltaic energy sector in Brazil. The focus is on expanding photovoltaic power installed capacity in MG from 510 MW (December/2018) to 2,000 MW in 2022.

In addition to increasing the state's installed electricity generation capacity and strengthening the production of the photovoltaic energy generation chain, the project also contributes to increasing the participation of clean energy in the energy matrix and reducing greenhouse gas emissions.

The Sol de Minas Project also carries out a diagnosis and a review of relevant legislation, including environmental, to simplify the regulation of the photovoltaic energy sector, promote investments, and foster innovation processes and technological connections making Minas Gerais companies more competitive.

Considering the national grid emission factor, and its future projection, we can estimate the potential of avoided emissions by substituting the electricity consumed from the grid (SIN – National Interconnected System, in Portuguese) with the electricity produced by local photovoltaic systems. It is possible to calculate the amount of CO2e avoided with the photovoltaic generation through the relation between the electricity generated in a period and the average CO2e emission factor of the SIN in that same period. All installed capacity was assumed as a distributed-scale PV with a capacity factor of 15%, referring to the average of the Southeast region.

Assuming that the 2,000 MW of photovoltaic renewable energy electricity generation in 2022 replaces the emissions from the Brazilian interconnected system in the current policy scenario, Minas Gerais would avoid 0.18 MtCO2e emissions in 2022. In the long term, considering no capacity additions and the projected emissions factor for the Brazilian interconnected system, the State would avoid 0.08 MtCO2e emissions in 2030. In total, it would lead to the cumulative mitigation of 1.67 MtCO2e from 2018 until 2030, as shown in Figure 42.



Source: Authors, based on Governo do Estado de Minas Gerais, 2021

Figure 42. PV Installed capacity in Minas Gerais and the avoided emissions in relation to the SIN

3) Energy Recovery from Wastes

Energy recovery from wastes is the conversion of non-recyclable waste materials into usable heat, electricity, or fuel through a variety of processes, that is often called waste to energy. According to the energy program for Brazil (BEP), at the Energy recovery of waste in Minas Gerais report (Great for Partnership, 2021), Minas Gerais has a technical potential of 178 million m^3/year of biogas from sanitation services (wastewater and urban solid waste). Wastewater has a biogas production potential of 46.4 million m^3/year that can generate 65 GWh/year of power, while urban solid waste has 131.6 million m^3/year of biogas production potential that can generate 184 GWh/year of power. This value considers the short- and medium-term potential that does not have major viable technological barriers. Uberlândia and Vespasiano-BH are potential poles of biomethane production from urban solid waste.

It is also possible to infer the potential mitigation with the energy recovery from biogas, instead of using the grid energy. Considering that 1 m^3 of biogas has a concentration of 55% methane, the density of methane as 0.72 kg/m3, we can estimate the avoided emissions. One of the mitigation options is to burn the biogas in a biogas flaring system (Mitigation 1), preventing its release into the atmosphere, and the other one is replacing natural gas by biogas in a typical thermoelectric plant (Mitigation 2), also preventing its release into the atmosphere.

Table 41 shows the avoided emissions in both mitigation cases.

Table 41. Avoided emissions potential of biogas electricity generation in Minas Gerais.

Activity	Technical Potential of Biogas (million m^3/year)	Power generation potential (MWh/year)	Avoided emissions due to flaring (Mt CO_2e)*	Avoided emissions due to natural gas replacement (Mt CO_2e)*	Total avoided emissions (Mt CO_2e)
Sanitation services (wastewater and urban solid waste)	**178**	**249,338**	**1.97**	**0.05**	**2.02**
Wastewater	46.4	65,009	0.51	0.01	0.53
Solid waste	131.6	184,329	1.46	0.04	1.50

* No details regarding the baseline emissions are available.
Source: Authors, based on Governo do Estado de Minas Gerais, 2021

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