Analyses and Modeling Energy & GHG Balance for Sustainable Enegy Planning

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Abstract: *The objective of this study is to analyze and determine the architecture of an energy and greenhouse gas balance addressed to Araçatuba's Administrative Region, located in Sao Paulo, Brazil. The used methodology has two aspects: the energy variables, where the research and calculation procedure are essential to consolidate data from several agencies involved in the sector, and environmental variables which the procedure is to use methodologies developed by IPCC where specific data from the region under study is used, when possible. Thus, in 2008, results that local production of energy is 5,667.1 × 103 toe, value much superior to the regional consumption that is 659,8 toe. For the GHG emissions values, -872,55 Gg CO_2 was generated from combustion, 84.60 Gg CH4 from cattle and 10.79 Gg N_2O from crops. All these emissions converted into CO_2e result a total of 4,267 Gg CO_2e. From these results it is concluded that the region is potentially an environmentally friendly area that has potential for sustainable development.*

Keywords: Energy resources, Power generation planning, Environmental factors, Global warming and Sustainable development

INTRODUCTION

The concern over global warming has raised the need for more rational use of energy and alternative energy sources. Planning to meet these needs, instruments that quantify consumed and supplied energy and identify locations of consumption is what an energy balance seeks to provide, a solid database for policy makers.

With the increasing attention to climate changes, another type of balance became necessary, one that tracks data related to greenhouse gas emissions.

The Energy and GHG Balance of Araçatuba is a response to the needs for data and information on the supply and consumption of energy and their intrinsic relationship with the environment of Araçatuba's Administrative Region (from portuguese, RAA).

The data was consolidated for each municipality of RAA to plot differences between them, because there are large and small municipalities, each one with distinct characteristics, such as energy consumption, population density, urban and rural population etc.

The RAA comprises 43 municipalities and is located in West Paulista. Has an approximate area of 18,801 km^2 and represents an important pole in hydro power generation of São Paulo state.

In 2008, the region population reached 722,171 inhabitants, in 2000 this value was 672,572 inhabitants. With this, from 2000 until 2008 the population increased by 7.37%, an annual growth of 0.79%.

This balance is based on being a trusted source of information and data to be used as an instrument of studies and analyses, decisions and choices in west of São Paulo. This is achieved by presenting, in a single document, the historical series of supply and consumption of energy and GHG emissions.

In addition to addressing the supply and demand for energy, has also been evaluated soil usage, CO_2 emissions from combustion of fuel energy, N_2O emissions from agricultural crops, CH_4 emissions from cattle and CO_2 and CH_4 emissions from reservoirs in large hydro power plants.

METHODOLOGY

In this paper are described two types of methodology, one related to data acquisition and the other to GHG calculations. All the values are specified for each municipalities of RAA.

A. Data Acquisition

The main data source was ANP (from portuguese, Agência Nacional do Petróleo, Gás Natural e Biocombustíveis). ANP provided the consumption from 2000 until 2008 for the following fuels: gasoline, hydrous ethanol, diesel oil and LPG [10]. The values for natural gas were obtained from [47-48]. Other fuels such as fuel oil and kerosene were estimated from the data found in [1].

For the municipal electricity energy consumption, data were found in [1] and [8].

The land occupied by livestock (for grazing), agricultural crops and cattle population were obtained from IEA (from portuguese, Instituto de Economia Agrícola) for the years 2000 to 2008 [7].

The firewood and charcoal consumption were obtained indirectly for RAA from land use of Pines and Eucalyptus, found at [7], together with the consumption of these two energy sources in the State of São Paulo found at [14]. It was considered that these energy sources consumption are provided by internal supply which depends on vegetation of pines and eucalyptus available (land use). In this way, relating energy consumption and specific land use from state of São Paulo with land use from RAA, the consumption of these energy sources for RAA were obtained.

B. Calculation Procedures

The calculation was based on [3] which explain in detail the methodology.
The equation is:
$N_2O_{SOILS} = N_2O_{DIRECT} + N_2O_{PASTURE} + N_2O_{INDIRECT}$, where:
N_2O_{SOILS}: Total amount of N_2O emitted, in kg N_2O-N;
N_2O_{DIRECT}: Direct N_2O emissions from agricultural crops, in kg N_2O-N = $(F_{SN} + F_{AW} + F_{BN} + F_{CR}) \times E_{F1} + F_{OS} \times E_{F2}$:
F_{SN} = synthetic nitrogen applied to agricultural soil, in kg N = 0;
F_{AW} = nitrogen present in the manure used as agricultural fertilizer, in kg N = 0;
F_{BN} = nitrogen fixed biologically, in kg N = 2 x $Crop_{BF}$ x $Frac_{NCRBF}$;
$Crop_{BF}$ = soybean production, in kg of dry matter;
$Frac_{NCRBF}$ = nitrogen content in soybean cultivation, in kg N/kg of fry matter = 0.03 (IPCC, 1997);
FCR = nitrogen present in the former cultural that return to the ground, in kg N = $[(2 \times Crop_{BF} \times Frac_{NCRBF}) + (2 \times Crop_0 \times Frac_{NCR0})] \times (1 - Frac_R) \times (1 - Frac_{BURN})$;
$Crop_0$ = production of all cultures, except soya, in kg of dry matter;
$FracNCR_0$ = nitrogen content in crops not associated with nitrogen fixation by bacteria, in kg N/kg of dry matter = 0.015 (IPCC, 1997);
FracR = fraction of total biomass of culture that is removed from the field as harvest, in kg N/kg of total harvested biomass = 0.45 (IPCC, 1997)
$Frac_{BURN}$ = fraction of former cultural burnt in kg N/kg N in residue = 0.25 (IPCC, 1997);
EF_1 = direct emission factor of nitrogen applied to agricultural soil, in kg N_2O-N/kg N applied = 0.0125 (IPCC, 1997)
F_{OS} = area of organic soils cultivated – Histosols, in hectare;
E_{F2} = emission factor for digestion of organic soils due to its cultivation, in kg N_2O-N/ha = 7 (IPCC, 1997)

- $N_2O_{PASTURE}$: N_2O from soil fertilization by cattle (pasture), in kg N_2O-N:

This emission takes into account the types of livestock. As no information related to them were found, was not possible to follow the IPCC methodology. To achieve indirectly the values of this emission, a Brazilian study case previously released [3], where the methodology was entirely executed, was used as reference. The following procedure describes the process used to reach the desired information based in [3]:
$N_2O_{PASTURE} = E_{MILKRA}A + E_{CUTRA}A$; K_{MILK} = RMILKMCT / E_{MILKMC}T; $E_{MILKRAA} = R_{MILKRAA} / K_{MILK}$
Where:
$R_{MILKMCT}$: dairy cattle flock of São Paulo, available in [3], in head of cattle; $E_{MILKMCT}$: emission from dairy cattle flock in São Paulo, available in [3], in kg N_2O-N; $R_{MILKRAA}$: dairy cattle flock in RAA (IEA, 2009), in head of cattle; K_{MILK}: emission factor of dairy cattle, in head of cattle /kg N_2O-N; $E_{MILKRAA}$: emission from dairy cattle in RAA, in kg N_2O-N; E_{CUTRAA}: emission from beef cattle in RAA, in kg N_2O-N; Similar process for beef cattle.
$N_2O_{PASTURE}$ emissions for the years 1989 to 1995 extracted from [3] permitted to obtain a constant factor for both livestock, dairy and beef. Resulting in the following factors: K_{MILK} = 1.58730 head/kg N_2O-N e K_{CUT} = 1.288659 head/kg N_2O-N.

- $N_2O_{INDIRECT}$: Emission, which considers the atmospheric deposition of NH_3 and NO_x and leaching and runoff in kg N_2O-N:

This emission has not been considered due to lack of data but EMBRAPA (2002) [3] calculated this type of emission and the values of $N_2O_{INDIRECT}$ could increase by 40% the total amount of N_2O emissions depending the regional statistics.
The results are expressed in N_2O-N. To convert it to N_2O is necessary to multiply it by 44/28. (IPCC,1997)
Twenty-nine agricultural crops were considered for the calculation and the dry matter values were extracted from [3].
Table 1 shows the agricultural crops used and the percentage of dry matter of each one.

TABLE I - DRY MATTER FROM TYPICAL AGRICULTURAL CROPS

Culture	Dry matter	Culture	Dry matter
Avocado	25.0%	Orange	12.3%
Pineapple	14.6%	Lemon	9.7%
Cotton	93.5%	Papaya	9.3%
Garlic	36.2%	Castor beans	91.5%
Peanut	93.5%	Cassava	38.0%
Rice	87.6%	Mango	16.5%
Banana	24.6%	Watermelon	6.4%
Sweet Potato	35.0%	Melon	7.2%
Coffee	80.0%	Corn	89.4%
Forage Sugarcane	23.2%	Soya	89.8%
Sugarcane	89.0%	Sorghum	89.0%
Kaki	22.9%	Tangerine	12.2%
Onion	21.8%	Tomato	6.2%
Bean	87.4%	Grape	18.4%

Source: (EMBRAPA, 2002)

C. Calculation of CO_2 Emissions from Combustion of Fuel Energy

To calculate CO_2 emissions (carbon dioxide) a Top-Down approach was used [4,5].
Top-Down calculations consider only the final energy source consumption without worrying about the final use. The difference between final use and final consumption is the way the energy source is applied, if it is in combustion or in chemicals reactions. This impact in different emissions factors by unit of determined energy source.
IPCC recommends using Top-Down approach in countries that do not have adequate statistics on energy sources consumption.
The general equation used is displayed below:

$$\omega = 10^{-3} * \{[(\alpha + \beta - \chi - \delta - \varepsilon) * \varphi * \gamma] - \eta\} * \lambda * 44/12$$

Where:
ω = real annual CO_2 emission (Gg CO_2); α = annual production of primary energy, measured in original unit; β = annual primary and secondary import energy, measured in original unit; χ = annual primary and secondary export energy, measured in original unit; δ = annually loaded energy into international bunkers, measured in original unit; ε = Annual change of energy supplies (positive, if increased inventories), measured in original unit; φ = conversion factor to convert originals units to terajoules (TJ/original unit); γ = carbon emission factor per unit of energy in the fuel (t C/TJ); η = annual quantity of carbon stocked in non-energetic products (t C); λ = carbon fraction actually oxidized in combustion
Table 2 shows the carbon emission factor (γ) by energy source.

TABLE II - DRY MATTER FROM TYPICAL AGRICULTURAL CROPS

Energy Source	**Emission factor (tC/TJ)**
Gasoline	18.9
Aviation Kerosene	19.5
Illumination Kerosene	19.6
Diesel Oil	20.2
Fuel Oil	21.1
LPG	17.2
Asphalt	22.0
Anhydrous Ethanol	14.81
Hydrous Ethanol	14.81

Source: (COPPE, 2002)

D. Calculation of CH4 Emissions from Cattle

The calculation is based on methodology developed by the IPCC and the parameters used are those provided by the IPCC (1996) for Latin America and those estimated by EMBRAPA (2002) [17].
Through these parameters and those related to the Brazilian Southeast region, the following factors calculated in [17] were used (table 3).

TABLE III - EMISSION FACTOR OF CH4 BY TYPE OF CATTLE

Source	Type of cattle	Emission of CH_4 (kg CH_4/head/year)
Enteric Fermentation	beef	60
	dairy	65
Manure	beef	2
	dairy	5

Source: (EMBRAPA, 2002)

By multiplying the number of livestock by each one of the factors in the table above, the total emission of CH_4 in the year due to livestock can be found.
More details concerning the methodology can be found in [17].

E. Calculation of CO_2 and CH_4 Emissions from Reservoirs in Large Hydro Power Plants

Lima (2002) estimated CO2 and CH4 emissions in various reservoirs in Brazil. None present in RAA was estimated, for this reason the emissions in RAA were estimated based on Lima's results.
Lima (2002) reached a power law relation of aquatic plants area by years after inundation. The relative area of aquatic plants is used to estimate CH_4 emissions. With this data, this assessment assumes that this function also serves to CO_2 emissions, and that even the curve being drawn according to reservoirs from Brazilian northern region, it suits to reservoirs in RAA.
Fig. 1 shows the power law relation used to calculate CO_2 and CH_4 emissions in RAA's reservoirs.

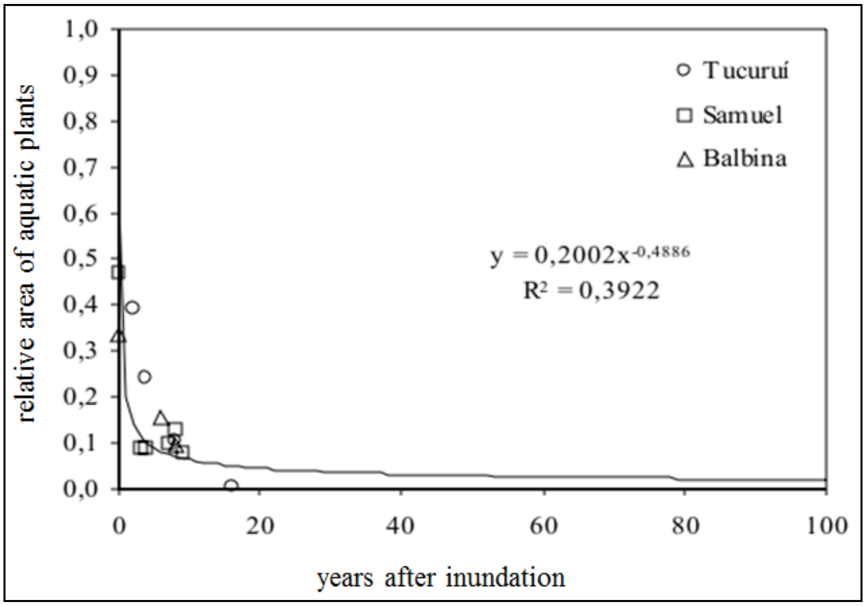

Fig. 1. Power law relation of aquatic plants area by years after inundation in Amazon's reservoirs. Source: (LIMA, 2002)

To exemplify the calculation, the following procedures were made:
K_{BB} = use of the power law relation (Figure 1) with x = 36 (1999 - 1963) = 0.034757991; $K_{CH}4$ = 22.6 (measurement of CH_4 from reservoir Barra Bonita presented in Table IV) / K_{BB}; K_{CO2} = 1537 (measurement of CO_2 from reservoir Barra Bonita presented in Table IV) / K_{BB}; K_{UHERAA} = use of the law power relation from Figure 1 with x = (actual year – entry year); $E_{CH4UHERAA}$ = K_{UHERAA} x K_{CH4} x A_{UHE}, in kg CH_4/day; $E_{CO2UHERAA}$ = K_{UHERAA} x K_{CO2} x A_{UHE}, in kg CO_2/ day; A_{UHE} = Flooded area by the reservoir (available in Table IV), in km^2.
More information can be found in [19] and [20].

TABLE IV - SAMPLES OF TIMES ROMAN TYPE SIZES AND STYLES

Reservoir	Flooded Area (km^2)	Operation entry year	Measurement (1999) - kg/km^2/day	
			CH_4	CO_2
Barra Bonita	312	1963	22.6	1537
Ilha Solteira	1357.62	1978	-	-
Nova Avanhandava	218.05	1982	-	-
Três Irmãos	659.59	1993	-	-
Jupiá	321.68	1974	-	-

RESULTS

A. Production and Consumption of Energy Sources in RAA

Sugarcane production is very strong in the region, from 2005 until 2008 the number of sugarcane plants with nonzero production, jumped from 13 to 20. This reflects the production of Hydrous Ethanol which also increased considerably in parallel with the increase in the quantity of sugarcane plants. The number of sugarcane plants in RAA with nonzero production is showed in Figure 2 and the production of ethanol is in Figure 1.

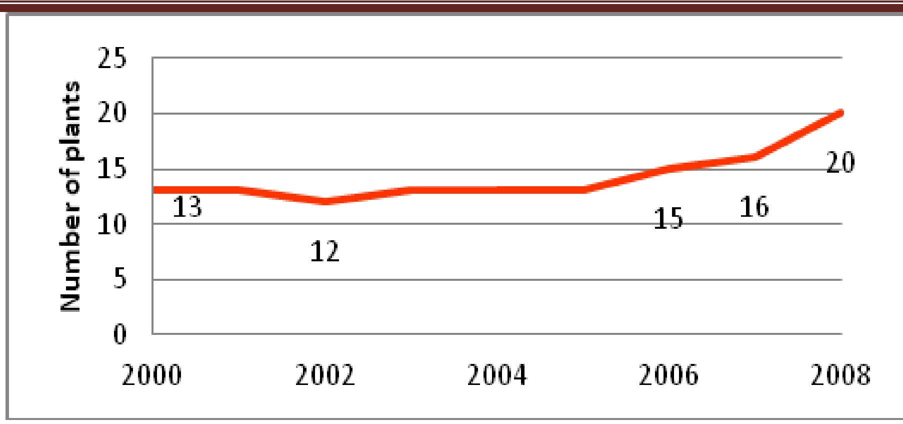

Fig. 2. Number of sugarcane plants in RAA with nonzero production. Source: (UNICA, 2009)

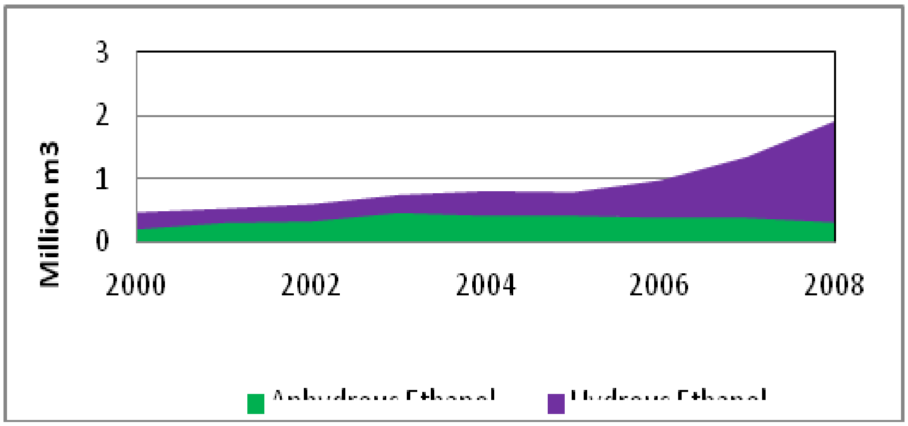

Fig. 3. Ethanol production in RAA. Source: (UNICA, 2009)

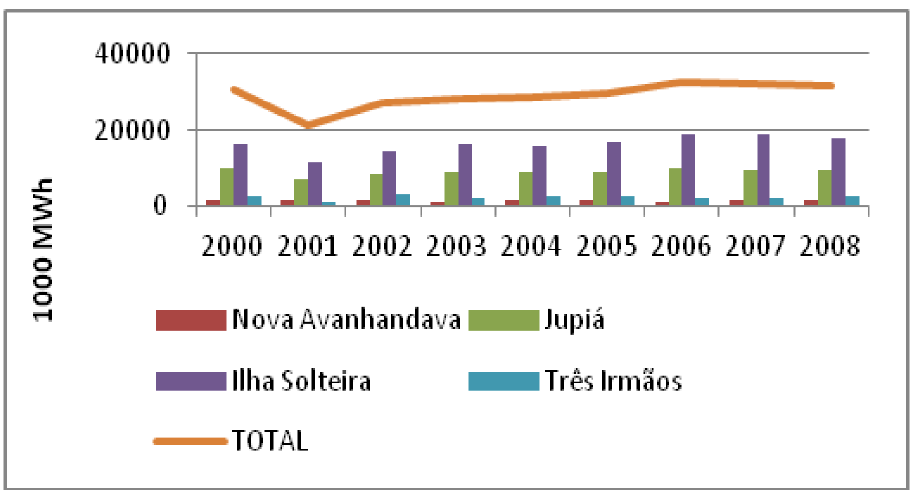

Fig. 4. Hydro power generation in RAA (MWh). Source: (SSEESP, 2009)

In addition to ethanol production, hydro power generation is also a differential of the region, containing four large hydro power plants: Ilha Solteira (3,440 MW), Jupiá (1,551.2 MW), Três Irmãos (807.5 MW) and Nova Avanhandava (347.4 MW). In addition to that, in 2008, the region had others 16 thermal power stations. In total, RAA has 6,366.3 MW installed which is equivalent to 32.6% of São Paulo capacity. Figure 4 shows the generation of the 4 large hydro power plants for the years 2000 to 2008.

In the year 2001, a power generation reduction occurred because of the low reservoirs levels caused by an unusual long dry season in the Brazilian southeast region. The power generation was 30% lower when compared to the year 2000.

The pipeline whose origin is in Bolivia (Gasbol pipeline) crosses several municipalities of the RAA, but the municipality of Araçatuba is the only one supplied with natural gas.

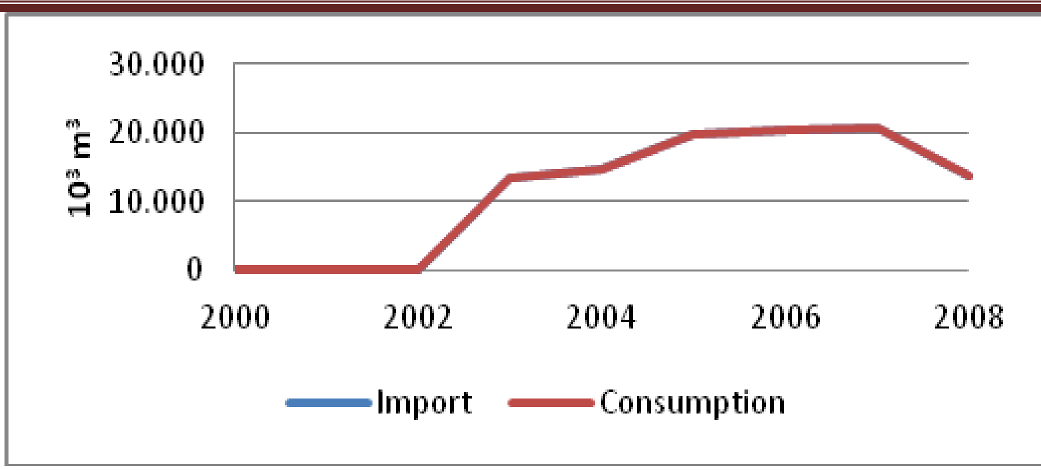

Fig. 5. Natural Gas consumption in RAA. Source: (ANP, 2009)

Figure 5 shows the consumption of natural gas in Araçatuba. It is possible to see that the natural gas distribution started at the end of 2002; from 2002 until 2007 the growth was impressive, however in 2008 consumption fell over than 30%. The Industry sector is the natural gas main consumer and the second is the transportation sector.

Currently sales of flex-fuels cars are much higher than cars moved only by gasoline, not only in RAA but as well in Brazil. As the region is a big ethanol producer, the price of this energy source has a big advantage over the gasoline price as can be seen in figure 6 below. In this figure, the gasoline and ethanol prices are compared.

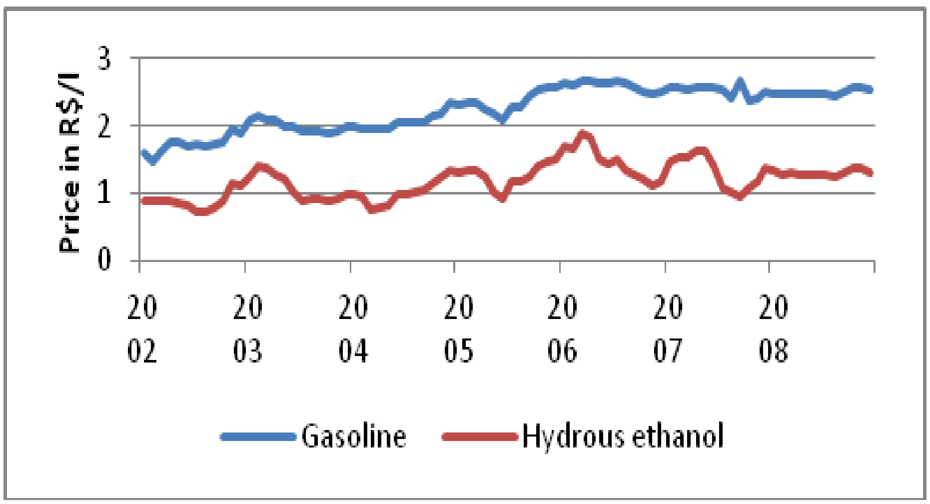

Fig. 6. Evolution of ethanol and gasoline prices in Araçatuba (Brazilian currency Real/liter). Source: (ANP, 2009)

As the ethanol is cheaper than the gasoline, as shown in figure 6, ethanol is gaining market quickly, with a very fast growth over the past years. Figure 7 presents the consumption of anhydrous ethanol (25% of gasoline composition, in Brazil) and hydrous. The hydrous ethanol is directly used in the flex-fuels cars.

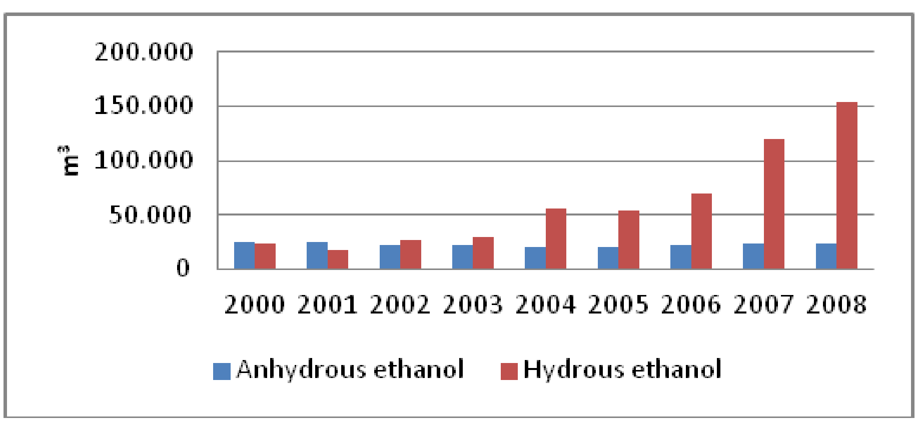

Fig. 7. Ethanol consumption in RAA (m3). Source: (ANP, 2009)

The total consumption of energy sources is show in figure 8. The petroleum products, which are entirely imported to the region, continue to be the main energy source consumed in RAA. However, over the years the increased production and use of ethanol has caused reduced use of petroleum derivatives.
The Diesel Oil is the main Oil product used because it is used in large quantities in trucks and tractors in agricultural areas.

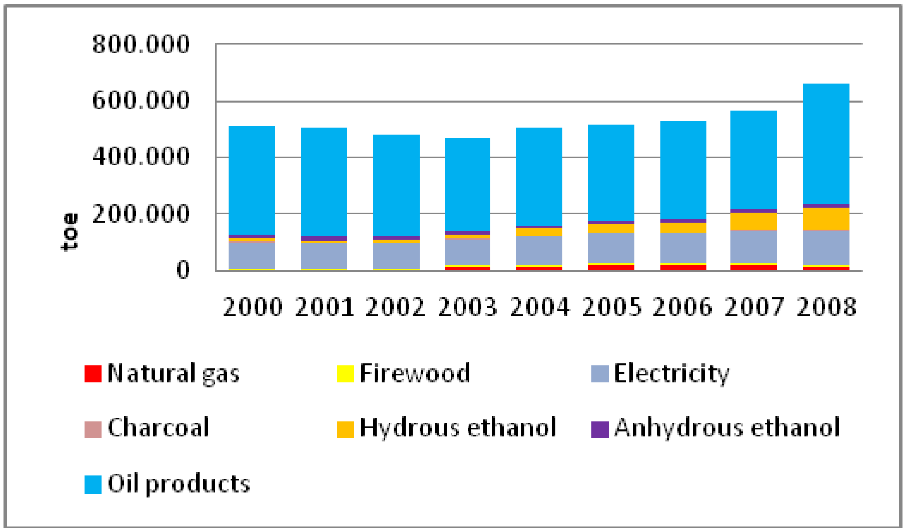

Fig. 8. Energy sources consumption in RAA (toe). Source: (ANP, 2009) and (SSEESP, 2009)

B. Soil Usage

Soil usage represents the footprint of RAA towards socioeconomic activity with emphasis on agricultural crops, mainly sugarcane.
The region has a total area of 1,880,000 ha. In 2008, at least approximately 80.6% or 1,514,531 hectares of the total area was occupied by agricultural crops, peaking in 2004 with 90.7% or 1,705,477 ha.
Figure 8 shows that areas with sugarcane and pastures are predominant in the region. This reflects the high productivity of sugarcane and the cattle population. There are a big variety of agricultural crops in RAA, but their occupied areas are very small when compared to sugarcane and pasture ones.

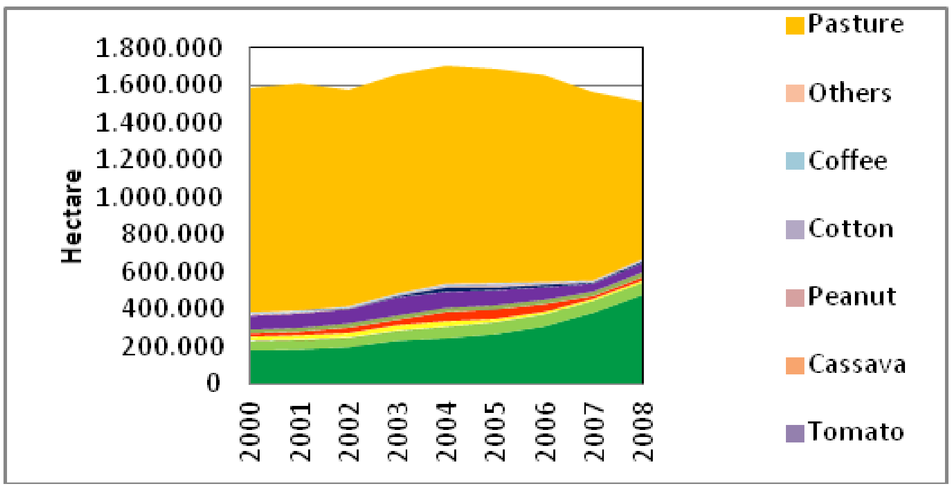

Fig. 9. Soil usage with agricultural crops in RAA (ha). Source: (IEA, 2009)

Areas with pasture are losing land for the production of sugarcane. Corn, which has a significant plot, also appears to lose land. Its area was, in 2000, 74,035 hectares and in 2003, 97,689 hectares. Over the years, till 2008 reached 47,848 hectares, a reduction higher than 35% compared to the 2000 values.
Greenhouse Gas Emissions
Today we have the evidence of the relationship of global warming with anthropogenic emissions of greenhouse gas, this being the main reason for concern about global climate change (GCC), that is the reason to track GHG emissions and thereby create mechanisms to reduce emissions of the main gases that cause this global phenomenon.

The main six GHG identified in the context of the Kyoto Protocol are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFC) and perfluorocarbons (PFC). In this this balance are estimated emissions of three of these gases: CO_2, N_2O and CH4.

The CO_2 is responsible for 60% of the greenhouse effect and their stay in the atmosphere comes to hundreds of years, being produced on a large scale by the combustion of fossil fuels. For this reason it is the anthropogenic gas with the greatest influence on global warming.

The N_2O participates with 6% of the greenhouse effect and it is released by micro-organisms in the soil from the nitrification process. Its concentration is due to, fundamentally, intense use of fertilizer nitrogen compounds.

The CH_4 is the major component of natural gas and its main source is from geological deposits known as natural gas fields. An alternative method to obtain methane is via biogas generated by the fermentation of organic matter. The livestock sector produces methane because of the digestive processes of the animals. Today we have the evidence of the relationship of global warming with anthropogenic emissions of greenhouse gas, this being the main reason for concern about global climate change (GCC), that is the reason to track GHG emissions and thereby create mechanisms to reduce emissions of the main gases that cause this global phenomenon.

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C. CO_2 Emission from Combustion

CO_2 emissions are classified as either biogenic - BE, or non-biogenic - NBE. BE are derived from biomass combustion and do not contribute to the greenhouse effect since the equivalent vegetable matter used is replaced, because the process of photosynthesis removes from the atmosphere the corresponding quantity of carbon released in combustion. There is a consensus that the use of biomass as energy in a renewable system effectively, i.e. with replacement of the used biomass, results in a zero CO_2 emission balance. For this reason the charcoal and firewood (BE) emissions are computed as zero because it is supposed that in RAA the consumption is the same as its internal production. NBE are related to combustion of others energy sources, as petroleum derivatives, coal and natural gas.

Figure 10 shows CO_2 emissions from combustion of fuel energy. When ethanol production is considered, the CO_2 emissions in RAA become negative because the volume of produced ethanol is higher than the total RAA energy consumption. The ethanol production in RAA is destined for the Brazilian market. The ethanol production is treated as a negative combustion because sugarcane crop absorbs carbon from the atmosphere.

The year 2006 was the first year that the CO_2 emissions became negative. While the total energy consumption was almost the same as in the year 2005 (figure 8), the ethanol production increased (figure 7). In the years 2007 and 2008, both the ethanol production and the energy consumption have increased, but the first one increased much more, resulting in a negative CO_2 emission.

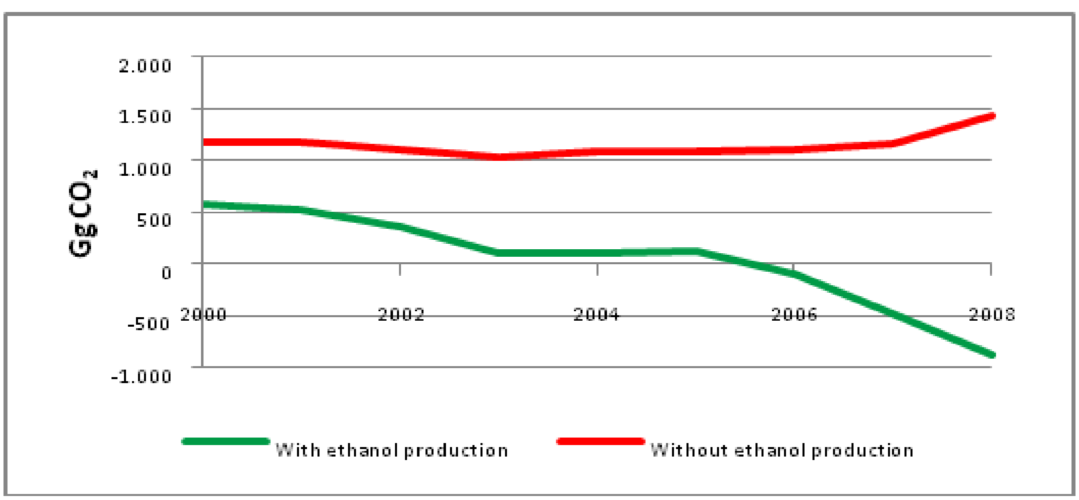

Fig. 10. CO_2 emissions from combustion of fuel energy in RAA (Gg CO2)

D. N_2O Emission

One molecule of N_2O has warming potential 296 times greater than one molecule of CO_2 (IPCC 2001), however their real impact contributes less to global warming because the N_2O concentration in the atmosphere is a thousand and two hundred times smaller than the CO_2 concentration.

Due to many agricultural crops and the significant increase in the intensity of land use in RAA for sugarcane crop, it is interesting to analyze the N_2O emissions.

Figure 10 presents the N_2O emissions from the main agricultural crops in RAA. As can be seen in the figure, the sugarcane is the main source of N_2O emission in RAA. In the same time it impacts negatively in the CO_2 emissions (figure 11), it increases significantly the N_2O emission.

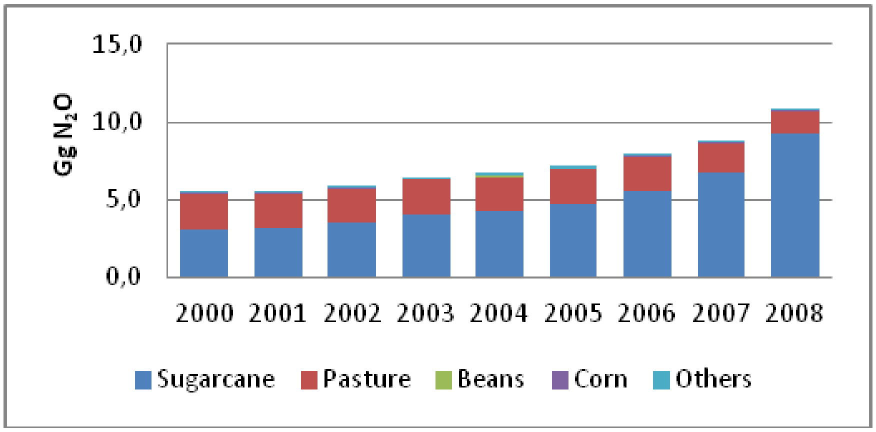

Fig. 11. N_2O emission in RAA (Gg CO2)

E. $CH4_2$ from Cattle

In RAA there is a high volume of CH4 emissions due to the large population of ruminants (cattle). In 2000, approximately 64% of the total area of the RAA was composed with pasture, in 2007, this value passed to 53% and in 2008 was estimated in 36%.

CH_4 emissions from cattle may be divided into beef and dairy, and subdivided into enteric and manure. Their values depend directly on the number of animals.

Figure 12 presents the cattle population in RAA for the years 2000 to 2008 and figure 13 presents the calculated emissions assuming the subdivisions above.

The results show that the CH_4 emissions related to the enteric origin are 30 times higher than those related to the manure origin (table IV), expressing how intense is the CH4 production in the ruminant digestive process. The IEA categorizes the cattle into 3 types: dairy, beef and mixed. In this balance, the mixed cattle was considered as the same as the beef cattle because there is no such classification in the IPCC methodology. The mixed cattle are the mix between the beef and dairy cattle.

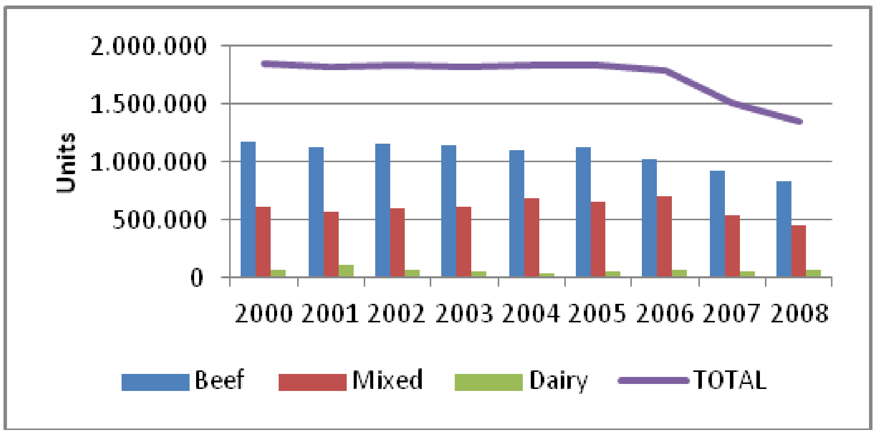

Fig. 12. Cattle population in RAA. Source: (IEA, 2009)

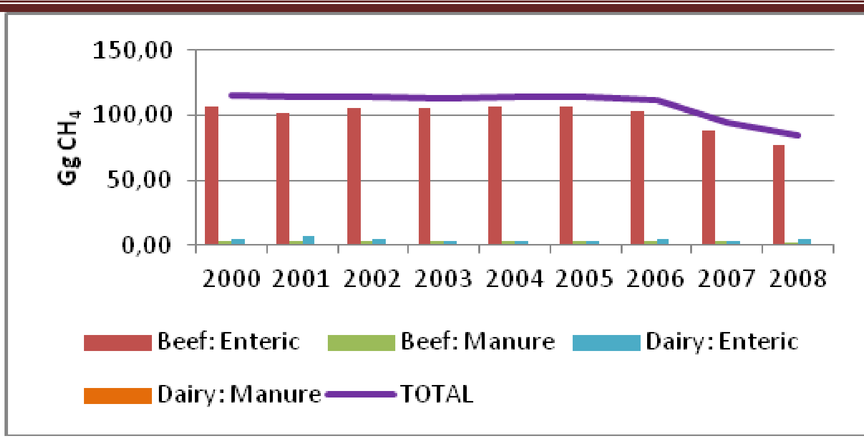

Fig. 13. CH_4 emission from cattle in RAA (Gg CH_4)

F. Emissions of CH_4 and CO_2 from Reservoir

Emissions from reservoirs are influenced by biological factors (aquatic plants), quality of organic matter and nutrients, activities of bacteria and physical factors.

The emitted gases from reservoirs are due to the decomposition of flooded and formed biomass during the photosynthesis. As the flooded biomass has its carbon inventory being reduced over time, the emissions tends to decrease as well.

Figure 14 and 15 show the CO_2 and the CH_4 emissions from reservoirs in RAA for the years 2000 to 2008. As commented above, the emission volume tends to decrease over the years.

The results show that the Ilha Solteira reservoir is the biggest emitter in RAA, close followed by the Três Irmãos reservoir. One important detail about these two reservoirs is that Ilha Solteira reservoir has 1,357.62 km^2 and Três Irmãos reservoir has 659.59 km^2. Although the Três Irmãos reservoir area is the half of Ilha Solteira reservoir, the emission is slightly lower. The reason for this difference is that Ilha Solteira reservoir is 30 years old while Três Irmãos is 15 years old.

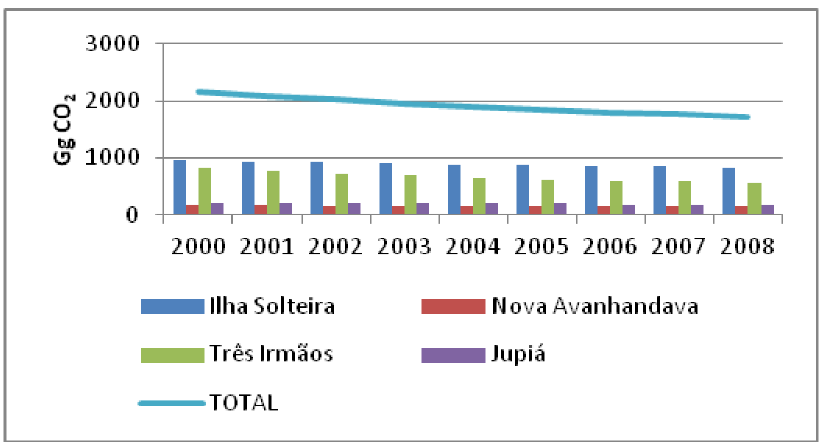

Fig. 14. CO_2 emissions from reservoirs in RAA (Gg CO_2)

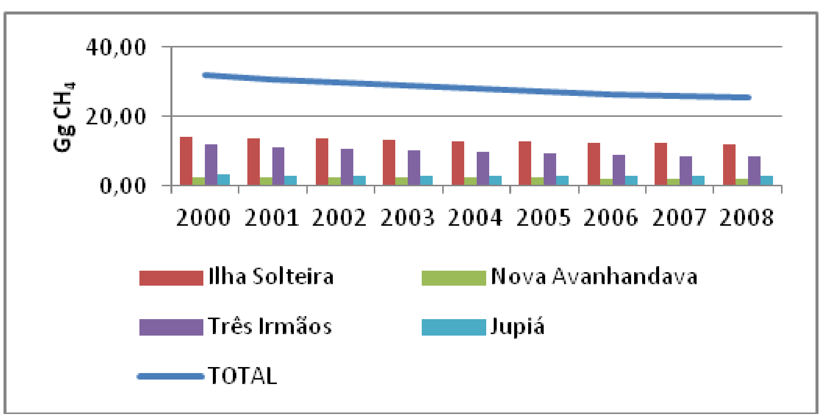

Fig. 15. CH_4 emission from reservoirs in RAA (Gg CH_4)

G. Equivalent Carbon Content

It is possible to "convert" greenhouse gas emissions in terms of CO_2 equivalent. This characterizes the global warming potential (GWP), index proposed by the IPCC that describes the characteristics of GHG.
The GWP compares gases between themselves and their different impacts on the climate. This parameter is a measure of how much a given mass of GHG contribute to global warming. Table V shows the GWP for CH_4 and N_2O.

TABLE V - GWP FOR GHG. SOURCE: (IPCC, 2001)

Gas	Global Warming Potential (Lifetime)		
	20 years	100 years	500 years
CO2	1	1	1
CH4	62	23	7
N2O	275	296	156

Using the "100 years" values, all emissions can be converted to CO_2e, enabling direct comparisons between different gases. Figure 16 presents total CO_2e emissions in RAA. In this figure it is possible to observe that the volume of CO_2 from combustion is very low when compared to the others sources of emission.

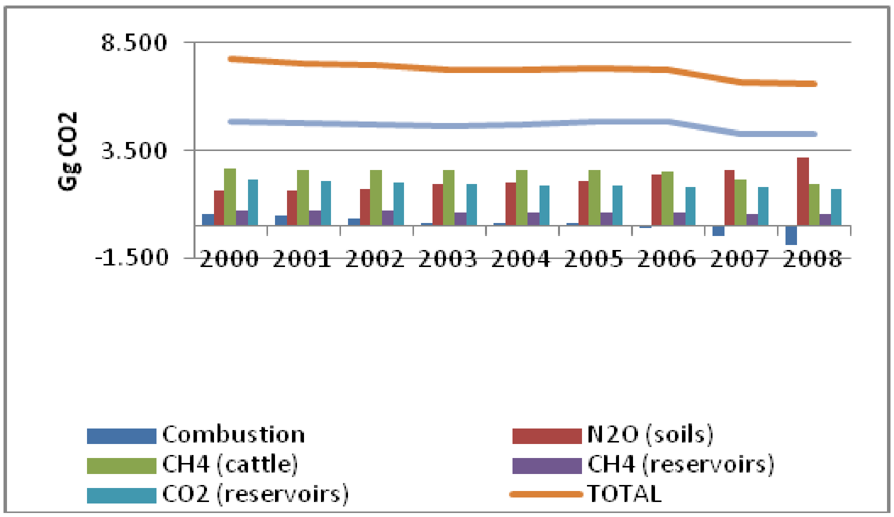

Fig. 16. CO_2e emissions in RAA (Gg CO_2)

The CO_2e emissions from soils are the highest when compared to the others sources analyzed, followed by the CO_2e from cattle. Although the CO_2 emissions from combustion have contributed negatively in the last years, the total emission for the year 2008 is over 6,500 Gg CO_2e. These negative contributions are helping to decrease the total emission over the years, while the expectation is to increase.

CONCLUSION

As the data presented, it is concluded that the RAA is a large producer of renewable energy in contrast to its consumption of fossil energy. In 2008, the main source of energy was petroleum products (427,113 toe), with 64.7% of the total consumption, followed by electricity (122,351 toe) with 18.5% and by anhydrous ethanol (91,292 toe) and hydrous ethanol with 13.9%. Natural gas (12,123 toe) represented only 1.8% of the total. The consumption of ethanol must be evidenced because in 2000 it was only 25,805 toe, i.e., from 2000 until 2008 the consumption increased by 254%.
Analyzing the emissions and disregarding those from reservoirs, in 2000, the cattle emissions (CH_4) was the biggest with 2,653 Gg CO_2e, followed by agricultural crops (N_2O) with 1,631 Gg CO_2e and finally by the combustion of fossil fuels with 589 Gg CO_2. In 2008, the emissions from agricultural crops were ranked first with 3,194 Gg CO_2e, followed by the cattle with 1,946 Gg CO_2e. The "exchange" of the main emission source is a reflection of the sugarcane expansion in RAA and the reduction of the cattle population and pasture land.
It can be concluded that in cities with predominant rural aspects, most impacting emissions are from cultural crops and livestock.
The simplistic introduction to mitigate GHG in this case, unlike the energy sector, is more complex, since they are now discussing livestock and agricultural production, both important for sustaining food for humanity. However it is important to make clear that the sphere of food safety is different from energy and at the same time both have one link in origin in maintenance of human species on the planet.

Analyzing only the RAA, agricultural sector is the main culprit for GHG emissions. On the other hand, when observed globally, emissions from fuels combustion are much higher [13], whose mitigation can be done in various ways such as using alternative and renewable energy sources.

In conclusion, a regional balance that comprehends energy and greenhouse gas emissions delivers important information that can help the analyses of a specific region and can be used as an instrument for policy makers. This paper shows in a simplified way how much data can be gathered that can lead to a more comprehensive vision in the regional ambit.

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