

Impact of Brazil's Biofuel Program and Carbon Intensification of The Electrical Grid on Subnational GHG Emissions: Western Metropolitan Region of São Paulo (CIOESTE)

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Overview

Most of the energy generated in the world is consumed within urban areas, and after the Paris Agreement, cities gained prominence in the climate mitigation agenda as an alternative route for climate actions deployment and because of the sensitivity towards climate risks that cities are exposed. As a result, a growing number local governments have been observed to be implementing sub-national climate policies and commitments, often reproducing national regulation and commitments metrics such as total GHG reduction pledges without taking in consideration the jurisdiction of the emission sources and the governance over them. Through a case study analysis of a sub national region, the present article assesses the impact of two emission sources that influence sub-national governments. An energy demand model was developed to evaluate the region's energy demand projections and to quantify the GHG emissions for 2020. Additionally, two alternative scenarios were applied, the first one consider an increase of the carbon intensity of the emission factor of the electricity grid change, and the second consider the GHG emissions reduction from the bio fuel addition to commercialized gasoline and diesel.

Keywords – CIOESTE; Climate Change; Subnational Policy; Energy demand forecast; GHG reduction; Mitigation.

1. Introduction

After the Paris Agreement, cities gained prominence in the climate mitigation agenda due the key role that they play in the deployment of low-carbon technologies, as a large share of energy is consumed inside the boundaries of cities.

Most of the world energy consumption happens within urban centers, from 60 to 80% of the total energy generation, corresponding to approximately 70% of global GHG emissions (UN-Habitat. 2016). Nevertheless, local governments have less influence over the energy supply-side management because it is often outside their jurisdiction, diminishing local governance over GHG emission from the energy sector (SETO, K. 2014).

This problem is critical when it comes to subnational climate policies that usually are based on national commitment's metrics and practices. In particular, when establishing GHG reductions targets that encompasses indirect emissions from electricity generation¹.

The present work consists of modeling the energy demand of the eight cities that compose the Inter-Municipal Public Consortium of the Western Metropolitan Region of São Paulo (CIOESTE) and will provide a projection of GHG emissions from the previously mentioned sectors of CIOESTE's region for 2020, considering the forecasted growths of the population and national economy.

Comparisons of alternatives scenarios with the BAU projection, will enable the evaluation of the impact on GHG emissions in 2020 that result from the increased share of biofuels in commercialized gasoline

¹ Commonly classified as scope 2 GHG emissions (Fong, W. K, 2014).

and diesel as proposed at the federal level, and the increase in the carbon intensity of the emission factor (EF) of the electricity grid.

1.1 – Brazil context

In Brazil, GHG emissions from cities and states, are highly influenced by activities that are under federal jurisdiction such as the composition of transport fuels and electricity generation. All gasoline and diesel commercialized in Brazil must meet rules set by the national fuel agency including the percentage of biofuels mixed within diesel and gasoline, which are expected to increase by 2020 leading to a GHG reduction in the transport sector all over the country (ANP, 2016).

A similar situation is observed with electricity generation. Brazil's integrated electric system is subject to federal agencies that are responsible for the system operation framework and electricity generation planning. From 2011 to 2014 a constant increase in the carbon intensity of the EF of the grid was observed due to the increased share of fossil fuel generation capacity in the electricity power generation mix. With the drought observed during the aforementioned years the CO₂ EF for electricity generation became more carbon intensive. The decrease in hydroelectric production has been replaced by fossil based thermoelectric. In 2011, the electricity generation factor was 29 kg/ MWh, by 2014 it was 135 kg/MWh.

Brazil's integrated electric system is subject to federal agencies that are responsible for the system operation framework and electricity generation planning including the quantity of renewables sources that are added to the grid. Municipal governments have no influence on the power generation-side management, therefore any variation of the electrical grid is out of local government control.

2. Methodology

The following sectors are considered in this work: residential, commercial, industrial, public lighting, public service, and transportation. As the rural sector represents less than 1% of added value of the region, it not be considered in the analysis.

Two alternatives were modeled and compared to a Business as Usual projection (BAU). The first alternative considers GHG emissions reduction from biofuel addition to commercialized gasoline and diesel (Biofuel mixture increase alternative). The second alternative evaluates the GHG emissions variations from an increase of the carbon intensity of the EF of the electricity grid change (Grid E.F. increase alternative).

3. Premises

The following data sources were used: The State Data Analysis System (SEADE – Fundação Sistema Estadual de Análise de Dados); the state Energy Department of São Paulo (Secretaria de Energia e Mineração Estadual), and the Brazilian Institute of Geography and Statistics (IBGE – Instituto Brasileiro de Geografia e Estatística). Considering that the eight municipalities that encompass CIOESTE have very different profiles, all assumptions considers the time series for each municipality although we usually discuss the overall figures for CIOESTE region.

The analysis take in account the available time series of CIOESTE municipalities, from 2010 to 2014, and projects energy demands until 2020 using the macroeconomic indexes such as GDP, population, residents per household, average income to forecast the energy demand projection.

CIOESTE population presented a steady growth rate, approximately 1.0% per year, from 2010 to 2014, while the Brazilian population growth rate in the same period was approximately 0.8% per year (IBGE)

with a constant reduction. One of the reasons that can explain CIOESTE's demographic is the migration caused by the large number of jobs opportunities in the São Paulo Metropolitan region. The Brazilian Energy Ten Year Energy Expansion Plan considers that the population growth will decrease to 0.6% per year, for the population forecast we have considered that CIOESTE average population growth rate will reduce linearly to 0.8% by 2020 (MME/EPE 2015).

The rate of people per household in the region shows a regular and steady decrease in all municipalities. In 2010 CIOESTE had an average of 3.37 people per household. The forecast reflects that this rate is expected to steadily drop to 3.00 people per household in 2020.

In order to use the Gross Domestic Product (GDP) as a forecast metric we calculated the real GDP for the base year (2010) considering the inflation deflators from the World Bank² and the US dollar exchange rate of the base year (USD = 1,76 BRL³). The future economic scenario was based on the International Monetary Fund's (IMF) projection for Brazilian GDP growth from 2014 to 2020. The results per municipality are presented on *Table 1*.

CIOESTE Municipalities	2010	2011	2012	2013	2014	2015 (forecast)	2016 (forecast)	2017 (forecast)	2018 (forecast)	2019 (forecast)	2020 (forecast)
Barueri	17,066	18,089	19,263	19,888	19,582	18,838	18,216	18,125	18,397	18,765	19,140
Carapicuíba	1,706	1,795	1,837	1,996	2,003	1,926	1,863	1,854	1,881	1,919	1,957
Cotia	3,864	4,184	4,206	4,323	4,293	4,130	3,994	3,974	4,033	4,114	4,196
Itapevi	2,968	3,105	3,451	3,560	3,762	3,619	3,500	3,483	3,535	3,605	3,678
Jandira	1,165	1,176	1,176	1,196	1,248	1,201	1,161	1,155	1,173	1,196	1,220
Osasco	24,730	24,992	24,372	24,635	24,849	23,905	23,116	23,000	23,345	23,812	24,288
Pirapora B. J.	204	231	207	199	153	147	142	142	144	147	150
Santana P.	2,617	3,010	3,024	3,181	3,422	3,292	3,183	3,167	3,215	3,279	3,345
CIOESTE	54,319	56,583	57,536	58,979	59,312	57,058	55,175	54,899	55,723	56,837	57,974
Growth rate		4.2%	1.7%	2.5%	0.6%	-3.8%	-3.3%	-0.5%	1.5%	2.0%	2.0%

Table 1 - GDP fixed for 2010 (millions of USD)

4. Assumptions

4.1 – Energy Demand

In the following sections, we will present the assumptions and references considered for the energy demand forecast of CIOESTE.

4.1.1 Energy Demand – Residential

In the Brazilian residential sector the main energy inputs are electricity, liquefied petroleum gas (LPG), natural gas and in rural areas, firewood and charcoal. The latter three fuels are most commonly used for cooking and water heating (MME/EPE 2015). In urban areas, firewood and charcoal are losing their participation in the energy matrix since the 1980's due to the population's income increases and enlargement of LPG's distribution (SEESP, 2012), the consumption of firewood and charcoal are not significant in CIOESTE's municipalities, therefore these were not included in this analysis.

To determine the electricity consumption, the electricity intensity consumption per household was used, and the number of households. The estimation considered the electricity intensity growth rate based on the technical note issued by Empresa de Pesquisa Energética and the household size variation value were obtained from historical series of CIOESTE municipalities (EPE, 2016b).⁴

² Inflation, GDP deflator (annual %)

³ Base year 2010, reference OECD at <https://data.oecd.org/conversion/exchange-rates.htm>

⁴ Energy Research Company, the institution responsible for development of the Brazilian National Energy Plan

LPG and Natural Gas are used in the residential sector for heating purpose, both cooking and water heating, through direct combustion (MME, 2005). The forecast of those energy inputs was calculated considering the same premises of the State Energy Plan for 2020 (SEESP 2012). It is expected that the natural gas will displace LPG use, due to the expansion of natural gas distribution network, especially in urban areas. The parameters considered to estimate the residential energy demand for 2020 are summarized on Table 2 the values obtained for each municipalities are presented on the annexes.

Energy Input	Parameter	2010	2020	Unity	Reference
Electricity	Household size	3.37	3.00	persons/household	2010: historical series 2020: calculated
	Household size annual growth	-1.15	-1.15	%	2010: historical series 2020: linear forecast
	Residential energy intensity	237.9	287.4	kWh/household/year	2010: historical series 2020: calculated
	Electricity intensity growth rate	4.8	1.5	%	2010: historical series 2020: EPE, 2016
LPG	Demand variation		0.04	%	SEESP, 2012
Natural Gas	Annual consumption growth		5.0	%	MME/EPE 2015

Table 2 – Assumptions for residential energy demand forecast

The electricity demand for 2020 presented an average annual expansion of 3.5% per year, that can be explained as a combined effect of the increase of households (2.0% per year) and the growth of the residential average consumption (kWh per household per year).

National LPG demand assumptions were not adopted for CIOESTE as the national average expects an increase on the LPG, due the firewood and charcoal substitution. Therefore, the São Paulo Energy Plan premises were considered.

4.1.2 Energy Demand – Commercial

The commercial sector energy demand encompasses the following energy inputs: electricity, LPG and natural gas. Electricity corresponds to approximately 95% of total final energy consumption in the commercial sector, while the energy use for direct heating is mostly due to ovens, in activities such as bakeries, clothes dryers, restaurants, hotels.

For the commercial sector energy demand forecast, the correlation between the energy consumption and the value added was used. As illustrated in Figure 1, there is a high correlation between both variables. The same is observed with the added value from the commercial sector and the national GDP (Figure 2), which was the link between FMI's forecasts regarding Brazilian economic growth.

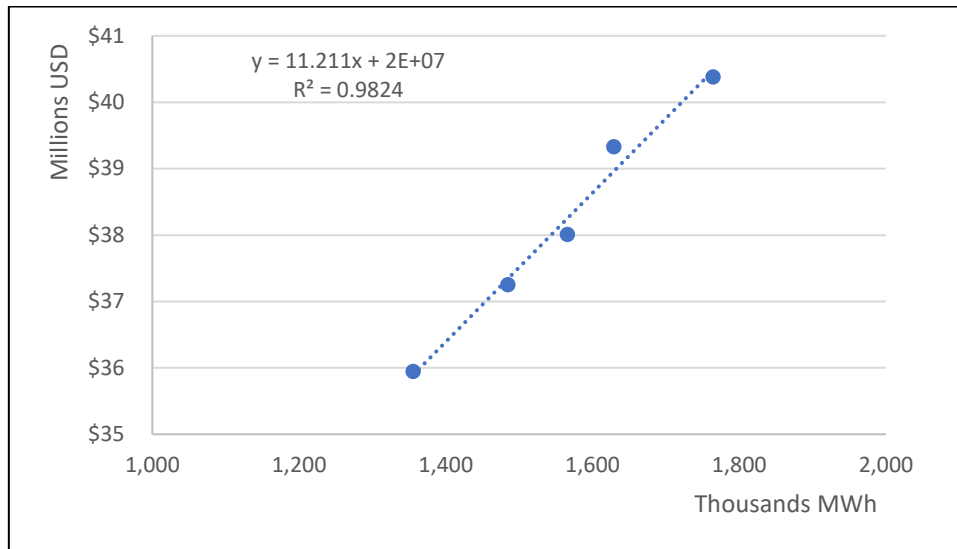


Figure 1 - Relation between energy consumption and value added for CIOESTE's commercial sector

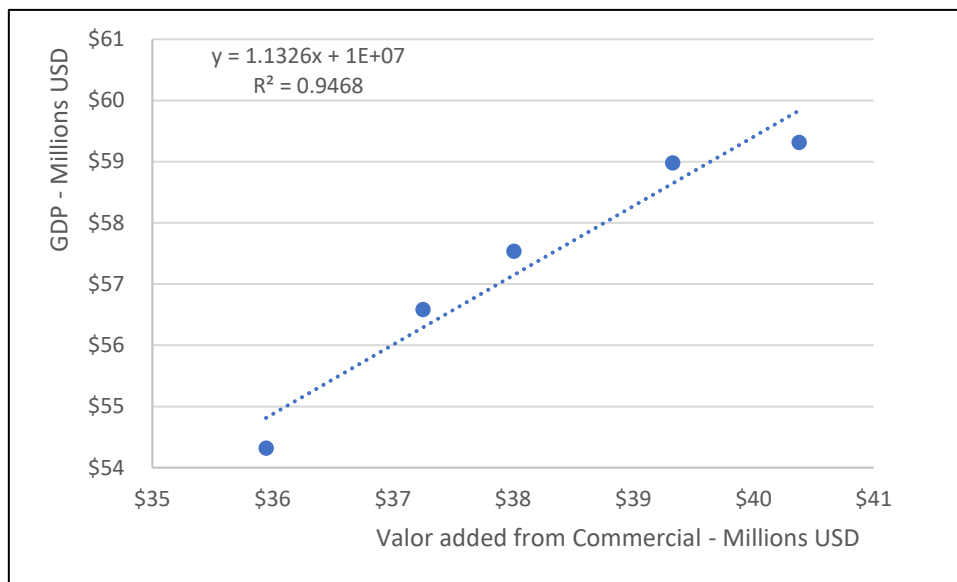


Figure 2 - Relation between valor added from the commercial sector and CIOESTE's GDP

Today natural gas represents approximately 2% of energy demand of the commercial sector and it is expected to have a more intensive growth in the next years than other fuels used for direct heating due the expansion of the natural gas distribution network, therefore the growth ratio adopted was not based on the sectoral value added. Then, our estimative considered the annual growth of natural gas foreseen by the Ten-Year Energy Expansion Plan 2024 (4.1%).

4.1.3 Energy Demand – Industrial

The industrial sector make use of the following energy inputs: electricity, diesel, LPG and natural gas and fuel oil as shown by Figure 3. The major industrial segments at CIOESTE region are pharmaceutical, equipment manufacturers, chemical, auto parts, printing, plastic, food producers, and electrical material suppliers. The aforementioned segments are responsible for more than 70% of the value added by the industry.

In contrast to the commercial sector, a correlation between the the CIOESTE energy demand of the industrial sector and the value added was not found.

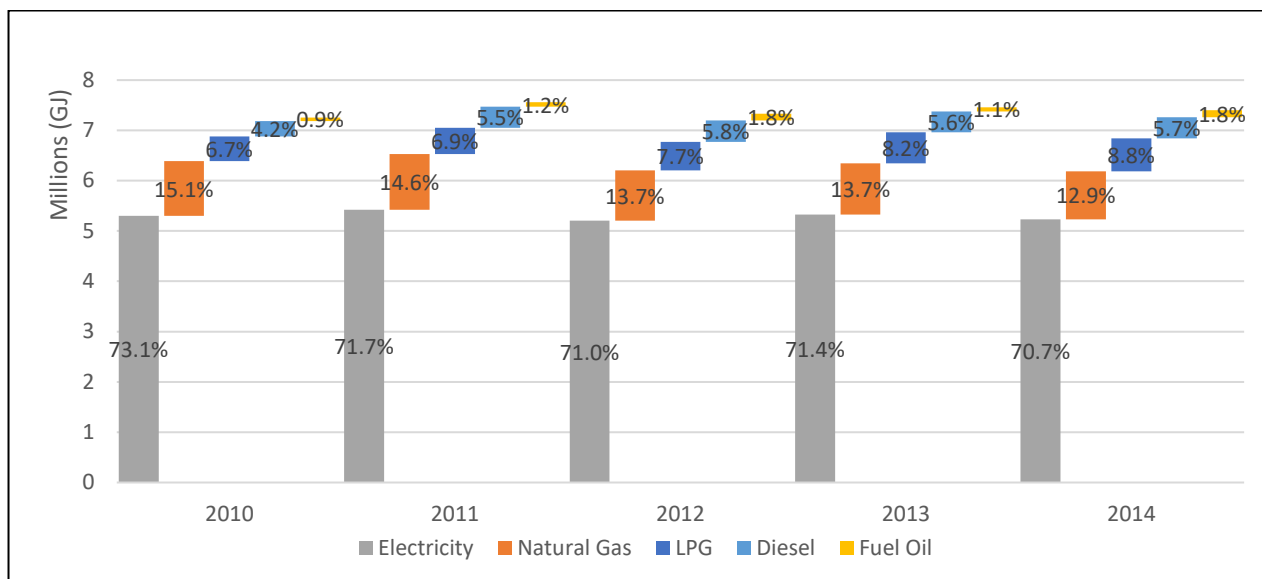


Figure 3 – Energy consumption of CIOESTE's Industrial sector

Considering the data limitation to evaluate the industrial energy demand per subsector, we applied EPE forecast annual growth for the value added of the transformation industry (0.6%)⁵ and multiplied it by the linear forecast of the sector energy intensity, shown in Table 3.

CIOESTE Municipalities	2010	2011	2012	2013	2014	2015 (forecast)	2016 (forecast)	2017 (forecast)	2018 (forecast)	2019 (forecast)	2020 (forecast)
Barueri	17.82	18.46	17.07	19.93	20.89	21.12	21.88	22.64	23.40	24.16	24.92
Carapicuíba	24.14	27.09	25.47	29.90	31.32	32.73	34.45	36.17	37.88	39.60	41.32
Cotia	19.87	20.55	20.64	20.29	21.65	21.59	21.92	22.25	22.59	22.92	23.25
Itapevi	38.29	32.52	33.36	37.72	37.25	36.76	37.08	37.39	37.70	38.01	38.33
Jandira	25.90	29.51	32.35	32.53	30.94	34.17	35.48	36.79	38.10	39.40	40.71
Osasco	34.27	34.74	34.26	32.57	31.61	31.24	30.49	29.74	29.00	28.25	27.50
Pirapora do Bom Jesus	85.05	78.80	122.18	172.12	245.28	264.82	306.20	347.58	388.96	430.34	471.72
Santana do Parnaíba	18.43	23.13	30.33	30.97	29.48	35.45	38.45	41.44	44.44	47.43	50.43
CIOESTE	24.81	25.46	25.66	27.27	27.67	28.43	29.18	29.94	30.69	31.44	32.19
Growth rate		3%	1%	6%	1%	0.0%	2.6%	2.6%	2.5%	2.5%	2.4%

Table 3 – Industrial energy intensity (toe/millions of USD)

4.1.4 Energy Demand – Public Sector

The public services sector's energy demand was estimated considering the assumptions adopted by Ten Year Energy Expansion Plan (MME/EPE 2015), presented in the Table 4 below.

Energy Input	Parameter	2020	Unity	Reference
Electricity	Annual growth	1.3	%	MME/EP 2015
LGP	Annual growth	1.3	%	MME/EP 2015

Table 4 – Assumptions for public service energy demand forecast

4.1.5 Energy Demand – Transport

The transport sector was also estimated considering the assumptions adopted by Ten Year Energy Expansion Plan (MME/EPE 2015), presented on the Table 5 below.

Energy Input	Parameter	2020	Unity	Reference
Diesel	Annual growth	3.2	% per year	MME/EP 2015
Gasoline	Annual growth	0.7	% per year	MME/EP 2015
Ethanol	Annual growth	4.8	% per year	MME/EP 2015
Natural Gas	Annual growth	1.4	% per year	MME/EP 2015

Table 5 – Assumptions for transport energy demand forecast

⁵ Characterization of the macroeconomic scenario for the next 10 years (EPE, 2016).

4.1.6 Energy Demand – Considerations

The energy sector and agriculture were not considered in the present analysis, because these sectors do not have a significant participation in CIOESTE economic activities. Even though city of Cotia still has some rural properties and agricultural activities, according to the available data, their value added are less than 1% of municipal GDP.

Regarding the use of fuel oil in the agricultural, commercial and public sectors, the National Energy Balance (EPE, 2015) accounts for them as less than 1% of total consumption, therefore the participation of this energy input was not considered in the sectors detailed in the previous sections. The same rationale was applied for diesel consumption in the public and commercial sectors that often rely upon back-up generators.

4.4 – Energy Demand Scenarios

Two scenarios were considered for 2020 in addition to the Reference Scenario: biofuel mixture increase, and grid EF increase. All of these represent conditions outside subnational jurisdiction and possess deep influence in local GHG emissions.

The BAU was designed considering that the biofuel mixtures in gasoline and diesel won't suffer additional change after 2014 (25% of ethanol in gasoline, and 5% of biodiesel in diesel), and the electrical EF calculated from the Ten years' expansion energy plan forecast (0.0746 kg/KWh⁶).

For the Biofuel mixture increase alternative the biodiesel mixture of diesel is expected to increase to 10% by 2020, in the same time horizon it is expected that gasoline will have 27% parcel of ethanol, both initiatives are part of Brazilian NDC's strategy to increase the bioenergy's participation in the Brazilian energy matrix and are simulated in the scenario 1, biofuel mixture increase. Those were the assumptions made for the Biofuel mixture increase Scenario.

The "Grid's E.F. Increase Alternative" considers 2014's value, historical highest value (0.1354 kg/KWh⁷), indicating that a climate context similar to 2014, could repeats itself in 2020. The BAU didn't consider these values, in order to assemble a forecast based only on 2014's data (MCTI, 2016)

The comparisons considered 2010 conditions in order to highlight the uncertainties that subnational governments are exposed to when adopting GHG reduction targets without considering the local government jurisdiction, sectoral plans, and national policies. In Brazil, most of the cities that have promulgated climate policies, have considered absolute GHG reductions targets using total GHG emissions from a city on a specific year as a reference.

5. Results

5.1 – Energy Demand Forecast - BAU

CIOESTE's energy demand is presented in Figure 4 detailed by sector. Historical data was used from 2010 to 2014. The period from 2015 to 2020 were projected considering the assumptions described in the previous sections.

⁶ Considering the total energy consumption forecast of 616.5 TWh, and related GHG emissions of 46 MtCO₂

⁷ Available at http://www.mct.gov.br/upd_blob/0241/241068.htm

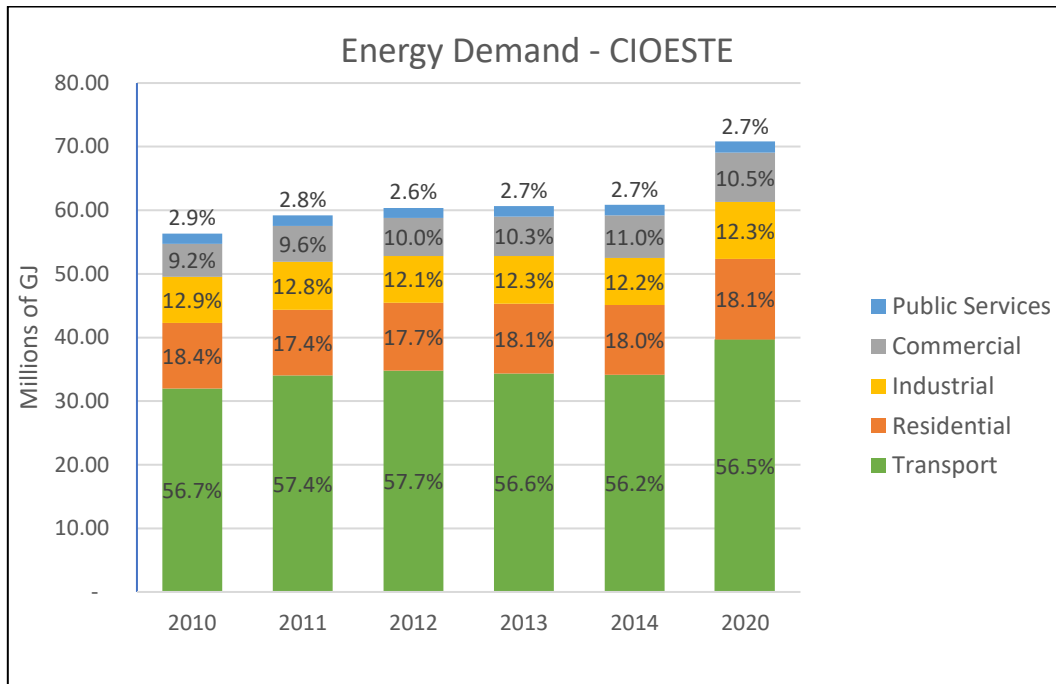


Figure 4 –CIOESTE’s Energy Demand

Considering the BAU, CIOESTE’s total energy demand is expected to grow 16% from 2014 to 2020 and an average annual growth of 2.3%, with an increasing participation of electricity as energy source (Figure 5) that can be explained by the growth of the commercial sector, which has electricity as its primary energy source, approximately 95%. A displacement of LPG consumption towards natural gas is also expected.

In 2010, CIOESTE’s energy matrix was 40% based on renewables sources, 17% of total energy consumption was from biofuels, ethanol and biodiesel, and 23% from electricity acquired from the Brazilian Integrated System, that was composed of 85% of renewables based power plants in 2010 (EPE, 2014). Figure 5 shows the renewable sources participation (inner circle), the energy consumption (middle circle) and the related GHG emissions (outer circle).

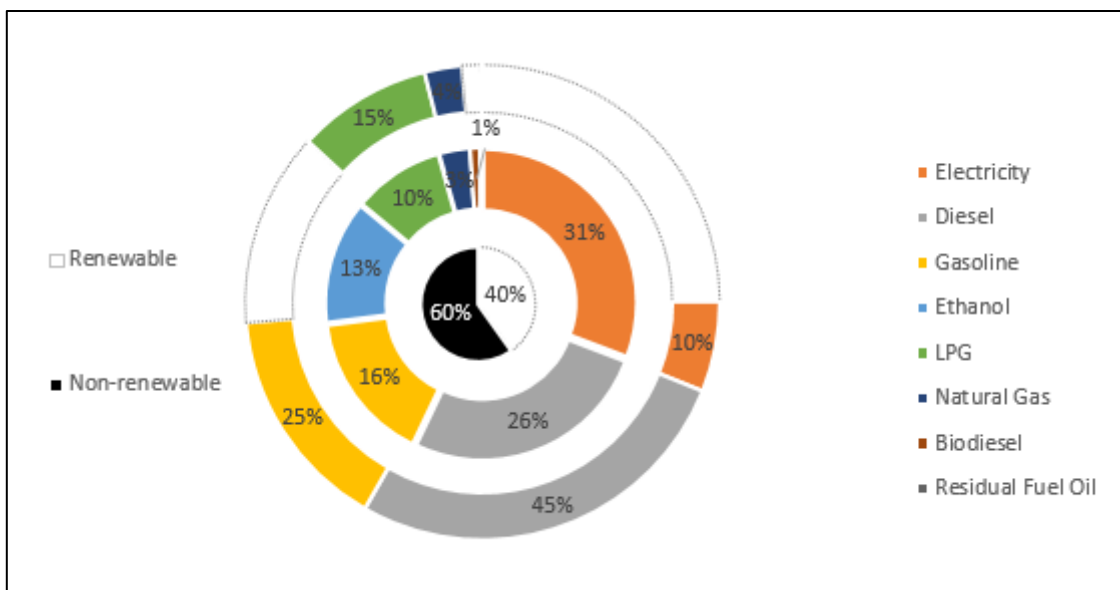


Figure 5 – Shares of total final energy demand by final energy carrier and shares of total primary energy resource type for CIOESTE (2010)

5.2 – Energy Demand & GHG emissions forecast

The GHG emissions from CIOESTE’s energy sector are presented on Figure 6 below.

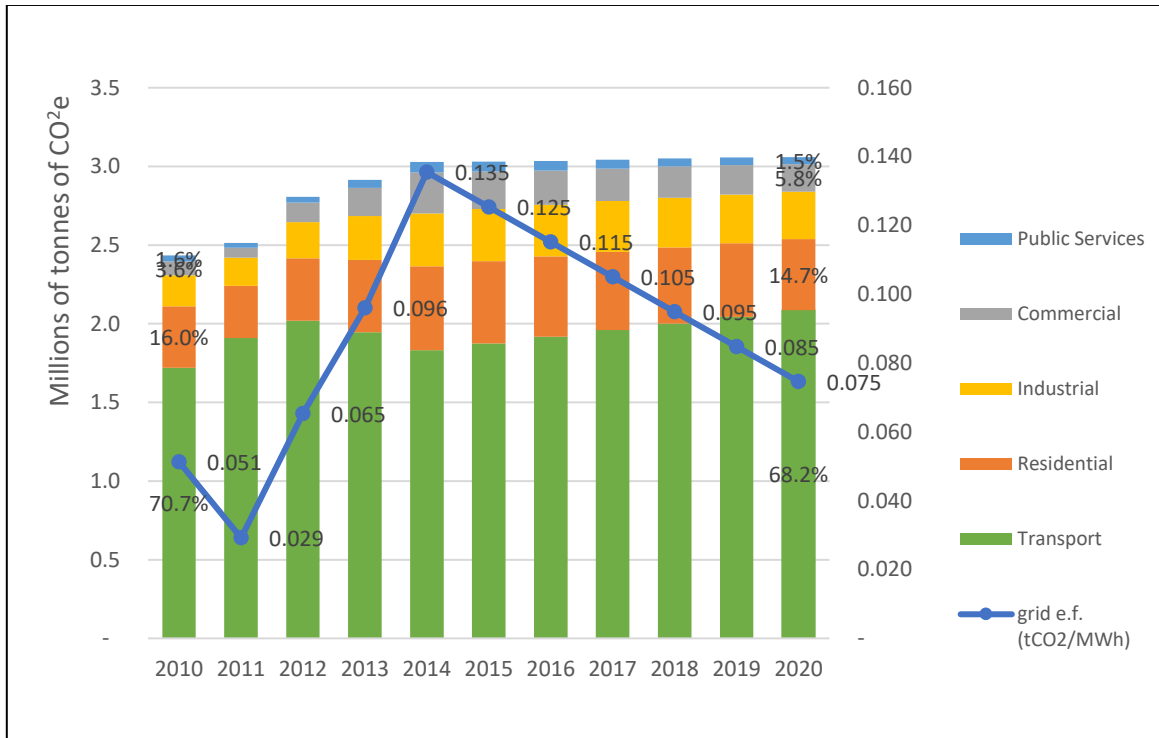


Figure 6 –CIOESTE’s GHG Emissions by sector and with the EF of the grid evolution (BAU)

GHG emissions after 2014 present a small increase (1.0%) because the increases in energy demand are compensated by the decrease in the grid’s EF. When comparing GHG emissions from 2010 with 2020’s forecast we notice an increase of 26 % of the GHG emissions from the energy sector.

Figure 7 shows a Grid’s E.F. Increase Alternative, that results in an increase of 42 % of total GHG emissions when compared with the base year (2010). of the grid’s EF, from 0.051 to 0.135 kg/CO₂e, represents 400,000 t CO₂e per year in 2020 (12% increase in total GHG emissions).

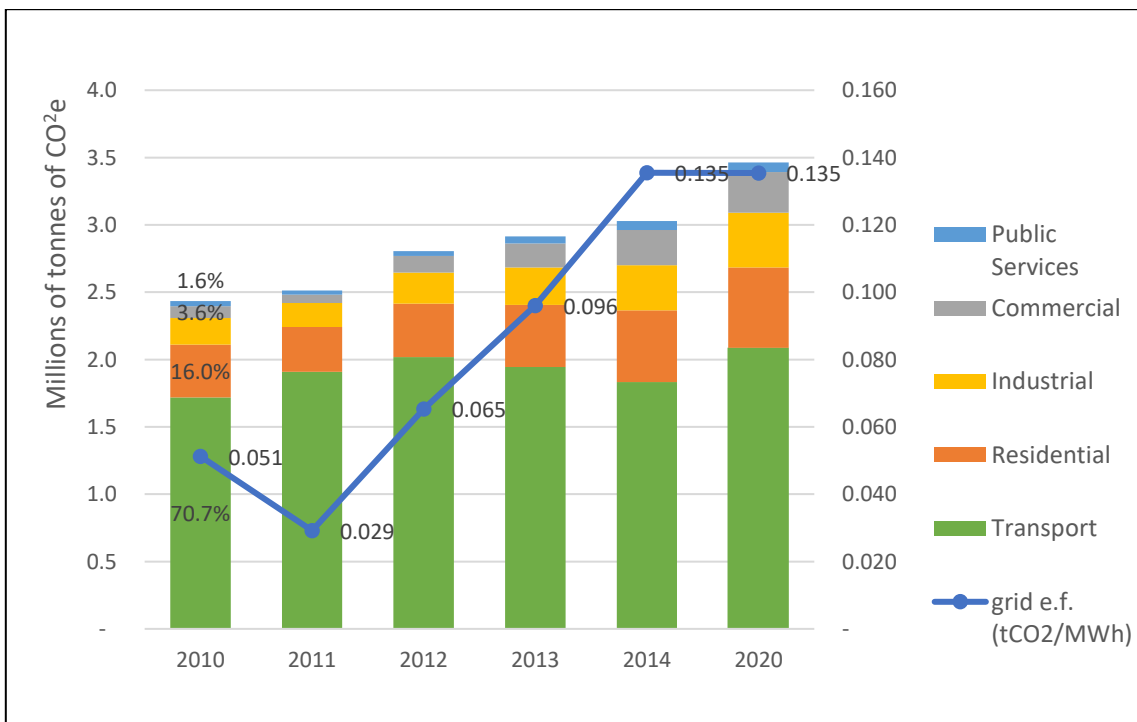


Figure 7 –CIOESTE’s GHG Emissions by sector and with the EF of the grid evolution (Grid’s E.F. Increase Alternative)

The biofuel mixture increase scenario are presented in Figure 8 below.

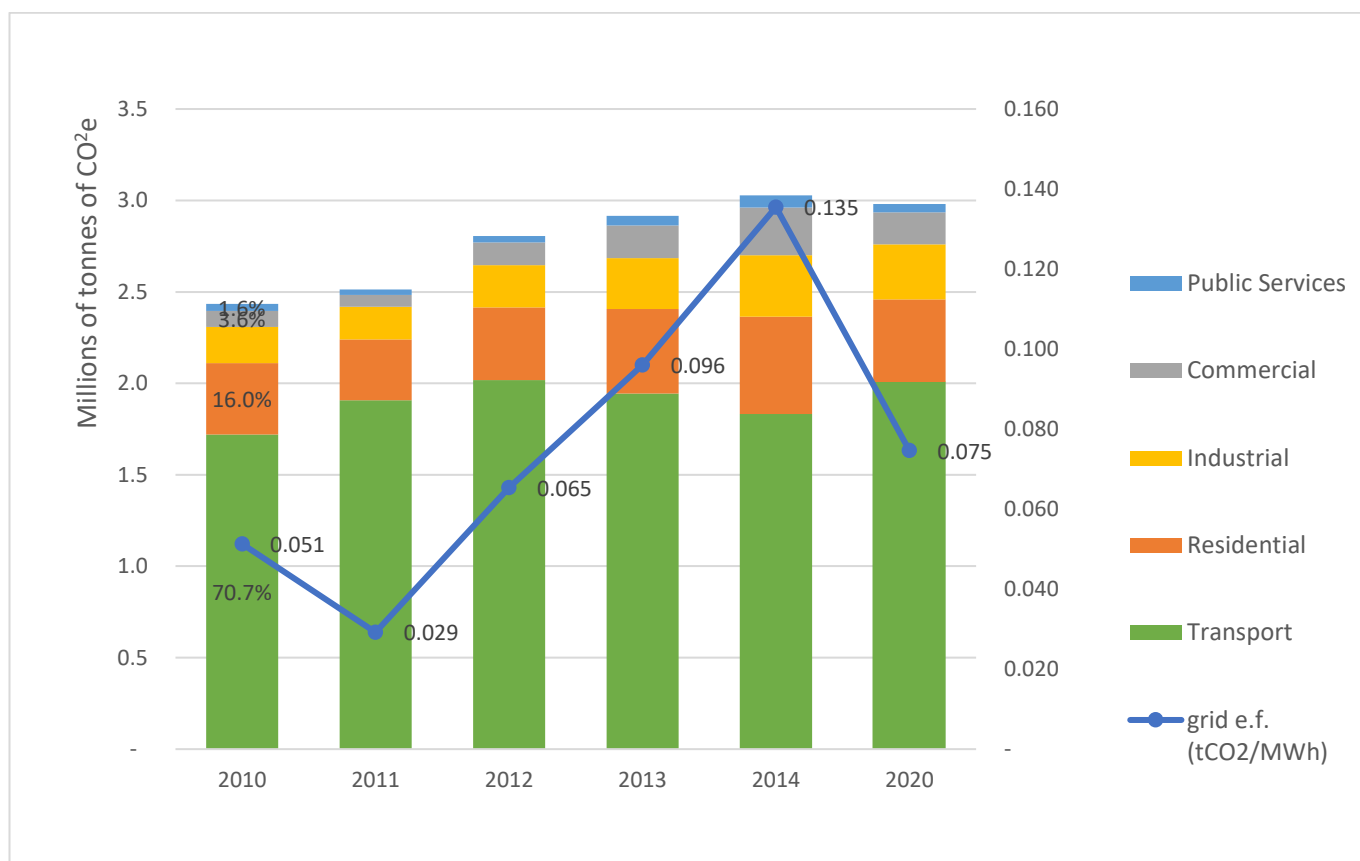


Figure 8 –CIOESTE’s GHG Emissions by sector and with the EF of the grid evolution (Biofuel mixture increase alternative)

The biofuel addition to the commercialized gasoline and diesel resulted in a GHG emission’s increase of 22% when compared to base year (2010) and a reduction of 1.6% when compared to 2014’s GHG emissions. When comparing with the BAU, the GHG emissions reduction is 79,000 t CO₂e per year in 2020 (2.7% decrease in relation to total GHG emissions of the BAU).

6. Discussion

As a first outcome, the present work provides a projection of GHG emissions of CIOESTE’s region for 2020 to help decision makers and policy developers to understand the impacts that national policies have under their jurisdiction. When comparing the alternatives with the BAU projection, it was possible to evaluate the impact on GHG emissions variation in 2020 that resulted from the increase of biofuels in commercialized gasoline and diesel as proposed at the federal level. The assessment also quantified the order of magnitude related to the carbon intensity variation of the EF of the electricity grid.

The main driver for the GHG emission reduction observed in the BAU (Figure 6) lies on a premise regarding the grid’s EF (EF) which considers a progressive decrease towards 2010’s value. Although the assumption is reasonable and can be backed by the grid’s EFs of the last two years (2015 and 2016), this trend can change dramatically due climate variations, such as the one occurred in 2014 adding a high risk to a subnational commitment of GHG emissions reductions that encompasses indirect emissions from electricity generation.

The increase of biofuel percentage in gasoline and diesel resulted in a reduction of 2.7% of the GHG emissions from the energy sector when compared with BAU. This measure corresponds, in absolute terms, to a reduction of approximately 80,000 tonnes of CO₂e per year.

Both alternatives evaluated indicates that subnational governments in Brazil are susceptible to GHG emissions variations that are not under their control. Therefore, any kind of commitment involving those GHG emission sources will require alignment with the national energy regulatory framework and plans. Otherwise there will be a risk that even successfully deployed mitigation measures wont contribute towards Cities' reduction pledges. As an example, when using exclusively GHG emissions targets the energy savings obtained from a successful energy efficiency policy could be clouded by the increase of the carbon intensity of the electricity grid EF.

Most of the cities in brazil that already have a municipal climate change policy in place, adopts reduction targets that does not differentiates GHG emission that are under the municipal jurisdiction from those outside their control. The present analysis present preliminary quantifications over those emissions generated by sources outside the local jurisdiction, indicating the importance of proposing a new metric for GHG emissions target that is compatible to the decisions that are under local government jurisdiction.

7. Acknowledges

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