GREENHOUSE GAS EMISSIONS INVENTORY OF THE CITY OF RIO DE JANEIRO IN 2012 AND UPDATING OF THE MUNICIPAL PLAN OF ACTION FOR EMISSIONS REDUCTION

Technical Summary

Mayor of the City of Rio de Janeiro
Eduardo Paes

Municipal Environment Secretary
Carlos Alberto Muniz

Municipal Environment Under-Secretary
Altamirando Fernandes de Moraes

Rio de Janeiro City Government Team
Nelson Moreira Franco – Coordination

Technical Team
Cláudia Fróes Ferreira
Rodrigo Rosa
Luiz Paulo Gerbassi
José Henrique Penido
Sergio Besserman
Luiz Roberto Arueira da Silva
Felipe Cerbella Mandarino
Marcio Moura Motta
Marcelo Hudson
Marcelo Abelheira
Elaine Martins Barbosa

Centro Clima/COPPE/UFRJ Team
Prof. Emilio Lèbre La Rovere, D.Sc – General Coordinator
Flavia B. Carloni, D.Sc. – Executive Coordinator

Technical Team
Gabriela Nadaud, M.Sc PPE – Researcher
Gustavo Malaguti, M. Sc. – Researcher and doctoral candidate PPE
Patrícia Turano de Carvalho, M.Sc PPE – Researcher
Raymundo Aragão, M.Sc – Researcher and doctoral candidate PPE
Renzo Solari, M.Sc PPE – Researcher
Saulo Loureiro, M.Sc – Researcher and doctoral candidate PPE
Tomás Bredariol – Researcher and master's degree candidate IE/UFRJ

Interns
Gabriel Pitta – Undergraduate Poli/UFRJ
Kárys Prado – Undergraduate Poli/UFRJ
Vitor de Oliveira Carvalho – Undergraduate Poli/UFRJ
Camila Neves – Undergraduate Poli/UFRJ
Yasmini Dopico – Undergraduate Poli/UFRJ
Priscilla Sarpa – Undergraduate UFF
Felipe Treistman – Undergraduate Poli/UFRJ
Seiti Ogawa – Undergraduate Poli/UFRJ
Nathalia Bastos – Undergraduate Poli/UFRJ

Administrative Support
Carmen Brandão Reis – Executive Secretary
Elza Ramos – Layout

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Message

The world has been watching the events taking place in Rio de Janeiro. The association of economic, social and historical factors has led to a period of great change. The opportunity to build a future based on sustainability, a priority for both the planet and civilization, must be seized.

The history of Rio is very closely linked to the environment. International awareness of the preservation of the environment was born in the city when the Earth Summit brought together the main political leaders of the world to discuss sustainable development. A discussion that was resumed during the United Nations Conference on Sustainable Development, Rio +20, in 2012. Recent weather events in the world reinforce the importance of preserving nature as a condition for our evolution and urge us to rethink the development model we should adopt.

Over these past four years, the City of Rio de Janeiro, through the firm actions of the City Government, has stood out in the efforts to address climate change, taking into account not only environmental, technological and economic dimensions but also cultural and political dimensions, requiring the participation of all segments of Rio society. Rio de Janeiro was one of the first cities in the country to define a Municipal Climate Change and Sustainable Development Policy, an initiative that enshrined the joint effort of the executive and legislative branches. It also established the Rio Climate Change and Sustainable Development Forum, made up of representative segments of the public sector, private sector and civil society, whose aim is to contribute to the search for feasible solutions for public policies in this area.

Once again, the city is a pioneer in environmental matters. In preparing its third Greenhouse Gas Emissions Inventory, the city becomes one of the first in the world to test the new global inventory standard, established by the WRI , World Bank, C40 and ICLEI, that is, one with more consistent, reliable, comparable and internationally recognized data. The study included in this document is more than an x-ray of the carbon dioxide emissions within urban limits; and it provides invaluable information to guide the city's development policy.

Furthermore, the road map acquires clearer features. The City Government and COPPE/UFRJ have drawn up a plan of action that includes the measures undertaken by the city to achieve the greenhouse gas reduction targets previously defined in the city's climate policy. These measures include doubling the number of bicycle lanes, expanding the reforestation program, installation of a waste treatment center, burning biogas, streamlining public transport by establishing bus lanes (Transcarioca, Transolímpica, Transoeste and Transbrasil), among others.

There are issues in the near future that will have significant environmental impacts, such as the deploying of the Steel Complex in the Zona Oeste, whose emissions have been included in this inventory. We shouldn't fear these challenges, which will generate jobs and income to the neediest area of the city. We should manage them with clarity and transparency on behalf of the collective interest. It is important to incorporate and disseminate the awareness of sustainability, so that it can become a tenet of our lives and enrich the legacy for future generations.

Carlos Alberto Muniz

Environment Secretary of the City of Rio de Janeiro

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Introduction

The greenhouse gas (GHG) emissions of a city, region or country arise from burning fossil fuels (oil products, natural gas and coal), waste treatment, industrial processes and changes in plant cover, among others. Practically all economic sectors of modern society (industry, services, transports, farming, and construction) produce carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions, the main GHG gases, to a greater or lesser extent. Estimates of GHG emissions have an inbuilt uncertainty because of the difficulty in obtaining data on all these activities and emission factors. This is even more so when dealing with cities, where delimiting the boundaries of the activities is more complex. Nevertheless, the City Government of Rio de Janeiro was one of the first cities to carry out a GHG emissions inventory on a municipal scale. In 2000, the City Government presented the inventory of the emissions of the three main GHG gases in the City of Rio de Janeiro for the years 1990, 1996 and 1998; and in 2010, it did it for the year 2005, in addition to developing Scenarios and a Plan of Action to mitigate its GHG emissions. The City Government now presents its third emissions inventory for these GHG in Rio de Janeiro, which amounted to 22.6 million tonnes of CO_2 equivalent (Mt CO_2e) in 2012, in addition to revising the estimates for 2005 (11.6 Mt CO_2e), always with the technical support of COPPE/UFRJ.

The reduction of GHG emissions in Rio de Janeiro is one of the strategic projects of the City Government. Emissions reduction targets were defined and consolidated in the Municipal Climate Change and Sustainable Development Law, enacted in January 2011. Targets were set using the total emissions verified in 2005 as reference. Reduction targets were defined as follows: avoid 8% of the 2005 emissions in 2012 (0.93 Mt CO_2e), 16% in 2016 (1.86 Mt CO_2e) and 20% (2.32 Mt CO_2e) in 2020.

Targets were established while many City Government projects for emissions reductions were being defined and detailed. Large-scale works and interventions such as the inauguration of the Waste Treatment Center in Seropédica and the operation of large high-capacity express bus lanes (BRTs) are leading to a significant reduction of GHG emissions.

On the other hand, GHG emissions avoided by the actions of the City Government were not enough to ensure an overall reduction of the level of GHG emissions in the city, which almost doubled from 2005 to 2012. Population growth and economic development of a city induce a rise in GHG emissions. While the city's population has been increasing slowly over the past few years (growth of 3.6% from 2005 to 2012), the economic dynamics began to accelerate in November 2009, when Rio de Janeiro was chosen as the host city for the 2016 Olympic and Paralympic Games (45% growth in the municipal GDP from 2005 to 2012). Deployment of a large-scale steel mill using coke (manufactured from coal) within the boundaries of the city at the end of 2010 also contributed to increase GHG emissions. The Companhia Siderúrgica do Atlântico (TKCSA) had gross on-site emissions of 8.8 Mt CO_2e (scope 1), even though attenuated by the company's major efforts, resulting in net GHG emissions estimated by the company to be around 6.3 Mt CO_2e in 2012. Changes in the country's energy policy, arising from decisions made beyond the responsibility of the city, such as the increased use of thermopower for electricity generation, increase use of gasoline due to price subsidies and growth in the number of private vehicles, in addition to the crisis in ethanol production, also contributed to the increase of GHG emissions in the City of Rio de Janeiro from 2005 to 2012.

As a result, the Rio de Janeiro City Government decided to steer public policies towards a low-carbon urban development. Investments and interventions must have a climate component in their priorities, demonstrating to economic agents and civil society that it is indeed a priority. Moreover, the main guideline of the City's Strategic Plan is tp promote sustainable development. The option of the City Government, with the support from the City Council, was to adopt realistic and transparent GHG emission reduction targets, in accordance with the public policies of City Government.

This decision allowed Rio de Janeiro to preside with New York the meeting of the cities participating in the C40 Climate Leadership Group, an entity bringing together 58 megacities of the world, during Rio+20. The C40 mayors made the commitment to reduce global greenhouse gas emissions by 1.3 billion tonnes by 2030, according to the policies being implemented in their respective cities. The commitment contrasted with the difficulty of achieving consensus in the multilateral area and with the absence of climate change debate during the United Nations Conference on Sustainable Development, Rio +20, promoted by national governments. Notwithstanding the leadership and autonomy of the cities, the perspectives and goals of national, regional and local governments, including the city of Rio de Janeiro, also suffer the direct consequences of these negotiations.

Within this context, the Government of the City of Rio de Janeiro presents herein the Greenhouse Gas Emissions Inventory of the city for the year 2012 and the update of the Municipal Plan of Action for Emissions Reduction.

Greenhouse Gas Emissions Inventory for the City of Rio de Janeiro for the Year 2012

Organization of the GHG Inventory of the City of Rio de Janeiro

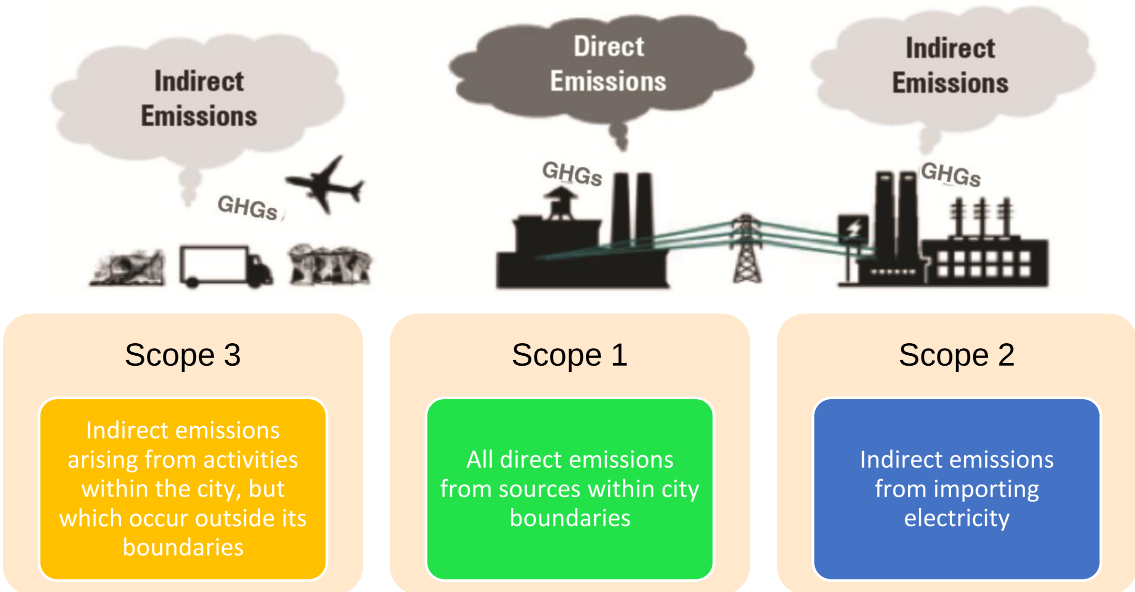
Several cities all over the world, including Rio de Janeiro, have been using the IPCC-2006 Guidelines (IPCC, 2006) to carry out their GHG inventories. However, in using a methodology originally developed for entire countries in a local context, the appropriateness of the transposition must be carefully checked, as several adaptation measures are needed. Since national inventories are a tool to help countries implement the commitments made under the UNFCCC, the methodology seeks to standardize information so that the inventories of different countries can be compared. In the case of states and cities, the aim of carrying out an inventory is to provide input for planning, but the possibility of comparing among states or cities is interesting for international validation and analysis of results. Thus, care must be taken to ensure that the required methodological adaptations are adequately addressed and clearly explained.

In the GHG emissions inventory of the City of Rio de Janeiro, presented below, the methodology employed was developed by Centro Clima/COPPE/UFRJ, based on the IPCC-2006 Guidelines and using the adaptations previously carried out in National Communications (BRASIL, 2004; 2010). Furthermore, in order to follow best international practices on the clear definition of boundaries and responsibilities of the city's emissions, the Global Protocol for Community-scale Greenhouse Gas Emissions (community protocol – GPC) was also used. This new joint initiative led by WRI/ICLEI/C40 aims to develop a global protocol for accounting of and reporting the GHG emissions of cities. The complete text of the protocol was made available in late March 2012 for public consultation and formally published in the second half of 2012 to test its application. Rio de Janeiro is one of 30 cities selected to take part in this pilot test of the protocol.

The sectors that are the subject of national inventories according to the IPCC-2006 Guidelines and that are used to build the inventory of the City of Rio de Janeiro are the following:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Wastes

These sectors were subdivided according to GPC recommendation and broken down with respect to emission sources, methods used to define the boundaries/responsibilities, and the calculations and emission factors employed. Also in accordance with GPC recommendations, emissions were quantified taking into account the Scope classification (Figure 1): all of scope 1 and 2 sources and as much as possible of scope 3 sources, depending on available data. The estimated amounts of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emitted by the city in the year 2012 were calculated.



Source: Adapted from WRI (2011).

Figure 1 – Classification of GHG emissions by scopes

With regard to the tiers[1] used, these depend on the availability of data for each assessed emission source. The same goes for the emission factors, which, whenever possible, were obtained locally. In the absence of local emission factors, the following were used, in order of priority: national figures, provided by Brazil's National Communications (BRASIL, 2004; 2010); when these were not available, values obtained were obtained from literature on Brazil; and as a last resort, default factors from the IPCC-2006 Guidelines were used.

As to the Global Warming Potential (GWP)[2], the figures established in the fourth IPCC report (AR-4) were used (IPCC, 2007): 21 for CH_4 and 310 for N_2O.

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[1] A tier represents a level of methodological complexity. Usually three tiers are provided. Tier 1 is the basic method, tier 2 the intermediate method and tier 3 is the one that demands most in terms of complexity and data requirements. Tiers 2 and 3 are considered the most accurate methods.

[2] GWP is a useful metric for comparing the climate impact potential of the emissions of different greenhouse gases Global warming potential compares the time-integrated radiative forcing over a specific period (e.g., 100 years) based on the instantaneous release of a unit mass and is a means of comparing the potential for climate change associated to the emissions of different greenhouse gases.

1. Energy

1.1. Features of the Sector in the City

In analyzing the energy use of the economic sectors of the City of Rio de Janeiro in 2012, particularly high are electricity (30.45% of total consumption), kerosene (22%), diesel (16.9%) and gasoline (13.6%). In electricity generation, blast furnace gas (BFG) corresponds to 64.2% of all fuels used, in addition to natural gas (34.8%) and fossil fuel, with about 1% of the total. Since the city has a heavy electricity demand, particularly in the residential sector, which accounts for 33.5% of the total demand, the City of Rio de Janeiro imports approximately 84.3% of the electricity it consumes.

In regard to bunker fuels[3], fuel demand refers to jet kerosene, 92.6%, and, on a smaller scale, to diesel, 7.4%.

Also significant are ethanol and coke imports used in transports and industry, respectively, since within the City of Rio de Janeiro, there are no coal mines or sugar cane plantations. Thus, the emissions originating in the demands for these fuels by the city in scope 3 must be calculated: both the balance of emissions from the sugar cane cycle and the fugitive emissions from the mines of the imported coal.

1.2. Methodological Approach

GHG emissions in the City of Rio de Janeiro were calculated using the structure proposed by the IPCC-2006 Guidelines, as shown by Table 1, below.

[3] Fuels burned in airplanes and ships are called bunker fuels.

Table 1 – Simplified structure of the inventory of energy use and the data required to calculate the emissions in the City of Rio de Janeiro

Energy Use	Data used
1.A) Fuel used	
1.A.1) Energy Industry	
1.A.1.a) Electricity production and electricity distribution losses	Consumption and losses of electricity and fuels
1.A.1.b) Petroleum refining	Electricity and fuel consumption
1.A.1.c) Manufacture of solid fuels and other energy industries	Coal consumption
1.A.2) Industry (amounts aggregated for the entire sector)	Electricity and fuel consumption
1.A.3) Transports	
1.A.3.a) Civil aviation	Fuel consumption
1.A.3.b) Road transport	Fuel consumption
1.A.3.c) Rail transport	Electricity and fuel consumption
1.A.3.d) Navigation	Fuel consumption
1.A.4) Other sectors	
1.A.4.a) Commercial/services	Electricity and fuel consumption
1.A.4.b) Public	Electricity and fuel consumption
1.A.4.c) Residential	Electricity and fuel consumption
1.A.4.d) Farming	Electricity and fuel consumption
1.A.5) Fugitive Emissions	Total consumption of natural gas (in m^3), amount of refined petroleum (in thousand m^3/year) and the amount of imported coal (in tonnes)

Source: Authors, based on IPCC (2006)

The volume of fuel sales was, conservatively, admitted to be the same as the total consumption. Possible variations in stock were ignored as it is extremely difficult to obtain this type of information.

To make the calculation methods used in the Rio de Janeiro inventory in the bottom-up approach clearer, Table 2 below shows the methodologies employed in each sector:

Table 2 – Methodological tier for each activity – sector

Bottom-up Approach	Tier adopted
1.A.1) Energy industry	Tier 2 for CO_2 and tier 1 for CH_4 and N_2O
1.A.2) Manufacture and construction industry	Tier 2 for CO_2 and tier 1 for CH_4 and N_2O
1.A.3) Transports	Tier 2 for CO_2 and tier 1 for CH_4 and N_2O
1.A.4) Other sectors	Tier 2 for CO_2 and tier 1 for CH_4 and N_2O

Source: Authors

These levels of detailing were selected according to the information available. As a rule, to improve calculations it would be necessary to know details of the combustion technologies used – which would require more research at the energy consumption source.

One of the main methodological issues faced when carrying out municipal inventories is the delimitation of the scope of the socioeconomic activities that properly reflects the responsibility of the City of Rio de Janeiro with respect to greenhouse gas emissions. The socioeconomic limits of the city are the first criterion, that is, the emissions generated within its geographical boundaries. But this alone is not enough, since it does not include important emission sources induced by the city such as fugitive emissions from coal or ethanol demand. Thus, in order to evaluate and account for emissions that fall under the responsibility of Rio de Janeiro, the following steps were considered:

- According to IPCC (2006), GHG emissions from the use of fossil fuels to generate electricity should be included (category 1.A.1). However, the City of Rio de Janeiro is not self-sufficient in electricity and imports around 84% of its total consumption. Therefore, in addition to the GHG emissions from the burning of fossil fuels to generate electricity within the city, the emissions from the imported electricity are also included, which are calculated using the emission factor of the National Interconnected System grid, according to UNFCCC ACM 0002 methodology, which, in 2012, was 0.0653 t CO_2/MWh for the South, Southeast and Mid-West grid. Imported electricity emissions are accounted for in scope 2.
- As to ethanol consumption in the transport sector, since it is renewable, it has zero CO_2 emission, as the emissions arising from its use have been previously sequestered as carbon when the sugar cane was growing. This doesn't occur with CH_4, whose emissions have impacts on the climate and are included like the other fossil-based emissions. In this inventory, CO_2 emissions from this fuel are included because of their origin:
    - The City of Rio de Janeiro does not produce ethanol nor does it have sugar cane plantations within its borders, so there are neither emissions nor reductions related to this activity.
    - Imported ethanol: emission occurs in the city but not the sequestration. Therefore, emissions are counted in scope 1 and the sequestration in scope 3, and they are calculated using the average emission factor obtained from Macedo *et al* (2008). The emission

factor in Macedo *et al* (2008) considers: (1) emissions from the use of fossil energy (the fuels consumed or the electricity acquired, that is, the direct energy inputs); and (2) the emissions from other sources not reabsorbed by photosynthesis during the growth of sugar cane (non CO_2 gases from the burning of the straw, decomposition of fertilizers, etc.).

Emission factors come mostly from IPCC (2006), with the adaptations introduced in the Second National Inventory (BRASIL, 2010), and EPE (2013), as described previously, for both bottom-up and top-down calculations, with the exception of the ethanol emission factor in scope 3 and the emission factor for the imported electricity, used as described in the above paragraph (BRASIL, 2010).

Exceptionally, to calculate the emission factor for the electricity generated within the City of Rio de Janeiro, the emission factor for blast furnace gas (BFG) – used to generate part of the electricity in the city, was taken from an International Energy Agency publication (IEA, 2005).

To calculate the emission factor for the electricity generated inside the City of Rio de Janeiro, data from the existing energy supply mix of the city was used. In this case, data came from the only public utility, the Santa Cruz Thermopower Plant, and from two selected self-generators. These plants together generated 2,696 GWh (231.8 thousand tep) of electricity (19.8% corresponding to the public utility and 80.2% corresponding to the self-generators). This generation uses five fuels; the most significant being BFG (64.2%) and dry natural gas (34.8%). Using these fuels, in 2012, the emission factor for electricity generation was 14.0 Gg CO_2/thousand tep, 1.02 kg/TJ, for CH_4 and 1.0 kg/TJ, for N_2O.

In the City of Rio de Janeiro, electricity demand in 2012 was 1,475,600 tep, where 84.8% of this amount was imported, that is, electricity from the national grid. To calculate the energy emissions imported by the city, the average factor for the year from the National Interconnected System for inventories was used, obtained from MCTI (2013)[4]. For 2012, this figure was 0.0653 t CO_2/MWh. This value was converted to Gg CO_2/thousand tep (assuming that 1 tep = 11.63 MWh), resulting in 0.76 Gg CO_2/MWh.

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[4] *http://www.mct.gov.br/index.php/content/view/72764.html*

1.3. Anthropogenic GHG Emissions and Removals in the Year 2012

Below are the results for GHG emissions resulting from energy consumption. There are five sub-sectors, namely: Energy Industry, Industry, Transports, Other Sectors (Residential, Commercial/Services, Public and Farming) and Fugitive Emissions.

A special section is also included on the technical and non-technical losses associated to electricity distribution, merely for information.

1.3.1. Sectoral Emissions

Table 3 and Figure 2 show the emissions per gas and in CO_2e calculated for the City of Rio de Janeiro. It can be seen that the transport sector is the most significant, responsible for some 40% of the emission of the city's sub-sectors. Within this sector, road transports are the highest emitters.

Table 3 – Emissions of the energy use sub-sectors in the City of Rio de Janeiro in 2012 (Gg)

Sectors	CO_2	CH_4	N_2O	CO_2e
Energy sector consumption	**3,169.56**	**0.03**	**0.01**	**3,171.93**
Losses	2,084.36			2,084.40
Coke production	1,085.20	0.03	0.01	1,087.53
Residential	**1,888.15**	**0.01**		**1,889.65**
Commercial/services	**1,626.88**			**1,626.88**
Public sector	**562.33**			**562.80**
Farming	**0.68**			**0.68**
Transports	**6,600.82**	**1.13**	**0.42**	**6,753.77**
Road	4,847.65	1.13	0.37	4,985.51
Rail	93.05			93.05
Air	1,650.38		0.05	1,664.87
Water	10.34			10.34
Industry	**2,497.19**	**0.03**	**0.01**	**2,499.79**
Mineral extraction and processing	2.15			2.15
Non-metallic minerals	63.60			63.66
Metalworks	1,621.15	0.03	0.01	1,623.48
Paper and pulp	0.02			0.02
Chemicals	115.01			115.12
Textiles	0.78			0.78

Sectors	CO_2	CH_4	N_2O	CO_2e
Food products	19.55			19.55
Beverages	19.32			19.32
Other industries	39.61			39.61
Electricity*	616.00			616.00
Total	**13,176.05**	**1.17**	**0.43**	**13,333.57**

**It wasn't possible to break electricity emissions down by industry type.*

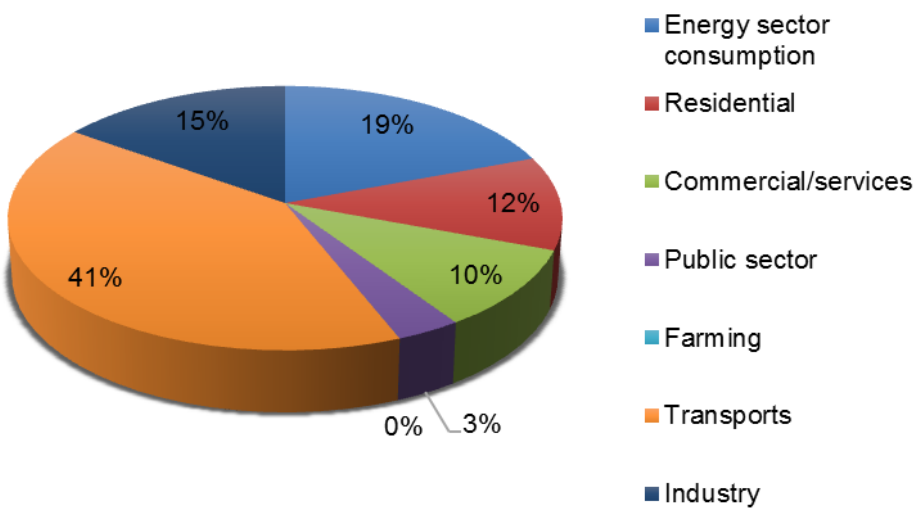


Figure 2 – Share of sub-sectors in total emissions of the energy use sector in the City of Rio de Janeiro in 2012

1.3.2. Electricity Distribution Losses

According to LIGHT, within the City of Rio de Janeiro there were 8,536 GWh of technical and non-technical losses arising from electricity distribution in 2012. These losses generated emissions to the sum of 2,084.40 Gg CO_2e (Table 4).

Table 4 – Emissions from electricity distribution losses per scope for each GHG – 2012 (Gg CO_2e)

	CO_2	CH_4	N_2O	CO_2e
Total	2,084.36	0.0001	0.0001	2,084.40

1.3.3. Fugitive Emissions

Based on the available data, the fugitive emissions included in this inventory include those related to the natural gas distribution network, emissions from the only refinery operating in the city and emissions from the imported coal consumed in the city. The fugitive emissions that occurred outside the city (scope 3) associated to the oil and natural gas production and refining chain to supply the demand for oil and gas products in the city could not be included due to lack of data.

Rio de Janeiro imports coal for use in its steel industry and the coal is acquired outside its boundaries. According to IPCC, coal mining also engenders fugitive emissions. Therefore, considering the principle of responsibility for emissions, fugitive emissions corresponding to the amount of coal acquired by the city were included and allocated to scope 3.

Table 5 – Fugitive emissions – 2012 (Gg CO_2e)

Fugitive emissions	CH_4	CO_2	N_2O	CO_2e
Refining	39.95	0.05		40.96
Coal	1,103.99			1,103.99
Gas distribution	0.11	13.90		291.96
Total	1,144.05	13.95		1,436.91

1.4. Bunker Fuels

IPCC recommends accounting for international bunker fuels consumption (international aviation and maritime transport) separately, merely for information purposes, since these amounts are not part of the national emissions. In accordance with this principle, in the City of Rio de Janeiro, none of the emissions calculations of fuels carried out up to now have included jet kerosene consumption in international flights or diesel for long haul international navigation, whose emissions are presented separately in this item (Table 6).

Table 6 – Bunker fuel emissions (Gg) per type of GHG per consumed fuel (in thousand tep) – City of Rio de Janeiro – 2012

Type of fuel	thousand tep	CO_2(Gg)	CH_4 (Gg)	N_2O (Gg)	Gg CO_2e
Jet kerosene	503.8	1,493.2	0.011	0.042	1,506.5
Marine diesel	40.6	124.6	0.001	0.003	125.6
Total	**544.4**	**1,617.7**	**0.011**	**0.046**	**1,632.1**

1.5. Consolidated Results for the Energy Sector

Table 7 summarizes the emissions resulting from the energy sector. The main consumer of the energy sector in the City of Rio de Janeiro is transport. The reasons for this are the predominance of road transport and the high degree of saturation of the city's roads. In addition to transports, the energy sector, particularly self-generator plants, have a significant share of the total sector emissions.

Table 7 – Total GHG emissions of the energy sector in the City of Rio de Janeiro by scopes – 2012 (Gg CO_2e)

Sectors	Scope 1	Scope 2	Scope 3	Total
Energy Sector Consumption	**2,702.10**	**469.83**		**3,171.93**
Distribution losses	1,614.57	469.83	–	2,084.40
Coke production	1,087.53	–	–	1,087.53
Residential	**1,574.94**	**314.71**	**–**	**1,889.65**
Commercial/services	**1,283.12**	**343.56**	**–**	**1,626.68**
Public sector	**439.43**	**123.36**	**–**	**562.80**
Farming	**0.54**	**0.14**	**–**	**0.68**
Transports – total	**7,049.54**	**20.09**	**–315.86**	**6,753.77**
Road	5,301.37	–	–315.86	4,985.51

Sectors	Scope 1	Scope 2	Scope 3	Total
Rail	72.96	20.09	–	93.05
Air	1,664.87	–	–	1,664.87
Water	10.34	–	–	10.34
Industry – Total	**2,361.05**	**138.74**		**2,499.79**
Mineral extraction and processing	2.15	–	–	2.15
Non-metallic minerals	63.66	–	–	63.66
Metalworks	1,623.48	–	–	1,623.48
Paper and pulp	0.02	–	–	0.02
Chemicals	115.12	–	–	115.12
Textiles	0.78	–	–	0.78
Food products	19.55	–	–	19.55
Beverages	19.32	–	–	19.32
Other industries	39.61	–	–	39.61
Electricity	*477.25*	*138.74*	–	*616.00*
Fugitive emissions – total	**1,254.42**	**0.00**	**182.49**	**1,436.91**
Refining	40.96	–	–	40.96
Coal	921.50	–	182.49	1103.99
Natural gas distribution	291.96	–	–	291.96
Total	**16,665.14**	**1,410.43**	**–133.37**	**17,942.41**
Bunker fuels	1,632.10	–	–	1,632.10
Total with bunker fuels	***18,297.14***	***1,410.43***	***–133.37***	***19,574.51***

Figure 3 shows the responsibility of the sectors in the final amount of GHG emissions. The main sector responsible for emissions, adding together all scopes and including bunker fuels, is transport, corresponding to 34.5% of total emissions, followed by energy sector consumption with 16.2% of total emissions, mostly due to electricity distribution losses. On the other side of the scale, the sectors with the smallest shares are farming, 0.003%, and the public sector, 2.88%. Fugitive emissions, with 7.34%, include fugitive emissions from refining, coal, both scope 1 and 3, and natural gas distribution.

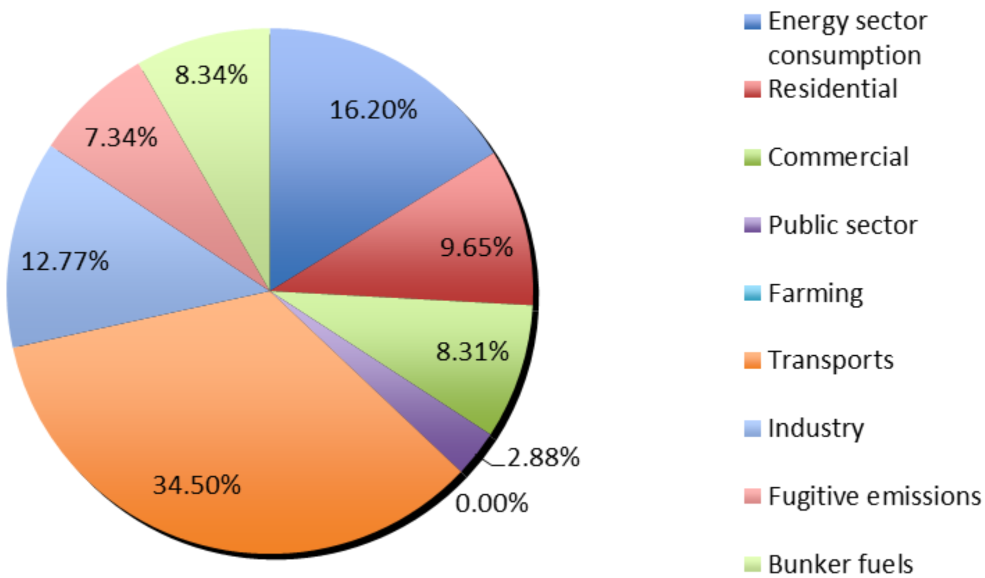


Figure 3 – Percentage of GHG emissions in Gg CO_2e by sub-sectors of the energy use sector in the City of Rio de Janeiro in 2012 (%)

With respect to emissions from the perspective of energy sources, the use of electricity has the greatest share, with 34.89%, followed by use of diesel, with 13.49% and gasoline, with 10.93% (Figure 4).

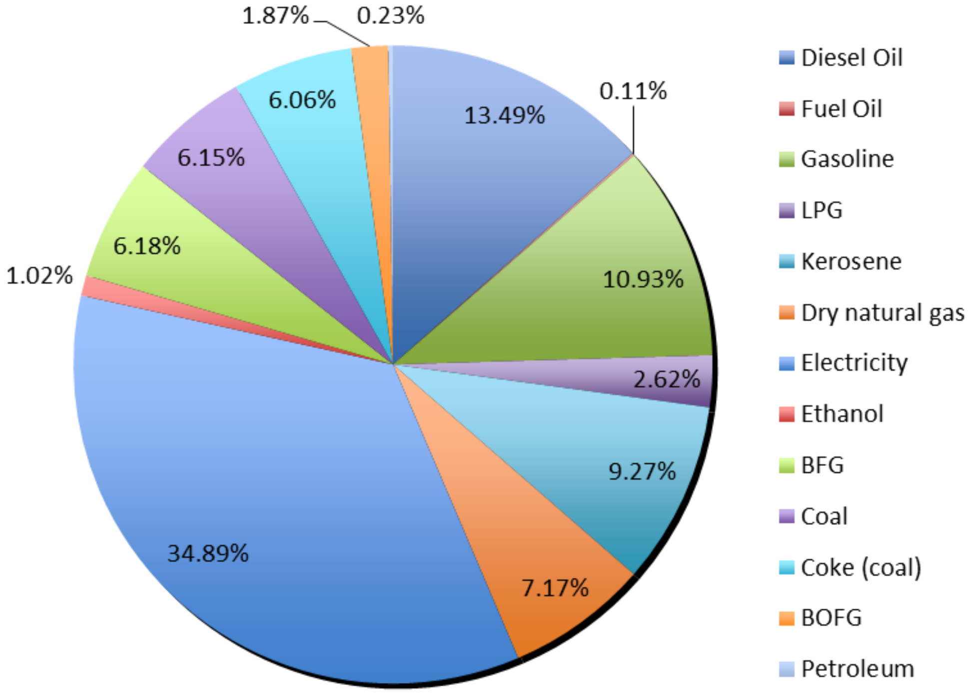


Figure 4 – Share of energy sources in total emissions in the City of Rio de Janeiro (%)

2. Industrial Processes and Product Use (IPPU)

2.1. Features of the Sector in the City

Among the industrial processes mentioned in the IPCC-2006 Guidelines, the following were identified for the City of Rio de Janeiro:

- Glass industry: according to FIRJAN and ABIVIDRO data, two glass manufacturers are established in the city.
- Methanol production: according to FIRJAN and ABIQUIM data, one company is installed in the city.
- Steel industry: according to FIRJAN and INSTITUTO AÇO BRASIL data, there were two steel mills operating in the city in 2012, one of them using integrated process – that is, the plant produces pig iron and steel, in addition to foundry coke. This integrated plant began production in 2010, with a reduced load, and in 2011 attained effective operational loads (still below maximum capacity).
- Lubricants – greases and oils – are used in practically all sectors of Rio's economy, from private passenger vehicles to industrial machinery. Emissions from their use are a result of their oxidation during their operating life.
- Paraffin, specially in the form of waxes, is used in various products, particularly as fuel in candles.
- Nitrous oxide (N_2O) is a direct greenhouse gas. According to IPCC, its uses include: medical purposes (anesthetic, analgesic, and veterinary); aerosol propellant, in the food industry; caustic and oxidizing agent, in semiconductor manufacture; oxidizing agent used with acetylene in atomic absorption spectrometry; in sodium azide (NaN_3) production; as fuel oxidizer in auto racing and specialized blowtorches. In the case of the City of Rio, medical uses and aerosol propellants are the largest emitter sources.

The city has a manufacturing plant for primary aluminum production, whose emissions in 2005 were calculated at 150.4 Gg CO2. According to information available at the ABAL (Brazilian Aluminum Association) website, the plant interrupted its operations in 2009, so there are no emissions in 2012.

Emissions associated to lime production occur during calcination, when CO_2 is released. The city has one industrial plant responsible for the production of hydrated lime. During data collection for preparing this inventory, when asked about the calcination process, the firm replied that this takes place in another unit of the industrial group, in another city. Therefore this inventory does not take into account emissions associated to lime production.

Below is an analysis of the GHG emissions arising from these activities for the City of Rio de Janeiro in the year 2012, according to type.

2.2. Methodological Approach

There are different processes for manufacturing glass. Normally, CO_2 is released in the melting stage, arising from the transformation of carbonates (with limestone, dolomite or soda ash). Accounting for the emissions from glass manufacture includes the fraction of recycled products (internally recovered or obtained in the market) added to production, since it reduces the need for carbonates at the melting stage.

Normally methanol is produced by reforming natural gas, with the production of "synthesis gas" – carbon dioxide (included in this inventory), carbon monoxide and hydrogen. The process also releases methane from leakages in equipment and pipes, in addition to the release ("venting") arising from incomplete combustion.

Steel production emits at different stages of production, from the primary conversion of the ore to the final refining stage, in which steel actually acquires its final properties. For methodological reasons, IPCC addresses greenhouse gas emissions in the following stages: foundry coke production; sinter production; pig iron production; steel production, Emissions during coke production, even in integrated steel mills, should be accounted for in the energy sector. The same procedure should be carried out for electricity generation, when carried out in a steel plant.

The data used to calculate product use emissions were supplied by ANP (National Petroleum, Natural Gas and Biofuels Agency) and refer to the sales in the city. Data are separated in only two categories. In this inventory, the volume of products sold in the city will be considered to be the volume actually used. In the case of nitrous oxide, data were obtained from N_2O suppliers in the city.

2.3. Anthropogenic GHG Emissions and Removals in the Year 2012

Total emission associated to glass manufacture is the sum of the emissions estimated for each industry, which is 4.35 Gg CO_2.

Total emission associated to methanol production was 4,637.6 t CO_2 / 0.1775 t CH_4 / 4,641 t CO_2e.

Total emissions for the steel sector in the City of Rio de Janeiro, for 2012, are summarized below:

Sinter production: 1,071.3 Gg CO_2

Pig iron production: 879.9 Gg CO_2

Steel production: 326.4 Gg CO_2

Total 2,277.6 Gg CO_2

Total emissions from the use of lubricants and greases were 29.1 Gg CO_2 in 2012. Emissions from the use of paraffin were 0.14 Gg CO_2.

N_2O emissions are considered to be the same as the amount sold, bearing in mind previous considerations on the emission factor. Although the formula presented by IPCC considers the annual average of the inventoried year and the previous year, because of the limitation of the available data, only the amounts of 2012 sales will be taken into account. Thus, emissions for 2012 are 127.4 t N_2O.

2.4. Consolidated Results

GHG emissions in the IPPU sector for 2012 are summed up in Table 8 and in Figure 5.

Table 8 – Results of GHG emissions for the IPPU sector in 2012

	CO_2 (Gg)	CH_4 (t)	N_2O (t)	CO_2 (Gg) 2012
Industrial processes	**2,286.59**	**0.18**	**0.00**	**2,286.59**
Glass production	4.35			4.35
Methanol production	4.64	0.18		4.64
Steel production:	2,277.60			2,277.60
Product Use	**29.24**		**127.40**	**68.73**
Lubricant use	29.10			29.10
Paraffin use	0.14			0.14
Nitrous oxide use			127.40	39.49
Total	**2,315.83**	**0.18**	**127.40**	**2,355.33**

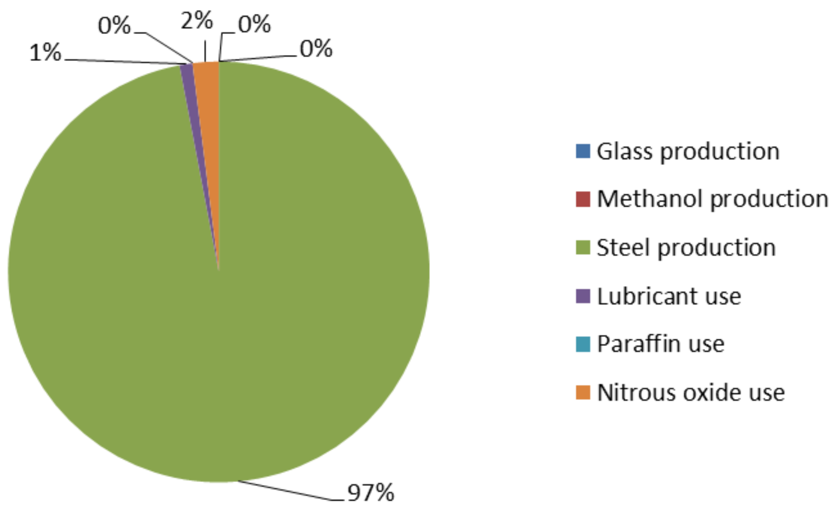


Figure 5 – Share of the industrial processes and product uses in the emissions total for the IPPU sector in 2012 (%)

All IPPU emissions are direct, that is, scope 1.

3. Agriculture, Forestry and Other Land Use (AFOLU)

3.1. Features of the Sector in the City

The Municipal Environment Secretariat (SMAC), using images from 2010, mapped the land use and cover in the City of Rio, dividing the city into three large classes of land use and occupation: Atlantic Forest Vegetation Areas; Urban and Anthropized Areas; and Other Classes. Table 9 shows the results of the mapping.

Table 9 – Classes of land use and cover in the City of Rio de Janeiro in 2010

	Surface (ha)
Atlantic Forest Vegetation Areas	
Montane Dense Ombrophilous Forest	882
Submontane Dense Ombrophilous Forest	347
Secondary Vegetation – Initial Stage	3,096
Secondary Vegetation – Intermediary Stage	6,117
Secondary Vegetation – Advanced Stage	16,500
Restinga (Sand bar)	1,959
Mangrove	3,399
Apicum (saltwater marsh)	1,323
Brejo (swamp)	1,666

Urban and Anthropized Areas	
Urban Area	53,117
Agriculture	5,249
Shrub-Arboreal Vegetation	8,662
Woody/Herbaceous Vegetation	13,593
Mining Areas	347
Exposed Land	68
Other Classes	
Rocky Outcropping	759
Continental Water Body	2,131
Beach	653
Reforestation	2,158

Source: adapted from SMAC, 2011. Available at: http://www.rio.rj.gov.br/web/smac/exibeconteudo?article-id=2367969

Farming activities in Rio de Janeiro are of little significance, mostly concentrated on the western side of the city. According to data from the State Agriculture Secretariat, the agricultural areas of the City of Rio de Janeiro have a total area of 2,570 hectares, mostly with annual crops. With respect to livestock, in 2011 there were a total of 74,500 animals, where 57,000 were poultry (chicken, quail, etc.), 6,800 heads of cattle and 2,600 swine (IBGE, 2013).

3.2. Methodological Approach

The main greenhouse gases associated to the AFOLU sector are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Carbon flows between the atmosphere and ecosystems are mostly controlled by absorption through plant photosynthesis and emission through respiration, decomposition and combustion of organic matter N_2O is mostly emitted by the ecosystem as a sub-product of nitrification and denitrification, while CH_4 is emitted from methanogenesis under anaerobic conditions in the ground, by manure management, enteric fermentation and during incomplete combustion when organic matter is burned.

In this sector, GHG emissions and removals are defined as those that occur in managed lands, that is, lands that undergo human intervention with practices that have social, ecological and production aims.

The AFOLU sector inventory was carried out using the IPCC methodology for preparing GHG emissions (IPCC, 2006), but was adapted to the conditions of the City of Rio de Janeiro and the available data.

In the case of farming activities, the origin of GHG emissions is the same as those determined by the IPCC. Only emissions from rice cultivation, burning biomass and wood products were not quantified in this inventory as they do not occur within the boundaries of the city.

3.3. Anthropogenic GHG Emissions and Removals in the Year 2012

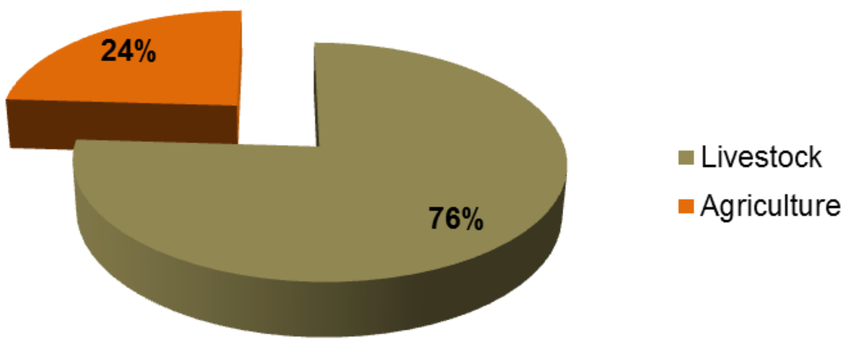
The AFOLU sector was responsible for the emission of 8,600 tonnes of CO_2e in the City of Rio de Janeiro in 2012. The main gas emitted was CO_2, followed by CH_4 and N_2O. A summary of the emission sources and respective amounts can be seen in Table 10, below.

Table 10 –GHG emissions in the AFOLU sector in City of Rio de Janeiro in 2012 (t CO_2e)

Land use and cover	Ent. Ferm.	Man. Mgt.		Fert. Use Nitrog.	Limestone use	Urea use	Total
(CO_2)	(CH_4)	(CH_4)	(dir. and indir. emissions N_2O)	(dir. and indir. emissions N_2O)	(CO_2)	(CO_2)	
t CO_2e							
-11,657.2	10,108.7	659.4	4,593.5	3,055.6	1,786.2	22.4	**8,568.5**

Source: Authors

According to the consolidated estimates, the emissions from enteric fermentation and manure management (animal husbandry) are the highest emitters in the AFOLU sector. The use of soil amendments is the second highest GHG emission source in the city (Figure 6).



Source: Authors

Figure 6– Share of sources in total AFOLU emissions in the City of Rio de Janeiro in 2012 (%)

As to change in land use and cover, the amount of carbon removals from reforestation and urban tree planting managed to offset 100% of total emissions from deforestation in the City of Rio de Janeiro in 2012, achieving negative emissions, that is, a net carbon removal from tree growth. This can be explained from the rates of deforestation, specially forest cover, associated to the increase of reforested areas for environmental restoration and urban tree planting (along streets and squares).

4. Wastes

4.1. Features of the Sector in the City

In the City of Rio de Janeiro, urban sanitation falls under the responsibility of Comlurb (Rio de Janeiro Urban Cleaning Company), subordinated to the Environment Secretariat, which, in addition to cleaning streets, manages and carries out the collection, transport, treatment and final disposal of solid wastes. Class II-A industrial wastes are collected by outsourced companies and sent to waste transfer stations (WTS), managed by Comlurb, for later disposal in landfills. Since industrial wastes go through WTS, Comlurb has the statistical data relating to their production in the city. By the end of 2012, the biogas produced in treatment processes was only captured and burned in flares in some landfills, and was not used for energy purposes.

CEDAE-RJ (State Water and Sewage Company) is the company responsible for collection and treatment of domestic and commercial sewage in the City of Rio de Janeiro and covers, approximately, 80% of the population. The company provides water supply services (capture, delivery, treatment and distribution) and sanitary sewage services (collection, transport, treatment and final disposal). Of all the sewage collected and treated in sewage treatment stations (STS), only 2.3% falls under the responsibility of Foz Águas 5. The remainder is collected and treated by CEDAE.

According to information from CEDAE, from Foz Águas 5 – responsible for sanitation of the western part of the city – and from the National Household Sample Survey (IBGE, 2012), there are 5,089,239 persons with access to some kind of sanitation infrastructure in the City of Rio de Janeiro, out of a total population of 6,390,290. No information was found on the number of persons or households using septic tanks. According to CEDAE, the collected sewage that currently undergoes treatment is not treated with anaerobic systems, only the resulting sludge goes through this treatment system, before being sent on to landfills. According to the latest IBGE National Survey of Sampled Households – PNAD, 2011, the metropolitan region of Rio de Janeiro treats 70.6% of sewage in STS. Of the remaining 19.4%, 6.5% do not undergo any kind of treatment, that is, are it is thrown in water bodies *in natura*, while the rest is treated in septic tanks.

As to the sludge produced during treatment, the City of Rio de Janeiro sends part of the sludge to landfills.

4.2. Methodological Approach

The methodology adopted for calculations was based on the 2006 IPCC Guidelines. According to these guidelines, the half-lives of different types of residues vary from a few years to several decades. The First Order Decay method, FOD, requires that data from garbage dumps are collected or historically estimated for a period greater than 3 – 5 half-lives, in order to obtain accurate and acceptable results. That means that the GHG emission data for a particular year must be the sum of the influences of the methane emissions curves for the 50 preceding years. If a smaller time period is chosen, these data should demonstrate that they are not underestimated. Since no data series on waste generation and their disposal sites exists for the City of Rio de Janeiro that is consistent and covers such a period, a 30-year period was used, which reduces the risks of underestimating emissions to an acceptable range . At the last inventory, for the year 2005, data on waste disposal was obtained for the period 1975 to 2004. For this inventory, the period used in the last inventory was used together with the data for the 2005-2011 period, for landfills (both for USW and ISW) and for 2012 for thermal and biological treatments.

For emission factors and other parameters used in the methodology, default values for Brazil were used, obtained from the National Communications to the Climate Convention. In the absence of this information, default values from the IPCC Guidelines were used.

Sewage or liquid effluents are a source of CH_4 emissions when treated or anaerobically disposed of. They can also be sources of N_2O emissions, when this gas is produced by the decomposition of nitrogenated compounds present in the effluents discharged in water bodies. Although CO_2 emissions exist, they are not calculated because they are biogenic in origin, according to the same rationale used for the solid wastes emissions.

Both sewage treatment and sludge produced under anaerobic conditions result in methane production. The amount of gas produced depends on the characteristics of the sewage/effluent and of the temperature and type of treatment employed. The decisive factor in methane generation is the amount of degradable organic matter found, which is measured by the biochemical oxygen demand (BOD) and the chemical oxygen demand (COD). The larger the BOD or COD, the larger the methane production. With respect to the temperature, methane production increases proportionally to its increase, particularly in warm climates and in systems without appropriate control of this parameter.

Nitrous oxide is associated to the degradation of the nitrogenated compounds present in the sewage/effluent (urea, nitrate and proteins) and to the treatment processes, particularly tertiary systems, which are capable of removing these nitrogenated compounds. Direct N_2O emissions are generated in the nitrification process (aerobic process that converts ammonia and other nitrogenated compounds into nitrate – NO_3) as well as in the denitrification process (anaerobic process in which nitrate is converted into gaseous nitrogen – N_2), since they are intermediate products in both processes. N_2O emissions can occur both in treatment plants as well as in the water body that receives this sewage/effluent.

4.3. Anthropogenic GHG Emissions and Removals in the Year 2012

Applying the methodology to the various types of waste treatment, as detailed in previous items, we obtained the net methane and nitrous oxide emissions of each destination, in t CO_2, t Ch_4, t N_2O and Gg CO_2e. Results are presented in Table 11.

Table 11 – Net GHG emissions from solid wastes and liquid effluents in the City of Rio de Janeiro in 2012

Final Disposal	Carbon Dioxide Emissions (tCO_2)	Total methane emissions	Net methane emissions	Nitrous oxide emissions (t N_2O)	Net emissions (Gg CO_2e)
		(t CH_4)	(t CH_4)		
Solid Wastes	**443.40**	**92,439.14**	**81,226.11**	**1.24**	**1,706.58**
Urban Solid Wastes		89,656.57	78,443.54	1.24	1,647.70
Controlled Landfill		81,337.93	70,513.22		1,480.78
Sanitary Landfill		8,302.11	7,913.79		166.19
Composting		16.53	16.53	1.24	0.73
Healthcare Wastes		301.62	301.62		6.33

Final Disposal	Carbon Dioxide Emissions (tCO_2)	Total methane emissions	Net methane emissions	Nitrous oxide emissions (t N_2O)	Net emissions (Gg CO_2e)
		(t CH_4)	(t CH_4)		
Incineration	443.40				0.44
Industrial Wastes		2,480.95	2,480.95		52.10
Sewage and Effluents		**25,498.80**	**24,933.30**	**324.70**	**624.26**
Res + Com Sewage		21,635.40	21,069.90	272.60	526.97
STS		15,453.70	14,888.20	217.10	379.95
Septic Tank		5,803.80	5,803.80	41.90	134.87
Released *in natura*		377.90	377.90	13.60	12.15
Industrial Effluents		3,863.40	3,863.40	52.10	97.28
TOTAL WASTES	**443.40**	**117,937.94**	**106,159.41**	**325.94**	**2,330.83**

Source: Authors

The above table represents net emissions, since it includes methane capture. Taking into account the specific weight of methane, 0.716 kg/m³, the mass of recovered and burnt methane was 388,328.3 kg in Seropédica and 11,196,760.7 kg in Gramacho, making up a total of 11,600 tonnes of methane in 2012. In the Alegria STS, 565.5 tonnes of CH_4 (12 Gg CO_2e) were recovered.

Consolidating all results, the wastes sector was responsible for more than 2.5 million tonnes of CO_2 equivalent in 2012. The main gas emitted was CH_4, followed by N_2O and lastly by CO_2. The summary of emissions per source and scope is shown in Table 12.

Table 12 – Net emissions per source in the waste sector in the City of Rio de Janeiro in 2012 (Gg CO_2e)

Source	Emissions		
	Scope 1	Scope 3	Sum (1 + 3)
Sanitary Landfill	–	166.19	166.19
Controlled Landfill	463.00	1,017.80	1,480.80
Composting	0.73	–	0.73
Incineration	0.44	–	0.44
Industrial Wastes	–	52.10	52.10
Healthcare Services	–	6.33	6.33
Solid Wastes	**464.17**	**1,242.42**	**1,706.60**
Res + Com Sewage	526.97	–	526.97
Industrial Effluents	97.28	–	97.28
Effluents	**624.26**	**0.00**	**624.26**
TOTAL	**1,088.43**	**1,242.42**	**2,330.85**

Source: Authors

In the case of the solid wastes sub-sector, there are no scope 2 emissions. Thermal and biological treatment both fall under scope 1. The landfill, however, has scope 3 emissions, since the Gramacho, Seropédica and Nova Iguaçu landfills are situated outside the boundaries of the City of Rio de Janeiro.

It is obvious that landfills, be they controlled or sanitary, are the largest source of greenhouse gas emissions in the waste sector, responsible for about 70% of emissions, followed by treatment of domestic and commercial sewage (STS and septic tanks). Since the considered industrial solid wastes correspond to the share of class II-A that goes to landfills, other types of waste treatments – incineration, composting and thermal – together do not even add up to 1% of total emissions. This shows how much the sector has to evolve in terms of waste treatment technologies, not only to increase the recovery of biogas for burning or the use of methane, but also to expand energy generation plants and use of methane for vehicular purposes.

5. Consolidated Analysis of Results

5.1. Consolidated Results of City of Rio de Janeiro Emissions in 2012

Table 13, below, shows the total amounts obtained in the Greenhouse Gas Emissions Inventory of the City of Rio de Janeiro. The amounts are tabled per emission source and per gas, and the total amount is in carbon dioxide equivalent.

Table 13 – Total emissions for the City of Rio de Janeiro, in 2012, per GHG (Gg)

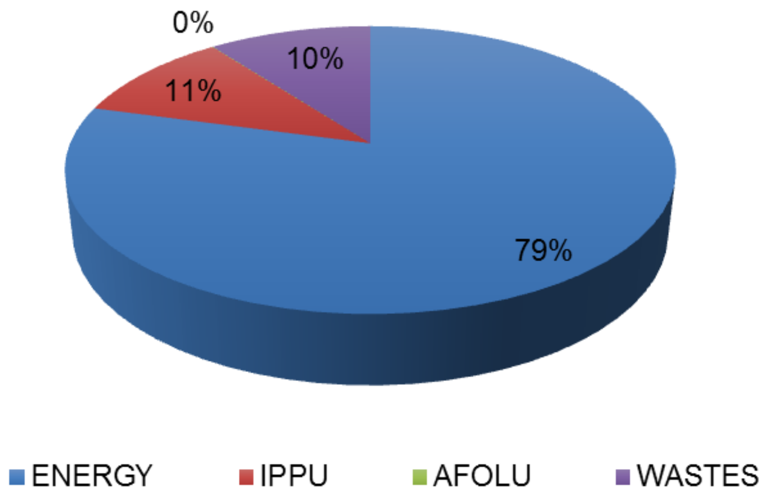
Gg	CO_2	CH_4	N_2O	CO_2e
ENERGY	17,489.66	15.15	0.44	17,942.41
Energy sector consumption	3,169.56	0.03	0.01	3,171.93
Losses	2,084.36	0.00	0.00	2,084.40
Coke production	1,085.20	0.03	0.01	1,087.53
Residential	**1,888.15**	**0.01**		**1,889.65**
Commercial/services	**1,626.88**			**1,626.88**
Public sector	**562.33**			**562.80**
Farming	**0.68**			**0.68**
Transports	**6,600.82**	**1.13**	**0.42**	**6,753.77**
Road	4,847.65	1.13	0.37	4,985.51
Rail	93.05			93.05
Air	1,650.38		0.05	1,664.87
Water	10.34			10.34
Industry	**2,497.19**	**0.03**	**0.01**	**2,499.79**
Mineral extraction and processing	2.15			2.15
Non-metallic minerals	63.60			63.66
Metalworks	1,621.15	0.03	0.01	1,623.48
Paper and pulp	0.02			0.02
Chemicals	115.01			115.12
Textiles	0.78			0.78
Food products	19.55			19.55
Beverages	19.32			19.32
Other industries	39.61			39.61
Electricity*	616.00			616.00
Fugitive emissions	**1,144.05**	**13.95**		**1,436.91**
Refining	39.95	0.05		40.96
Coal	1,103.99			1,103.99
Natural gas distribution	0.11	13.90		291.96

Gg	CO_2	CH_4	N_2O	CO_2e
IPPU	2,315.83	0.00	0.13	2,355.33
Industrial processes	**2,286.59**	**0.00**		**2,286.59**
Glass production	4.35			4.35
Methanol production	4.64	0.00		4.64
Steel production:	2,277.60			2,277.60
Product Use	**29.24**		**0.13**	**68.74**
Lubricant use	29.10			29.10
Paraffin use	0.14			0.14
Nitrous oxide use			0.13	39.49
AFOLU	**-9.85**	**0.51**	**0.02**	**8.57**
Land Use Change	**-11.66**			**-11.66**
Livestock		**0.48**		**10.11**
Enteric Fermentation		0.48		10.11
Agriculture	**1.81**	**0.03**	**0.02**	**10.12**
Manure Management		0.03	0.01	5.25
Soil amendments	1.81		0.01	4.86
WASTES	**0.44**	**106.16**	**0.33**	**2,330.83**
Solid Wastes	**0.44**	**81.23**	**0.00**	**1,706.58**
Urban Solid Wastes		78.44	0.00	1,647.70
Controlled Landfill		70.51		1,480.78
Sanitary Landfill		7.91		166.19
Composting		0.02	0.00	0.73
Healthcare Wastes		0.30		6.33
Incineration	0.44			0.44
Industrial Wastes		2.48		52.10
Sewage and Effluents		**24.93**	**0.32**	**624.26**
Res + Com Sewage		21.07	0.27	526.97
Industrial Effluents		3.86	0.05	97.28
TOTAL	**19,796.09**	**121.82**	**0.92**	**22,637.14**
Jet kerosene	1,493.20	0.01	0.04	1,506.50
Marine diesel	124.60	0.00	0.00	125.60
Bunker fuels	**1,617.70**	**0.01**	**0.05**	**1,632.10**
TOTAL with bunker fuels	**21,413.79**	**121.83**	**0.96**	**24,269.24**

Note: zeros mean marginal values. Inaccuracies are due to rounding.

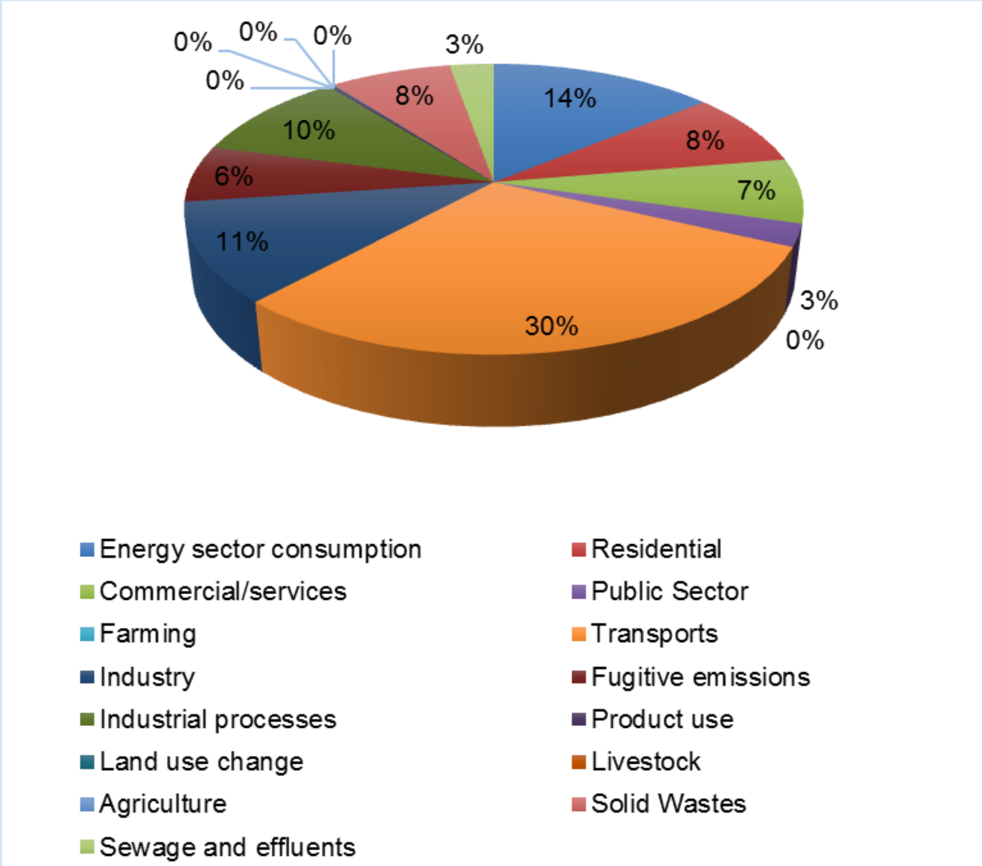
**When calculating industrial energy consumption emissions, it was not possible to break down electricity into industrial types, so its amount is presented on a separate line.*

Figure 7 and Figure 8 show the percentage sector shares in the total emissions in the City of Rio de Janeiro. The energy sector is clearly still the most significant sector, responsible for 79% of emissions. Taking a more detailed view of the sectors, transport is the highest emitter, corresponding to 30% of all emissions, followed by the energy sector (14%) and industrial energy consumption (11%).



Source: Authors

Figure **7** – Share of major sectors in total GHG emissions in the City of Rio de Janeiro in 2012 (%)



Other sectors – use of energy in farming, use of industrial products, land use changes and farming activities – together make up less than 1% of emissions.

Source: Authors

Figure 8 – Share of sub-sectors in total GHG emissions in the City of Rio de Janeiro in 2012

GHG Emissions from TKCSA

Steel mills, specially integrated mills, are energy-intensive industries and also large consumers of carbonaceous materials as reducing agents. Redox transformation of iron ore into metallic iron is carried out through physicochemical processes that necessarily release CO_2. Given the nature of the undertaking and the low industrialization of the city, an increase in the city's GHG emissions was expected when the ThyssenKrupp Companhia Siderúrgica do Atlântico (TKCSA) began operations.

A significant share of TKCSA carbon emissions is associated to power generation in its thermopower plant, reusing the energy content of the residual gas generated in blast furnaces. The use of blast furnace gases, together with the recovery and use of the coking steam, allow TKCSA to be completely self-sufficient in electricity and it even exports the surplus to other industries located in its complex and to the National Interconnected System (NIS). The energy made available to the NIS is enough to supply about two million households. In the 2012 TKCSA inventory, emissions related to the sale of electricity to third parties represented some 2.2 million tonnes CO_2e.

In addition to making use internally of co-products, TKCSA also sends carbonaceous and non-carbonaceous wastes to third parties, who use them as raw materials. This avoids direct emissions by these third parties – which, in corporate inventories can be considered emissions abatement. A case in point is the shipment of TKCSA blast furnace slag to a cement industry located within the steel complex, to be used for replacing clinker, which, in 2012, avoided the emissions of 516,000 tonnes CO_2e (according to TKCSA estimates, using World Steel Association methodology).

Because of its characteristics, TKCSA has the most modern energy recovery and reuse technology, making it the integrated steel mill generating the least GHG per tonne of produced steel. At the same time, the company also has a reforestation project in a 264-hectare area of the State Park of Pedra Branca, to partially offset its GHG emissions. This reforestation corresponds to more than double the amount carried out in the Tijuca Forest in the 19th century.

In the GHG emissions inventory of the City of Rio de Janeiro, the GHG emissions from TKCSA were accounted for as follows:

- Coke production emissions (from metallurgical coal) and electricity generation emissions were allocated to the energy sector (energy transformation centers), according to IPCC guidelines.
- Emissions from the production of sinter, pig iron and steel production, in blast furnaces and steelworks, were allocated to the industrial processes sector and to energy consumption (burning of fossil fuels) of the metal industry.

Carbon sequestration of reforestation promoted by TKCSA is included in the calculations of AFOLU emissions, as per IPCC guidelines: negative emissions from reforestation are subtracted from the positive emissions arising from deforestation and other land use changes.

GHG emissions avoided by the other aforementioned measures do not appear directly in the city's inventory because of the difference in methodology for calculating emissions of a city and those for corporate inventories. Nevertheless, they contributed to reducing the GHG emissions from cement and steel manufacture, since processes that emit more would be used to meet market demand.

Gross TKCSA GHG emissions in 2012 were 8.8 Mt CO_2e at the mill site (scope1), while net emissions, obtained from the difference between gross and avoided emissions, were estimated at 6.3 million tonnes CO_2e, for production of 3.5 tonnes of crude steel (total net steel produced), in the corporate inventory submitted by TKCSA to INEA.

5.2. Emissions by Scopes

In regard to scopes, the emissions of the City of Rio de Janeiro can be classified according to Table 14 below. Scope 2 emissions correspond to the electricity imported from the grid (National Interconnected System). Scope 3 emissions correspond to the balance of emissions from the ethanol production chain; the fugitive emissions of the coal consumed by the city, but which is mined outside its borders; and the wastes generated by the city, but taken for disposal in landfills outside its borders.

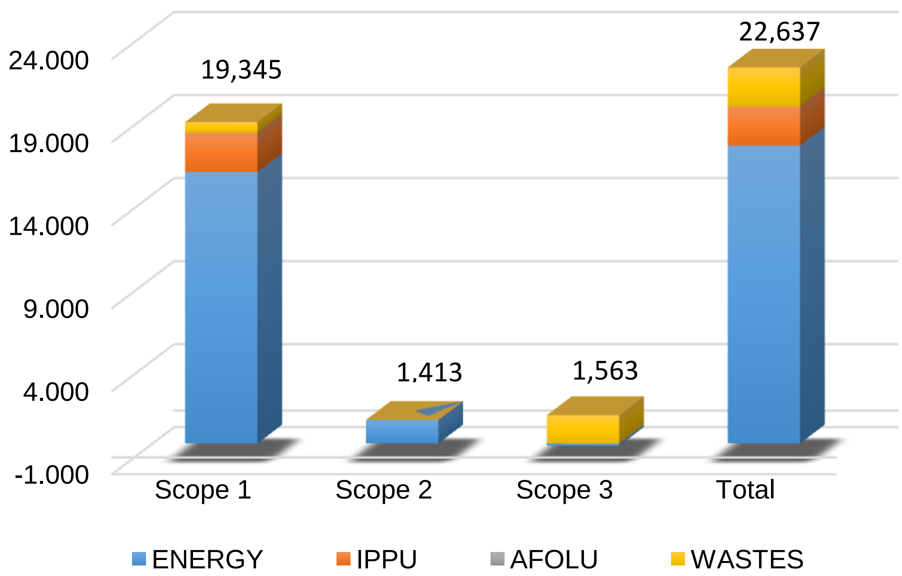
Table 14 – Total GHG emissions in the City of Rio de Janeiro, in 2012, by scope (Gg CO_2e)

	Scope 1	Scope 2	Scope 3	Total
ENERGY	16,346.49	1,413.43	-133.37	17,942.41
Energy sector consumption	**2,702.10**	**469.83**		**3,171.93**
Losses	1,614.57	469.83		2,084.40
Coke production	1,087.53			1,087.53
Residential	**1,574.94**	**314.71**		**1,889.65**
Commercial/services	**1,283.32**	**343.56**		**1,626.88**
Public sector	**436.44**	**126.36**		**562.80**
Farming	**0.54**	**0.14**		**0.68**
Transports	**6,733.68**	**20.09**	**-315.86**	**6,753.77**
Road	5,301.37		-315.86	4,985.51
Rail	72.96	20.09		93.05
Air	1,664.87			1,664.87
Water	10.34			10.34
Industry	**2,361.05**	**138.74**		**2,499.79**
Fugitive emissions	**1,254.42**		**182.49**	**1,436.91**
IPPU	2,355.33	0.00	0.00	2,355.33
Industrial processes	**2,286.59**			**2,286.59**
Product Use	**68.74**			**68.74**
AFOLU	8.57	0.00	0.00	8.57
Land Use Change	**-11.66**			**-11.66**
Livestock	**10.11**			**10.11**
Agriculture	**10.12**			**10.12**
WASTES	634.42	0.00	1,696.41	2,330.83
Solid Wastes	**10.17**		**1,696.41**	**1,706.58**
Urban Solid Wastes	**9.72**		**1,637.98**	**1,647.70**
Healthcare Wastes			**6.33**	**6.33**
Incineration	**0.44**			**0.44**

	Scope 1	Scope 2	Scope 3	Total
Industrial Wastes			52.10	52.10
Sewage and Effluents	624.26			624.26
Res + Com Sewage	526.97			526.97
Industrial Effluents	97.28			97.28
TOTAL	19,344.81	1,413.43	1,563.04	22,637.14

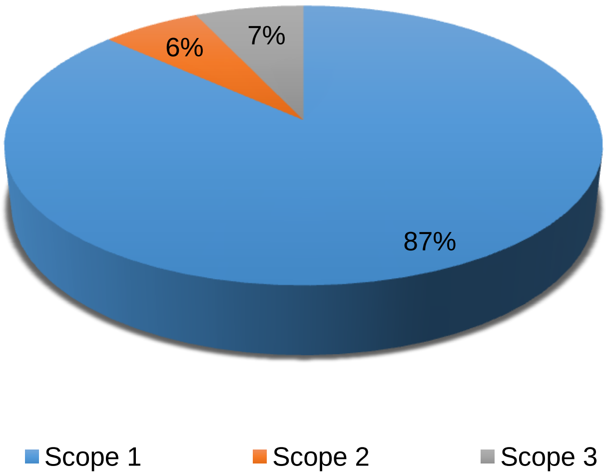
Source: Authors

Figure 9 and Figure 10 show that most of the emissions in the City of Rio de Janeiro are direct emissions, that is, scope 1 emissions. Scope 2 includes indirect emissions from importing grid electricity. Most significant in scope 3 is the wastes sector, since the city sends most of its solid wastes to be treated in landfills situated in other municipalities.



Source: Authors

Figure 9 – GHG emissions in the City of Rio de Janeiro, in 2012, by scopes (Gg CO_2e)



Source: Authors

Figure 10 – Distribution of emissions in scopes

5.3. Comparison to Baseline Year (2005)

As mentioned in the discussions on each sector, it was possible to revise and update the 2005 data for some sectors through more reliable new data or by methodological changes Table 15 below shows the 2005 amounts, original and revised, and the current results of the 2012 inventory. Variations refer to the increase in 2012 with respect to the revised 2005 amounts.

Table 15 – Comparison of GHG emissions for 2005 and 2012 (Gg CO_2e)

	2005	2005–rev	%	2012	%	Variation 2012/2005
ENERGY	**8,348.90**	**8,755.68**	**75%**	**17,942.41**	**79%**	**105%**
Energy sector consumption		214.90	2%	3,171.93	14%	1376%
Distribution losses		214.90	2%	2,084.40	9%	870%
Coke production*			–	1,087.53	5%	–
Residential	795.60	795.60	7%	1,889.65	8%	138%
Commercial/services	319.20	319.20	3%	1,626.88	7%	410%
Public sectors and others (farming)	210.90	210.90	2%	563.48	2%	167%
Transports	5,478.20	5,478.20	47%	6,753.77	30%	23%
Industry	1,416.40	1,416.40	12%	2,499.79	11%	76%
Fugitive emissions – total	128.60	320.48	3%	1,436.91	6%	348%
Imported coal*		–	–	1,103.99	5%	–
Natural gas	53.60	295.01	3%	291.96	1%	–1%
Refining emissions	75.00	25.47	0%	40.96	0%	61%
IPPU	**409.79**	**409.79**	**4%**	**2,355.32**	**10%**	**475%**
Industrial processes	393.02	393.02	3%	2,286.59	10%	482%
Glass production	13.87	13.87	0%	4.35	0%	–69%
Methanol production	98.15	98.15	1%	4.64	0%	–95%
Steel production:	130.60	130.60	1%	2,277.60	10%	1644%
Aluminum production+	150.40	150.40	1%	–	–	–
Product Use	16.77	16.77	0%	68.73	0%	310%
Lubricant use	16.70	16.70	0%	29.10	0%	74%
Paraffin use	0.07	0.07	0%	0.14	0%	100%

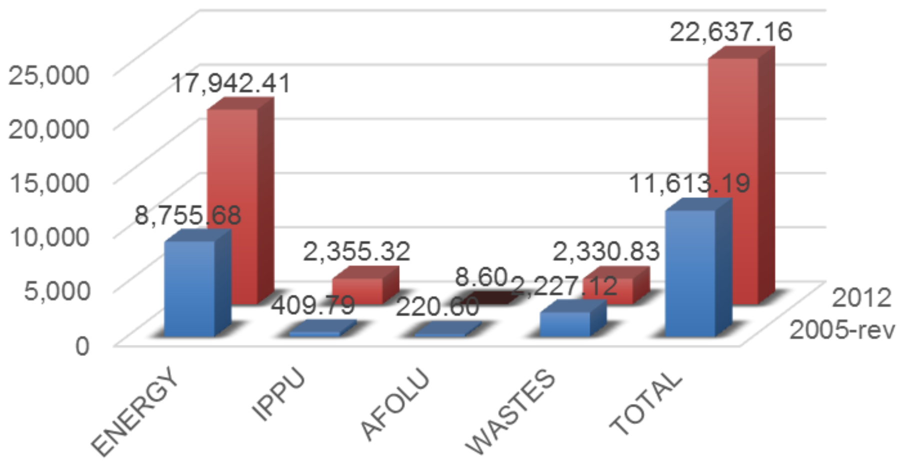
	2005	2005–rev	%	2012	%	Variation 2012/2005
Nitrous oxide use#	–	–	–	39.49	0%	–
AFOLU	**220.60**	**220.60**	**2%**	**8.60**	**0%**	**–96%**
Land Use Change	203.40	203.40	2%	-11.70	0%	–106%
Deforestation	254.90	254.90	2%	24.70	0%	–90%
Reforestation	-51.50	-51.50	0%	-36.40	0%	–29%
Livestock	10.80	10.80	0%	10.10	0%	–6%
Enteric Fermentation	10.80	10.80	0%	10.10	0%	–6%
Agriculture	6.40	6.40	0%	10.20	0%	59%
Manure Management	3.90	3.90	0%	5.30	0%	36%
Soil amendments	2.50	2.50	0%	4.90	0%	96%
WASTES	**2,372.50**	**2,227.12**	**19%**	**2,330.83**	**10%**	**5%**
Solid wastes	1,604.60	1,604.60	14%	1,706.58	8%	6%
Urban wastes	1,580.30	1,580.30	14%	1,654.48	7%	5%
Industrial wastes	24.30	24.30	0%	52.10	0%	114%
Effluents	767.90	622.52	5%	624.26	3%	0%
Domestic sewage	659.10	536.60	5%	526.97	2%	–2%
Industrial effluents	108.80	85.92	1%	97.28	0%	13%
TOTAL	**11,351.79**	**11,613.19**	**100%**	**22,637.16**	**100%**	**95%**
Bunker fuels	531.10	531.10	4%	1,632.10	7%	207%
TOTAL with bunker fuels	**11,882.89**	**12,144.29**	**100%**	**24,269.26**	**100%**	**100%**

** This activity was not available in the city in 2005.*

+ This activity no longer exists in the city.

 # It wasn't possible to obtain data to recalculate the year 2005 data.

Figure 11 shows how the major sector emissions varied in the analyzed years. Energy use is the main cause of the increase in emissions. This is due to: GDP growth; increased use of thermopowers for electricity generation; increased gasoline consumption due to price subsidies; and growth in the number of private cars; in addition to the crisis in ethanol production. Industrial processes and use of energy in industry also led to a significant increase in emissions due to the installation of a large-scale steel mill in the city. On the other hand, land use (AFOLU) saw expressive emissions reductions thanks to deforestation reduction efforts and the City Government's reforestation program.



Source: Authors

Figure 11 – Comparison of 2005 recalculated emissions and 2012 results (Gg CO_2e)

5.4. Analysis of Indicators

With respect to the carbon content of the GDP of the City of Rio de Janeiro, there is an increase in this indicator, as in the emission per capita, as shown by Table 16. But, as the population of the city did not grow significantly, the emission per capita almost doubled. However, the economic growth of the city from 2005 to 2012 occurred in activities that are more intense in their use of energy and their GHG emissions. The intensity of emissions per GDP unit increased by 34% in the period.

Table 16 – GHG emissions, GDP and population of the City of Rio de Janeiro, 2005 and 2012

	2005	2012	2012/2005 Increase (%)
Total emissions (million tonnes CO_2e)	11.61	22.64	95%
GDP (billion Reals at 2012 prices)*	167.00	242.50	45%
Population (million inhabitants)	6.10	6.32	4%
Total emissions/GDP (t CO_2e/million 2012 Reals)	69.54	93.35	34%
Total emissions per capita (t CO_2e/inhabitant)	1.90	3.58	88%

Source: Authors, with GDP and population data from IPP (2013).
Amount estimated from the 2010 amount.

6. Uncertainty Assessment

All inventories include a degree of uncertainty since they deal with estimates and not measurements. Thus, the amounts found for the City of Rio de Janeiro emissions are subject to uncertainties, be they from inaccuracy of basic data or from emission factors.

The very analysis of the inaccuracy of the estimates is not very objective since to make it precise, it would be necessary to have very detailed analyses of each studied item to remove all uncertainties. This is not feasible in the short term, nor is it relevant for all the analyzed items in so far as the inventory is a planning instrument that aims to identify the economic activities that warrant a more detailed study.

For this purpose, the uncertainties associated to each figure are merely an indication of where there is an opportunity to invest in databases and more knowledge of the processes that give rise to GHG emissions and carbon dioxide removals.

Table 17 – Assessment of uncertainties in the estimates of GHG emissions inventory for the City of Rio de Janeiro, in 2012

Sectors	CO_2	CH_4	Gg N_2O
ENERGY			
Energy sector	Average	Average	Average
Residential	Low	Average	–
Commercial	Low	–	–
Public sector	Low	–	–
Farming	Low	–	–
Transportation			
Road	Low	Average	Average
Rail	Low	–	–
Air	Low	–	Average
Water	Low	–	–
Industry			
Mineral extraction and processing	Low	–	–
Non-metallic minerals	Low	–	–
Metalworks	Low	Average	Average
Paper and pulp	Low	–	–
Chemicals	Low	–	–
Textiles	Low	–	–
Food products	Low	–	–
Beverages	Low	–	–
Other industries	Low	–	–
Fugitive emissions	High	High	–
IPPU			
Glass production	Low	–	–
Methanol production	High	High	–
Steel production:	High	–	–
Lubricant use	Low	–	–
Paraffin use	Low	–	–
Nitrous oxide use	–	–	High
AFOLU			
Use of land	High	–	–
Farming	Average	Average	Average
WASTES			
Urban solid wastes	–	Average	–
Composting	–	High	High
Incineration	High	–	High
Effluents	–	High	High
Bunker fuels (not included in total)	Average	High	High

Source: Authors

Update of the Plan of Action for Emissions Reduction of the City of Rio de Janeiro

1. Introduction

Since the beginning of the current administration, the Government of the City of Rio de Janeiro decided that the preparation of a Municipal Climate Change Plan was one of its priorities, in order to insert the issue of global warming in its planning, and to put forward and coordinate various actions and measures, already under analysis, that had the potential to reduce greenhouse gas emissions.

In this regard, in 2010, the Municipal Environment Secretariat, through its Climate Change Office, promoted the updating of the 2005 Emissions Inventory of the City of Rio de Janeiro to find out the level of emissions in the City and their main sources. Alongside this study, a study of GHG Emissions Scenarios was prepared to identify and quantify the reduction potential of the actions planned by the City Government, in addition to others that could be implemented, as well as a Plan of Action that included the measures that the City Government must undertake to achieve the greenhouse gas emissions reduction targets.

This study aims to estimate if the City of Rio de Janeiro achieved the emissions reductions projected at that time for 2012 and to update estimates for the years 2016, 2020 and 2025.

2. Energy

In the urban context of the City of Rio de Janeiro, the energy sector is the one responsible for most GHG emissions, as the 2012 inventory shows. Among the sub-sectors that represent energy emissions, particularly relevant are transports. Also noteworthy are industrial, commercial and residential use, specially because of fossil fuel-based electricity consumption.

Stationary sources

The 2009-2012 Strategic Plan (RIO DE JANEIRO, 2011) provided for two strategic initiatives that have impacts on these sources: the *Choque de Ordem de Conservação*, which, among other things, promoted conservation measures for public lighting; and the implementation of the *Bairro Maravilha* project, which improves degraded neighborhoods, including lighting. These initiatives have the potential to result in improved efficiency in the use of electricity. Nevertheless, it is difficult to evaluate how much was achieved in this regard.

The 2013-2016 Strategic Plan (RIO DE JANEIRO, 2013), also contains targets and initiatives related to energy use – namely: continuation of the *Bairro Maravilha* project; maintaining the rate of blackouts within international standards (less than 2%); reformulation of lighting along main thoroughfares, by replacing the technology (LED, Solar/Wind Energy); implementation of the *Morar Carioca* project, which aims to improve urbanization through urban equipment and infrastructure (water, sewage treatment, drainage, public lighting, garbage collection, containment, paving and public equipment) of 584 developable units – a total of 156,000 households by 2016 – and also intends to join the *Minha Casa, Minha Vida* program, in order to provide housing for 100,000 families; and the construction of the Olympic Park, which is to be the sustainable environmental, architectural, cultural and economic legacy of the 2016 Olympics. Most of these measures are not specifically geared to the energy sector, but are important due to their characteristics. For calculating purposes, the initiative to use LED has already converted 32,000 light sources.

It can be seen that the current strategic plan is bolder in its targets and initiatives with regards to stationary sources and their energy use. Actions that promote urbanization have a significant impact, but difficult to account for – but the reformulation of lighting on the main roads allows an emissions reduction of approximately 0.6 Gg CO_2e.

Mobile sources

More initiatives and targets are foreseen for this item, which is positive, since it encompasses significant emission sources and good opportunities for reduction.

The 2009-2012 Strategic Plan (RIO DE JANEIRO, 2011) has the following strategic targets and initiatives: Rio Bicycle Capital – consists in maintaining 150 km of existing bicycle lanes and implementing another 150 km of new lanes, new bicycle shelters and new public bicycle storage stations, integrating the cycle lanes to the public transport network; recover 300 km of public highways in the northern region by the end of 2012; reduce the average travel time of the main 20 routes of the city by at least 10% from 2009 to 2012; implement the Barra/Madureira extension of the TransCarioca and the Barra/Santa Cruz extension of the TransOeste by the end of 2012; streamline and implement physical-tariff integration of the bus network, including the creation of the Single Ticket, redefinition of lines to make them more efficient – eliminating the superimposition of lines – and integrating them to the mass transit systems (subway and train);TransCarioca – consists in the creation of an express bus lane connecting the Barra da Tijuca to Penha; *Ligação C* – consists in a connection from Bangu to Jacarepaguá (BRT); TransOeste – Grota Funda Tunnel – implementation of a BRT system from Santa Cruz to Barra da Tijuca and building a tunnel connecting the Barra de Guaratiba to Recreio dos Bandeirantes.

The 2013-2016 Strategic Plan (RIO DE JANEIRO, 2013) indicates the following strategic targets and initiatives directly or indirectly related to potential GHG emissions reductions from mobile sources:

- Repave 1,700 km of primary thoroughfares (*Asfalto Liso*) and 1,000 km of secondary roads of the city from 2009 to 2016.
- Halve the average traveling time of buses in the main routes of the city in *Ligeirão* systems – by streamlining regular buses, regulating passenger vans, integrating tariff, complementary transports (*Cabritinho*) – and reduce by at least 20% using BRS systems in the year each system is inaugurated, maintaining reduction in the following years.
- Integrate all public transport systems to the Single Rio Ticket system by 2016.
- Cover 60% of public transport users in the City of Rio de Janeiro who use at least one high capacity transport (train, subway or *Ligeirão*) by 2016.
- Conclude works and begin operations on TransOeste, TransCarioca, TransOlímpica and TransBrasil.
- Modernize 100% of the bus fleet by 2016, adopting modern buses with air conditioning, rear engines, green fuel and accessibility resources.
- Light Rail for the Centro – implement a system of light rail transit to connect the various transport modes (subway, train, ferries) to strategic points (Central Bus Station, Praça Mauá, Rio Branco and Presidente Vargas Avenues, Praça XV, Santos Dumont Airport).
- Waterway Transit Project – analysis of the feasibility for a waterway model for the lagoon complex in the Barra region as an alternative to road transport, in order to reduce the traffic in the main thoroughfares and contribute to increasing the tourist potential of the region.
- Sustainable Mobility Plan – consists in developing a Sustainable Mobility Plan, including the definition of policies and models for parking in public areas of the city.

- Green Rio – transformation of the Rio Branco Avenue – revitalizing it with tree areas, modern lighting, vacuum garbage collection and modern infrastructure. Complete closure of the road, organizing the transport system in a ring road outside the region connected to various transport options (underground, ferries and LRTs).
- Achieve 450 km of bicycle lanes from 2009 to 2016, integrating them to the various transport options in the city.

These projects imply in modifications whose emissions reductions are difficult to estimate. The expansion of bicycle lanes, for example, implies in the reduction of the use of motorized transport, but it would be necessary to carry out a study to calculate more precisely what this entails for the City of Rio de Janeiro. There are also initiatives with very few details – such as the Sustainable Mobility Plan – or even without any concrete execution perspectives, such as the Waterway Transit Project. Thus, this paper is limited to seeking an approximation of the avoided emissions of the measures for which a more robust forecast of operationalization exists and which imply in reductions for which there is basic information to permit calculations. Given these conditions, the BRT corridors stand out. Currently, in the conditions described in this document in the operation Scenario B, in 2012 it is estimated that there will be a reduction of 29.2 Gg CO_2e a year regarding the actions included in the strategic plans. For the year 2016, the total goes up to 241.2 Gg CO_2e.

There are also other projects – both from other levels of government, such as the expansion of the subway system – and the city government itself, such as the expansion of the BRS system, which is expected to include many of the main traffic hubs in Rio de Janeiro, which should result in GHG emissions reduction. However, it would be necessary to deepen the research of operational aspects of these initiatives to arrive at a representative number. Anyway, the amount avoided is significant and, taking into account other measures that do not fall under the responsibility of the city, it should reach the figures previously foreseen for the energy sector(523.3 Gg of CO_2e in 2025) in the Plan of Action to Reduce Greenhouse Gas Emissions in the City of Rio de Janeiro (CENTRO CLIMA, 2011).

2.1. Estimated Reductions

The estimates for emissions reductions contained in this paper suffer several limitations, since they lack specific data, are based on the available references, many of these from other urban contexts. Furthermore, given the nature of the planned actions, it isn't always possible to define precisely the resulting impact, in terms of GHG emissions. The methodology used for the energy sector in the Plan of Action developed in 2011 (CENTRO CLIMA, 2011) was adopted for the calculations – with updated information that became available since then.

The purpose of this work should be understood from this perspective. We don't expect to predict what will happen in the next few years nor estimate precisely the impact of each measure described herein. The goal is much closer to providing a basis for defining public policies in the field of climate change and energy – enabling a perception of the potential for emissions reductions that each type of planned activity has.

Given this, we calculated the amount of the abatements of Scenario B with respect to Scenario A with the duly updated data – as well as the reductions with regard to the strategic initiatives published by the City Government (RIO DE JANEIRO, 2011; 2013). Table 18 summarizes the results found.

Table 18 – Estimated GHG emissions reductions (Gg CO_2e)

	2012	2016	2020	2025
Reduced emissions/Energy – Stationary sources	0.69	0.74	0.74	0.74
Installation of LEDs in traffic lights (32,000 units)	0.64	0.64	0.64	0.64
Minha Casa, Minha Vida project (1,000 units)	0.05	0.1	0.1	0.1
Reduced emissions/Energy – fugitive emissions	5.7	17	11.4	11.4
Replacement of gas distribution network (*CEG*)	5.7	17	11.4	11.4
Reduced emissions/Transports – stationary sources	79.6	525	529.7	530.4
BRT – TransOeste (150,000 passengers/day)	7.7	15.5	19.2	19.3
BRT – TransCarioca (380,000 passengers/day)	0.0	48.2	48.7	48.9
BRT – 2nd Stage TransCarioca (150,000 passengers/day)	0.0	19.0	19.2	19.3
BRT – TransOlímpica (100,000 passengers/day)	0.0	12.7	12.8	12.9
BRT - Transbrasil (900,000 passengers/day)	0.0	115.7	115.9	116.1
BRS Copacabana	17.6	17.6	17.6	17.6
Jardim Oceânico Subway (230,000 passengers/day)	0.0	85.5	85.5	85.5
Subway – purchase of new rail cars doubles the numbers of passengers (+550,000 passengers/day)	51.1	204.4	204.4	204.4
Expansion of bicycle lanes network (300km)	3.2	6.4	6.4	6.4
Total	**85.99**	**542.74**	**541.84**	**542.54**

Source: Authors

With respect to the reductions related to the measures defined by the strategic plans, Table 19 summarizes the results:

Table 19 – Summary of estimated GHG emissions reductions (Gg CO_2e)

	2012	2016	2020	2025
Strategic Plans	29.2	235.8	240.5	241.2

Source: Authors

Note that in both tables, starting in 2016, avoided emissions practically stagnate. This is because there are no actions foreseen for these years; however, new initiatives are expected to emerge, changing these estimates. Furthermore, the measures planned in the strategic plans do not have such a high impact, since the city does not have the capacity or the responsibility of intervening in important aspects of the energy scenario such as, for example, rail transport.

In sum, emissions of the energy sector are the most significant ones and, within these, the transport sub-sector has the most potential for emissions reductions. In this regard, the Government of the City of Rio de Janeiro has been proactive, seeking opportunities in this area. Therefore it is developing initiatives such as BRS and BRT which will result in significant positive impacts for city emissions. There are actually projects that have not been included in the calculations of this study and which certainly have an impact on GHG emissions – such as the expansion of the BRS system to Centro, Ipanema/Leblon and even possibly to routes in Tijuca and Botafogo.

Nevertheless, there is much that can be done. With regard to stationary sources, the 2012 inventory shows that controlling self-generators could result in significant abatements. Furthermore, investments could be made in programs to increase energy efficiency or even provide incentives for distributed electricity generation with renewable sources. For mobile sources, the waterway transit project described above could yield good results, as this transport mode is not energy-intensive. It would be interesting to explore opportunities given the water bodies of the City of Rio de Janeiro – where waterways are abundant. In the near future, incentives for hybrid/electric vehicles could also be considered, for both private use and the public transport system.

Naturally, all this depends on organization and financial resources, which aren't always available to city governments. Further attention must be paid to probable synergies and dependencies that these initiatives share, as discussed in economic development literature (MURPHY K. SHLEIFER A. VISHNY R. W., 1989) – an example in case are the links existing between dissemination: of the generation of distributed electricity; of hybrid/electric vehicles; and of a smart grid. Therefore, the City Government is trailing a positive direction albeit with several restrictions. There is, however, still room for new projects that could even make sense economically.

3. AFOLU

With regard to the strategic plans for the City of Rio de Janeiro, specifically in the area of land use and forests, the city has been committing itself to several initiatives. Among these are two related to GHG emissions/removals. The first initiative is the continuity of the *Rio Capital Verde* program, where reforestation activities will be carried out until 2016, involving the consolidation of 2,000 hectares of already forested areas, with the implementation of green corridors, beginning in the region of Marapendi, Chico Mendes and Prainha. The second initiative includes the restructuring of more than 170,000 m^2 of squares and parks and the development of 15 management plans to plant more trees in the city, under the *15 Minutos Verdes* project.

These initiatives have the following goals:

- Reforest 1,700 hectares in new areas from 2009 to 2016, ensuring the management of areas that have already been reforested.
- Planting 500,000 new trees in parks, squares or protected areas by 2016.

Some of these initiatives were already being executed in 2012 in the City of Rio de Janeiro. Table 20 shows the results of the 2012 GHG emissions inventory, taking into account actions that have already been implemented and the estimates related to the actions of the city's Strategic Plan, with their projection for 2016.

Table 20 – Strategic plan actions and their carbon removals (Gg CO_2e)

Actions	2012	2016	2020	2025
Rio Capital Verde Project + Reforestation Efforts.	– 33.5	– 39.9	–	–
Reforestation of squares and parks.	– 2.8	– 9.8	–	–
Total removals	**– 36.3**	**– 49.7**		

**Negative values represent carbon absorption.*

3.1. Estimated Reductions

In order to measure the extent of the GHG emission mitigation efforts, with regard to the proposed and executed actions in the City of Rio de Janeiro, a comparison was made of the results of the proposed reforestation scenarios and with the mitigation actions of the Strategic Plan. Table 21 shows the behavior of the GHG emissions/removal over the analysis period.

Table 21 – Comparison of carbon removal by reforestation actions in the City of Rio de Janeiro (Gg CO_2e)

AFOLU	2012	2016	2020	2025
Scenario B	**– 44.9**	**– 48.1**	**– 50.7**	**– 51.2**
Scenario C	**– 52.9**	**-66.8**	**– 91.6**	**-120.0**
Strategic Plan actions	**– 36.3**	**– 49.7**	**–**	**–**

**Negative values represent carbon absorption.*

As shown above, the actions of the Strategic Plan for 2012 do not achieve the estimated emissions for scenarios B and C. This might be because the Rio City Government did not fully carry out the proposed activity in the scenarios, since it was based on preliminary information, because the city's Strategic Plan had not yet been completed at the time. However, for 2016, we can see that the actions proposed in the Plan have the potential to go beyond the estimated reductions for Scenario B of the same year, achieving up to 1.6 Gg CO_2e above the estimated amount. The totals estimated for Scenario C include reforestation of the Pedra Branca State Park, region under the jurisdiction of the State of Rio de Janeiro and as such is not included in the city's Strategic Plan.

On analyzing the emissions calculated for the year 2012 in comparison to the projected amounts in the 2010 scenarios study, it is possible to see that the estimated target for Scenario C, for the year 2012 was overshot (Table 6). This can be explained by the low rate of deforestation currently seen in forest areas and by the absorption of gases promoted by reforestation and maintenance and planting of trees in urban areas carried out until the year 2012.

Table 22 – Comparison of carbon emissions/removals for the City of Rio de Janeiro (Gg CO_2e)

AFOLU	2012	2016	2020	2025
Scenario A	**210.66**	**207.36**	**204.76**	**203.66**
Scenario B	**97.40**	**39.80**	**-17.20**	**-17.80**
Scenario C	**65.36**	**-16.64**	**-109.64**	**-138.14**
3rd GHG Emissions Inventory	**8.77**	**–**	**–**	**–**

In view of the results, it may be concluded that the Strategic Plan actions for the forest and land use sector in the City of Rio de Janeiro are important measures for mitigating emissions, since they contribute to the absorption of atmospheric carbon, thus helping to compensate the GHG emissions from deforestation and farming activities.

4. Wastes

With regard to the city's Strategic Plans for wastes, the city has been undertaking several initiatives, such as:

- Urban housing targets:
    - Bring urbanization activities – water, sewage treatment, drainage, public lighting, garbage collection, containment and paving – to 156,000 households by 2016, under the initiative *Morar Carioca*.
- Environment and sustainability targets:
    - Increase the coverage of the sewage collection network in AP 5 receiving treatment to 55% by 2016.
    - Collect 25% of all the recyclable waste produced in the city by 2016.

However, none of these actions have a direct relation to GHG emissions/removals. As mentioned, for both solid wastes as for sewage, the main emission mitigation actions are capture and burning or use of landfill biogas. The Gramacho, Seropédica, Nova Iguaçu and Alegria STS landfills, which receive wastes and sewage from the City of Rio de Janeiro carry out capture and burning of this gas, contributing to emission reduction, as shown in the table below.

Table 23 – Summary of estimated GHG emissions reductions (Gg CO_2e)

Actions	2012	2016	2020	2025
Reduced emissions/Urban Solid Wastes	**243.80**	**1,240.00**	**–**	**–**
Capture and burning of biogas in Gramacho Landfill	235.10	329.00	–	–
Capture and burning of biogas in Seropédica Landfill	8.70	911.00	–	–
Reduced emissions/Liquid Effluents	**11.90**	**–**	**–**	**–**
Total removals	**255.70**	**1,240.00**		

4.1. Estimated Reductions

In order to measure the extent of the GHG emissions mitigations efforts with respect to the actions proposed and executed in the City of Rio de Janeiro, the results of proposed mitigation scenarios were compared with the planned mitigation actions. Table 21 shows the behavior of the GHG emissions/removal over the analysis period.

Table 24 – Comparison of carbon removal by the actions in the area of wastes for the City of Rio de Janeiro (Gg CO_2e)

	2012	2016	2020	2025
Scenario B	**824.20**	**1,278.50**	**1,335.60**	**1,402.50**
Solid wastes	974.30	1,486.10	**1,543.10**	1,609.90
Effluents	-150.10	-207.60	-207.50	-207.40
Scenario C	1,175.90	1,684.70	1,762.50	1,860.20
Solid wastes	1,064.20	1,630.90	1,708.70	1,806.40
Effluents	111.70	53.80	53.80	53.80
Estimated actions	**255.70**	**1,240.00**	**–**	**–**
Solid wastes	243.80	1,240.00	–	–
Effluents	11.90	–	–	–

**Negative values represent increased emissions.*

Even though methane has been recovered in the Gramacho, Seropédica, Nova Iguaçu and Alegria STS landfills, there recoveries were not enough to reduce the 2012 emissions as expected in the scenario studies. One of the main reasons for not achieving the reductions was a change in the schedule for implementing the burning of biogas for industrial use (purified biogas as fuel for the REDUC refinery). The regulatory uncertainties and the impact on the carbon market probably influenced the decisions of private actors (in this case, Petrobras).

The gas pipeline that connects the purification plant to REDUC started operation in July 2013. At the end of 2013, capture and burning of biogas in the Seropédica waste treatment center, begun in November 2012, should be quite higher than the initial forecast. Biogas, burned in a flare since June 2009 will achieve the initial projection of 12,000 m³/h by the end of 2013. The use of this technology is also justified as it is more sustainable than simple biogas burning, although it is more complex to implement. Changes in schedules prevented the city from achieving the 2012 target, but it is closer to achieving it by the end of 2013, according to Table 25, below.

Table 25 – Emission reductions verified for 2012 and estimated for 2013 (thousand tonnes CO_2e)

GHG emissions reduction – RJ	2012	2013
Capture and burning of biogas in the Gramacho Landfill	237	413
Capture and burning of biogas in the Seropédica WTC	18	425
Total (thousand tonnes CO_2e):	**255**	**838**

Since the trend is to expand sanitation in the city — for example, all wastes should be sent to 100% sanitary landfills, which produce more greenhouse gases as a result of their anaerobic condition — it is expected that emissions will continue to increase, if more efforts are not employed to increase the recovery of the generated biogas or to adopt technologies that generate less greenhouse gases, such as organic composting plants, thermal plants for electricity generation or even use of recovered methane in vehicles and increased recycling.

5. Consolidation of Estimates

According to the updated 2005 inventory results, the total city emissions in 2005 amounted to 11,613 tonnes CO_2e. Thus, emission reduction targets provided for in law correspond to 929,000 tonnes CO_2e (8% of 2005 emissions) in 2012. For 2016, the 16% would mean 1,858,000 tonnes CO_2e.

Due to reasons already mentioned, the estimates of the current study show that the actions carried out by the City Government until 2012 were not enough to achieve the 8% target. However, for 2016, the projected actions, if actually implemented, will be close to achieving the 16% target, as shown by Table 26.

It should be stressed that the city is thriving and it is necessary to consider that the Complexo Siderúrgico do Atlântico, which is not yet operating at its full capacity, should achieve it by 2016. Given that for production of 3.5 million tonnes of crude steel, gross emissions for the complex amounted to 8.8 million tonnes CO_2e, and net emissions 6.3, in 2012; with a full load of 5 Mt of crude steel, these emissions will be greater and will probably overshoot the reductions foreseen by the city's mitigation actions.

Table 26 – Estimated emissions reductions for 2012 and for the Strategic Plan period (2013-2016) in the City of Rio de Janeiro (thousand tonnes CO_2e)

Reduced emissions	2012	2016
Energy – stationary sources	0.7	0.7
Energy – fugitive emissions Replacement of gas distribution network (CEG)	5.7	17
Energy – transports	79.6	525
BRTs (1 in 2012, 4 in 2016)	7.7	211.1
Copacabana BRS	17.6	17.6
Subway expansion	51.1	289.9
Expansion of bicycle lanes network (300km)	3.2	6.4
Agriculture, Forests and Land Use – AFOLU	36.3	49.7
Urban Solid Wastes	243.8	1,240
Capture and burning of biogas in Gramacho Landfill	235.1	329
Capture and burning of biogas in Seropédica Landfill	8.7	911
Liquid effluents	11.9	–
Total Emissions Reductions	*378.00*	*1,832.40*
Targets of the City Climate Change Policy	*929*	*1,858*

References

References

BRASIL, 2004. *Comunicação Nacional Inicial do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança no Clima.* Ministério da Ciência e Tecnologia. Brasília.

______, 2010. *Segunda Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança no Clima.* Ministério de Ciência e Tecnologia. Brasília.

CENTRO CLIMA, 2011. *Plano de Ação para a Redução de Emissões dos Gases de Efeito Estufa da Cidade do Rio de Janeiro.* Centro de Estudos Integrados sobre Meio Ambiente e Mudanças Climáticas/ COPPE-UFRJ. Rio de Janeiro: CENTRO CLIMA.

EPE, 2013. Empresa de Pesquisa Energética (Brasil). *Balanço Energético Nacional 2013: Ano base 2012 .* Empresa de Pesquisa Energética. Rio de Janeiro.

IEA, 2005. *Energy Statistics Manual*. International Energy Agency. Paris: OCDE/IEA.

IBGE, 2012. *Pesquisa Nacional por Amostra de Domicílios – PNAD 2011*. Instituto Brasileiro de Geografia e Estatística. Rio de Janeiro. Available at: <http://www.ibge.gov.br/home/estatistica/populacao/trabalhoerendimento/pnad2011/>. Accessed on: 16 May 2013.

_______, 2013. *Pesquisa Pecuária Municipal – PPM 2011.* Available at: <http://www.sidra.ibge.gov.br/bda/acervo/acervo2.asp?e=v&p=PP&z=t&o=4>. Accessed on: 23 August 2013.

IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories.* National Greenhouse Gas Inventories Programme/IGES. Intergovernmental Panel on Climate Change. Japan.

______, 2007. *Annex I (glossary) to the fourth assessment report.* Intergovernmental Panel on Climate Change. Geneva, Switzerland.

IPP, 2013. *PIB Municipal: Conceituação, metodologia e análise para a Cidade do Rio de Janeiro*. Instituto Municipal de Urbanismo Pereira Passos. Rio de Janeiro: Prefeitura da Cidade do Rio de Janeiro.

MACEDO, I. C., SEABRA, J. E. A., e SILVA, J. E. A. R., 2008. "Green house gases emissons in the production and use of ethanol from sugarcane in Brasil: the 2005/2006 averages and a prediction for 2020". *Biomass and Bionergy*, n. 32, p. 582-595.

MCTI, 2013. *Fatores de Emissão de CO2 pela geração de energia elétrica no Sistema Interligado Nacional do Brasil*. Brasil: Ministério de Ciência, Tecnologia e Inovação.

MURPHY K., SHLEIFER A., VISHNY R. W., 1989. Industrialization and the Big Push. *Journal of political economy*, v. 97, n.5.

RIO DE JANEIRO, 2011. *Plano Estratégico da Prefeitura do Rio de Janeiro 2009-2012: Pós – 2016 O Rio mais Integrado e Competitivo*. Rio de Janeiro: Prefeitura da Cidade do Rio de Janeiro. Available at: < http://www.rio.rj.gov.br/dlstatic/10112/2116763/243779/ planejamento_estrategico_site.pdf>. Accessed on: 14 sep.

RIO DE JANEIRO, 2013. *Plano Estratégico da Prefeitura do Rio de Janeiro 2013-2016: Pós – 2016 O Rio mais Integrado e Competitivo*. Rio de Janeiro: Prefeitura da Cidade do Rio de Janeiro. Available at: < http://www.rio.rj.gov.br/dlstatic/10112/2116763/4104304/planejamento_estrategico_1316.pdf>. Accessed on: 12 sep.

SMAC, 2011. *Mapeamento da Cobertura Vegetal e do Uso das Terras do Município do Rio de Janeiro.*Secretaria Municipal De Meio Ambiente. Rio de Janeiro: Prefeitura da Cidade do Rio de Janeiro. Available at: http://www.rio.rj.gov.br/web/smac/exibeconteudo?article-id=2367969

WRI, 2011. *Technical Assistance to the City of Rio de Janeiro on Citywide Greenhouse Gas Monitoring System.* Washington: World Resource Institute/World Bank.

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DEPARTAMENTO DE TRÂNSITO DO ESTADO DO RIO DE JANEIRO – DETRAN-RJ

EDITORA O DIA

ENERGYWORKS DO BRASIL – GRUPO NEOENERGIA/CENTRAL DE COGERAÇÃO AMBEV-RIO

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Acronyms

ABAL – Brazilian Aluminum Association

ABIQUIM – Brazilian Chemical Industry Association

ABIVIDRO – Brazilian Technical Association of Automatic Glass Industries

AFOLU – Agriculture, Forestry and Other Land Use

ANP – Brazilian Petroleum, Natural Gas and Biofuels Agency

AR-4 – IPCC Fourth Assessment Report

BOD – Biochemical Oxygen Demand

BRS – Bus Rapid Service

BRT – Bus Rapid Transit

C40 – Cities Climate Leadership Group

CEDAE-RJ – State Water and Sewage Corporation

COD – Chemical Oxygen Demand

COMLURB – Rio de Janeiro Urban Cleaning Company.

ETE – Sewage Treatment Station

FIRJAN – Federation of the Industries of the State of Rio de Janeiro

FOD – First Order Decay

GHG – Greenhouse gases

GPC – Global Protocol for Community-scale Greenhouse Gas Emissions

GWP – Global Warming Potential

ICLEI – Council for Local Environmental Initiatives

IPCC – Intergovernmental Panel on Climate Change

IPPU – Industrial Processes and Product Use

LRT – Light Rail Transit

NOAA – National Oceanic & Atmospheric Administration

PNAD – National Survey of Sampled Households

RSI – Urban Industrial Wastes

RSU – Urban Solid Wastes

UNFCCC– United Nations Framework Convention on Climate Change

WRI – World Resources Institute

WTC – Waste Treatment Center