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Emission of CO2 from the Consumption of Electric Power and Fuel in Mato Grosso do Sul: A Data Envelopment Analysis

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Abstract

With the progress of humanity, energy production and consumption has gradually increased over the years. In mid-1970, energy production and consumption started to have importance not only to progress and to the society, but also to the environment and, in this case, its impacts on the environment also increased, causing, for example, greenhouse gas emissions. Thus, understanding the relationship between energy consumption and its effects on society and the becomes essential for companies to achieve the goals of sustainable development. In this sense, the objective of this article is to identify the municipalities of the state of Mato Grosso do Sul with greater efficiency in the years 1991, 2000 and 2010 from the data envelopment analysis of 78 municipalities. As a result, only one municipality has very high efficiency regarding the energy consumption, population density, gross domestic product and fuel consumption and observed a reversal of efficiency between the years of 1991, 2000 and 2010 resulting in a worsening in the efficiency of the municipalities in terms of the relationship of energy consumption and its effects on the population and the environment.

Index terms—

1 Introduction

conomic growth and energy are related topics between themselves, in the light of the modifications of the energy matrix from the industrial revolution and, since then, the use of fossil energy in the world has been growing and creating a link of dependency with the productive sector. In addition to this question, higher energy consumption from the decade of 1970 draws attention to the effects on the environment (ANDRADE and MATTEI, 2011).

The energy consumption is an object of great discussions when it comes to the conditions of developing countries. Being the basis of productive activities, inevitably, the energy consumption causes impacts on the environment. Therefore, if in the past the energy was seen only as an input for the production, currently, is at the center of the debate of environmental preservation (MONTEIRO et al., 2012).

The study of the relationship among energy development, production and consumption and their effects, including greenhouse gas emission (GHG), it is a topic widely discussed in the national and international literature (DOGAN and SEKER, 2016; LIU, 2017) ??GUNEY, 20019).

Some developed studies demonstrate the correlation and even the cause-and-effect relationship among energy consumption and the quality of life and social progress, as is the case mentioned by Palmira et al. ??2018), they describes that investment in renewable energy use benefits the society allowing, including a reduction in the emission of greenhouse effect gases.

In this sense, it is clear that the global model of production and use of energy, mostly depend on fossil fuels, which in turn emit greenhouse gases causing damage to the environment (HINRICHS and KLEINBACH, 2003).

According to the International Panel on Climate Change (IPCC), the advance of anthropogenic emissions of greenhouse gases is the predominant cause of global warming (LEAL, 2015). In a complementary way, the world energy report, produced by the International Energy Agency (IEA), exposes the report of 2018 that the governments of the major world powers have made clear the message that, about to the promises on the issue of climate change, that the use of fossil fuels, particularly natural gas and oil, will continue to be based on the energy system (IEA, 2018).

Continuous Emissions of GHG will cause more heating and have the potential to seriously damage the natural environment, and affect the global economy becoming the most urgent global threat more in the long term for the prosperity and security of future generations (ZHANG, 2016).

The IEA projections indicate that global demand for energy will pass be 17.3 billion tons of oil equivalent (toe) in 2030. In this case, the demand would be met by the supply of sources that emit greenhouse gases in their majority, resulting in greater participation in the global energy matrix in 2030 ??IEA, 2018).

Due to that, the concern with the energy production and use, and their impacts on the environment and society, has gained prominence, allowing the development of actions to improve the energy production and consumption also guaranteeing the reduction of GHG emissions, among them, the CO 2.

The reduction of CO 2 emissions is seen as one of the items of the Sustainable Development Goals (SDGs) of the United Nations Organization (UNO). Goal 7, which deals with clean and affordable energy, establishes that the reduction of emission levels of CO 2 is fundamental to achieving this goal (UN, 2018).

The ODS has been defined also in terms of identifying the need to work the use of energy related to sustainable development. According to UN data (2016), the use of energy from fossil fuels is responsible for around 60% of total GHG emissions, ratifying the importance of production and use of clean energy in order to mitigate GHG emissions and for sustainable development (APERGIS et al., 2018).

Overall there are seventeen Sustainable Development Goals (SDGs) and 169 goals, which range from issues such as, for example, combating poverty through the conservation of biodiversity in rivers, lakes, and oceans (MARCOVITCH, 2016).

In Brazil, the electric energy consumption in 2016 amounted to 460.8 TWh, value 0.9% lower than the one registered in 2015, and the per capita consumption of 2,228 kWhhab -1 . According to EFE (2017), the sectors that contributed most to this reduction were the industrial (-1.3%), followed by energy (-7.7%) and commercial (-2,4%).

In Mato Grosso do Sul (MS), in the last ten years, the main source of energy was water, however, the largest source of energy consumption by the productive sector was the firewood, with 30% of the total, on average. Still, the energy use increased from 5,077.89 tons of oil equivalent (toe) in 2010 to 5,379.66 in 2015, reaching to consume 7,757.77 PTE in 2014, an increase of 5.94% (BEN-MS, 2016).

Regarding the emission of GHG emissions, in 2016, the total number of anthropogenic emissions associated with the Brazilian energy matrix reached 428.95 million tons of carbon dioxide equivalent (Mt CO2-eq), being the largest part (194.3 Mt CO2-eq) generated by the transport sector. In 2010, the carbon intensity of the economy was 0.15 kg CO 2 (US$ppp) -1 . According to IEA (2014), Brazil remains less intense in carbon about European economies (-11%), North American (-50%), and Chinese (-70%). The Brazilian electrical sector issued, on average, 101.3 kg CO 2 to produce 1 MWh of energy, very low index when compared with countries of the European Union (366.2) (489.2) and China (772.1) (EPE, 2017).

The system of Estimates of Emissions and Removals of Greenhouse Effect Gases (SEEG) produces annual estimates of emissions of greenhouse gases (GHG) in Brazil, according to the guidelines of the Intergovernmental Panel on Climate Change (IPCC). From the data of the platform SEEG, 1.58 billion tons of CO 2, being that the change of land use forest was dumped in the country, an increase of 12% compared to the year 2015.

Historically, 83% of the CO 2 emissions in Mato Grosso do Sul, between 2002 and 2014 occurred in function of the sector of land use change. The energy sector is the second sector that emitted CO 2 the most along the historical series, 15.45%, and the fourth and fifth placings, respectively, industry and waste, with 0.93% and 0.004% ??SEEG, 2017).

When disaggregating the MS data of the sectors regarding the emission of CO 2 of the SEEG basis, it is realized that the land use change for farming and other activities represents 83.6% of the total real change of soil, being the main source of induction for the emission of CO 2 in the State. In the case of the energy sector (which belongs to the group of services), the transport activity represents 60.7% of the total of the sector.

The average estimated emission of CO 2 , the group land-use change, is approximately 30.76 million tons and the energy sector of 5,690 million tons. Industrial processes and wastes have an average of 342 thousand tons and 1.43 billion tons of CO 2 . With the record of emissions in 2015 and 2016, MS is in 14th place in the ranking of Brazilian state emitters of CO 2 ??SEEG, 2017).

Due to the emission of GHG emissions in the environment, derived from the production and consumption process, which in turn, demand energy, this article has as objective to identify the municipalities of the state of Mato Grosso do Sul with greater efficiency, being that the interpretation of this efficiency means having good results in the local quality of life with low consumption of electrical energy and fuels.

Thus, the work has sought to describe the effects of GHG emissions in a state that has three biomes (Pantanal, Cerrado and Atlantic Forest), among which two are recognized by ??NESCO (2000) as humanity world heritage. Therefore, the relevance of the work consists of identifying the municipalities that best promote quality of life for its citizens with low power consumption, thus ensuring better conservation and maintenance of natural resources existing in the state.

2 II.

3 Material and Methods

In the present study, the universe considered are 78 cities of Mato Grosso do Sul, where the indicators related to growth and economic development, as well as the consumption of electrical energy in these municipalities will be analyzed. The municipality of Paraíso das Águas was created in 2003 and, therefore, has no data in the same period of research, being thus removed from the survey universe. The historical and comparative statistical methods will serve as auxiliary methods in the search for the identification of the efficiency of the municipal energy consumption.

From the context that energy efficiency can contribute to the environment and the society itself it will be carried out, using data envelopment analysis (DEA), based on secondary data, if there is efficiency in the use/consumption of electric energy in the selected municipalities.

The data envelopment analysis (DEA) was developed by **??**harnes et al. (1978) and is based on the use of linear programming for analysis of measures of comparative efficiencies of the so-called decision making units (DMU), which uses the same inputs to generate the same outputs (ANGULO- MEZA et al., 2005).

The DMU 0 technical efficiency will be achieved through a PPNL (problem of non-Linear Programming), model (1), in which the technical efficiency is obtained by maximizing the division between the weighted sum of "Outputs" (outputs) by the weighted sum of the "inputs" (inputs) (FERREIRA and GOMES, 2009).

(1) subject to:

Where: H 0 = efficiency of DMU 0 ; r = quantity of inputs; s = quantity of outputs; n = number of DMU; y jk = value of the dmu output j k ; x ik = value of the input i for the DMU k ; u j = weight on the output j; v i = weight on the input i; y j0 = value of the output j of the DMU 0 (DMU 0 = DMU observed); x I0 = value of the input of the DMU 0 .

The model (1) involves searching for values for u and v, also called multipliers, which are the weights, to maximize the weighted sum of the outputs (output virtual) divided by the weighted sum of the inputs (input) of the DMU 0 in the present study, subject to the restriction that this ratio is lower than or equal to one, for all the DMU k . This function is subject to the restriction that when the same set of coefficients of you j input and output v i are applied to all other units of services that are being compared, no unit will exceed 100% efficiency, or a ratio of 1.00.

In general, there are two models of DEA: BCC and CCR. The DEA -BCC model is based on the condition of scale variable returns, while the DEA-CCR model is based on constant scale returns. The data envelopment analysis also us to be oriented to inputs or outputs. In the case of being oriented to inputs, efficiency means that there should be reduction of resources, maintaining the same level of production, and the version is oriented toward outputs, remains unchanged the inputs **??**BANKER et al., 1984).

The DEA models may produce DMUs falsely v, because, if the DMU's number is too large, the application of the BCC model, usually results in benevolent results due to the characteristics of the mathematical model, which does not happen with the CCR model (ALI, 1993; ANGULO-MEZA et al., 2005).

In order to avoid the false-positive results the reversed border will be used for the analyzes of the results. The reversed border takes into consideration the reversal between input and output, allowing two interpretations: (i) the inefficient border consists of DMUs with the worst managerial practices, and (ii) that these same DMUs have the best practices, considering the opposite bias (SOARES DE MELLO et al., 2003).

If a DMU has high efficiency, this must be a result close to 1 in the standard default border and low level about the reversed border. Thus, it is not enough for the DMU to have a result considered efficient in what it is considered the best, but also it may not have poor performance when the analysis is its weak points **??**PIMENT et al., 2004).

In addition to the use of the reversed border, the composed border will be used for data analysis, whose result is through the standard border and the inverted one, using the arithmetical average between the standard efficiency, and the value of the complement of reversed efficiency, equation (**??**).

(2)

Those DMUs with efficiencies equal to 1 at the composed border will be considered with ideal levels of efficiencies. In table 1 the ranges of scales of efficiency for the DMUs in analyzes are described, taking as a reference to the ranges of the results of the Human Development Index (I.D.A.) of UNDP. This scale of outcome is adopted due to dealing with I.D.H. as being one of the most robust and accepted parameters for measuring the development, both human and social of a given locality. For the analysis of the use of electrical energy in Mato Grosso do Sul, it takes into account that each of the 78 selected municipalities will be a DMU. The array of variables is given in Table 2. For the calculation of demographic density, it was necessary to calculate year to year, the ratio between the size of the population and the size of the municipality to define this indicator from year to year. For the years 1991, 1995, 1998, 2000 and 2010 the areas of the municipalities are informed and were replicated for the remaining years sequentially. The size of the population of the municipalities, either estimate or census, are made available annually. The consumption of electrical energy, the GDP, and estimation of emission of CO 2 have data for all years.

Due to the data availability, the historical series covers the years 1991, 2000 and 2010. The option for the used variables had as a first criterion to be variables which the UN works on measuring sustainable development through its guide "Sustainable Development Indicators: landmark and methodologies" and second, to be able to describe the variables, population growth and its consequent pressure on the environment, in this case, measured by the CO 2 emission.

Based on the selected variables, it is assumed that these can be considered as primary indicators of CO 2 emission in the cities of Mato Grosso do Sul. Still, the energy consumption and total fuel (petrol, ethanol, diesel and aviation kerosene) remain as proxy variable for the impact on the environment through CO 2 emission.

4 III.

5 Results and Discussion

After the development of the models application, it was possible to observe that the best model, one that showed the best results was the DEA -BCC model, both directed to inputs and products, therefore, was the one that best represented the production border of the DMU's, in the specific case, the municipalities.

In response to the objective of the study, it was chosen to emphasize to the products-oriented models by adopting the bias to produce better results (maximize production), keeping constant the resources, i.e., it is sought to increase the products without changing the inputs.

The main concept regarding the best assessment, i.e., more efficiency, is not the municipality that holds more volume, but rather, the one uses the best resources that the same has. Therefore, the best municipality is the one that shows more efficient allocation of resources and investments, increasing the products/services offered to the local population, and not the one that holds greater absolute volume of resources.

From the results obtained in the DEA _BCC, model, it is noted that there is a reversal of efficiency along the historical series (Table 1). While in 1991, 28% of the 78 cities studied had high and very high efficiencies, in 2010, twenty years later, only 8% reported similar results. Only Jaraguari remained as high efficiency and very high in 1991, 2000 and 2010. In contrast, as the years went by a significant increase of municipalities in the range from very low efficiency was registered, leaving 28% from 78 to 59% of the total.

The year of 1991 can be considered the best of the studied period, because it presents a greater number of municipalities considered of high and very high efficiencies. As hypotheses for these results, the size of the population and the level of economic activity that was relatively minor compared to the year 2000 and 2010, can explain, at least in part, this beneficial effect for the municipalities and the environment.

The municipality of Jaraguari presents itself as the best efficiency considering the historical series, followed by Bandeirantes and Ribas do Rio Pardo. The fact that the ten-best place on efficiency are the municipalities with less than twenty thousand inhabitants, with little dynamic economic matrix.

Regarding the main cities of the State in terms of population, the best place from the geometric mean was Corumbá, in 29th position. Campo Grande, the capital of the State, appears in 43rd position, Dourados in 51st and Três Lagoas in 52nd position.

In the variation among the years considered in the survey, it was noted a significant improvement in the efficiency of the largest municipalities of MS (Table 2). In table 3 the position of each municipality of MS for each year studied is exhibited. From these results it is possible to observe the existence of change for lower in most of the municipalities in the passage of the years 1991 to 2010, and soon after, a slight improvement between 2000 to 2010. This result might have been achieved due to improvements in both energy consumption and by part of the population and economic growth.

More abrupt variations also stand out such as, for example, Bandeirantes, Costa Rica, Inocência, Jardim, Miranda, Nova Alvorada do Sul and Sidrolândia which changed the efficiencies more significantly, both for the purpose of better or worse efficiencies.

Regarding the general index calculated based on the efficiency of municipalities, Jaraguari leads the ranking, followed by municipalities Bandeirantes, Ribas do Rio Pardo, Bataguassu and Chapadão do Sul. Ladário, Santa Rita do Pardo, Douradina, Sete Quedas and Paranhos have the lowest efficiency (Table 4).

Volume XX Issue III Version I The general result reveals no municipality with a result considered as being of full efficiency, one where the combination among the development of the population, environment and society itself happens without loss of structural funds for any one of these variables, However, there have been many municipalities considered of low degree of efficiency.

6 Conclusion

From the use of the data envelopment analysis, it was possible to identify that only the municipality of Jaraguari is the one that presents better results in terms of efficiency and its relationship with the environment.

The existence of a reversal of efficiency between the years of 1991, 2000 and 2010 was observed regarding a larger number of municipalities with very low degree of efficiency and low in 2010 compared with 1991, i.e., a worsening is depicted in the municipalities efficiency considering the variables of energy consumption, population density, GDP and fuel consumption.

Part of this result can be explained by the increase of population and economic growth (measured by GDP) once when there is an increase of these two variables, the trend, ceteris paribus, is that there is greater pressure on the fuel and energy consumption.

Although there are improvements in 2010, the largest cities in the State also presented results of average efficiency, corroborating with the result somewhat positive in terms of emission of greenhouse effect gases in the state of Mato Grosso do Sul.

From this result, the necessity is evident of deepening the construction of public policies and even of the population awareness regarding the use/demand for energy and fuel in order to settle the emission of greenhouse gases, especially carbon dioxide in Mato Grosso do Sul, aiming at the environment and wellbeing preservation.

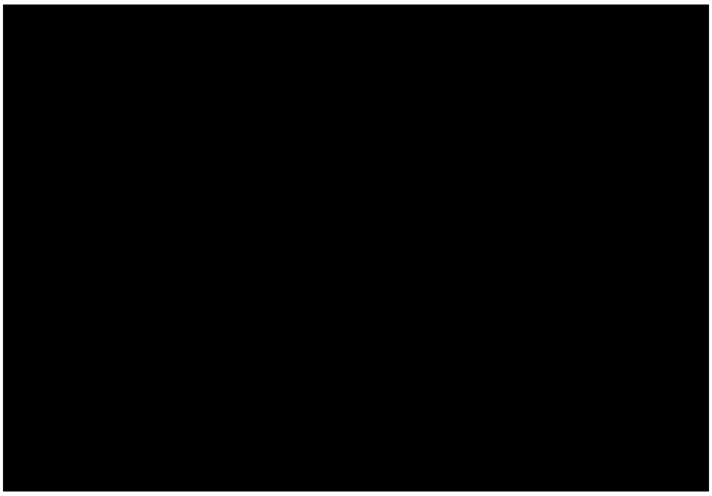

Figure 1:

1

Range of efficiency	Level of efficiency in the Standard border	Level of efficiency in the Reversed border
0.0000 -0.4999	Very low	Fully Efficient
0.5000 -0.5999	Low	Very High
0.6000 -0.6999	Medium	High
0.7000 -0.7999	High	Medium
0.8000 -0.9999	Very High	Low
1	Fully Efficient	Very low
		Source: Adapted from PNUD (2013).

Figure 2: Table 1 :

2

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Variable	Source	Function
Residential consumption of energy	SEMAGRO	Input
Demographic density	IBGE	Input
GDP	IBGE	Output
Fuel Consumption	SEMAGRO	Output

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Figure 3: Table 2 :

1

Level of efficiency	1991	2000	2010
Fully Efficient	-	-	-
Very High	15%	10%	4%
High	13%	4%	4%
Medium	23%	21%	10%
Low	21%	19%	23%
Very Low	28%	46%	59%

Figure 4: Table 1 :

2

Municipality	1991	2000	2010
Campo Grande	52nd	50th	30th
Corumbá	43th	51th	22nd
Dourados	53rd	52nd	51th
TrêsLagoas	55th	65th	32nd

Figure 5: Table 2 :

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Locality	1991	2000	2010	Locality	1991	2000	2010
Água Clara	67	7	44	Itaporã	57	32	38
Alcinópolis	70	11	21	Itaquiraí	72	46	11
Amambai	39	24	39	Ivinhema	34	62	25
Anastácio	3	31	62	Japorã	75	70	31
Anaurilândia	38	21	56	Jaraguari	2	4	5
Angélica	45	61	36	Jardim	4	71	70
Antônio João	26	56	42	Jateí	44	66	52
Aparecida do Taboado 20		44	55	Juti	17	28	41
Aquidauana	11	74	61	Ladário	64	77	76

Figure 6: Table 3 :

4

Locality	Compound	Position	Locality	Compound	Position
Jaraguari	0.86332	1st	Eldorado	0.50262	40th
Bandeirantes	0.797855	2nd	Dois Irmãos do Buriti	0.502114	41st
Ribas do Rio Pardo	0.764601	3rd	Ivinhema	0.501462	42nd
Bataguassu	0.718993	4th	Campo Grande	0.5	43th
Chapadão do Sul	0.699744	5th	Pedro Gomes	0.490507	44th
Terenos	0.697507	6th	Alcinópolis	0.487272	45th
Sao Gabriel do Oeste	0.678401	7th	Rochedo	0.485895	46th
Miranda	0.671448	8th	Nioaque	0.485031	47th
Costa Rica	0.659078	9th	Tacuru	0.478134	48th
Selvíria	0.658475	10th	Aral Moreira	0.475379	49th
Rio Verde de Mato Grosso	0.655793	11th	Angélica	0.467874	50th
Coxim	0.624702	12th	Dourados	0.466595	51th
Nova Alvorada do Sul	0.619682	13th	Três Lagoas	0.448169	52nd
Cassilândia	0.610265	14th	Mundo Novo	0.44206	53rd
Guia Lopes da Laguna	0.606411	15th	Itaquiraí	0.428691	54th
Batayporã	0.598736	16th	Jateí	0.427158	55th
Juti	0.585282	17th	Corguinho	0.426235	56th
Rio Brilhante	0.584991	18th	Taquarussu	0.423118	57th
Porto Murtinho	0.584737	19th	Glória de Dourados	0.417898	58th
Sidrolândia	0.579103	20th	Caracol	0.4122	59th
Bonito	0.574826	21st	Bela Vista	0.404383	60th
Camapuã	0.572985	22nd	Paranaíba	0.396612	61st
Amambai	0.557481	23rd	Aquidauana	0.396234	62nd
Iguatemi	0.556505	24th	Jardim	0.393169	63rd
Anastácio	0.555731	25th	Vicentina	0.365261	64th
Caarapó	0.555245	26th	Coronel Sapucaia	0.356066	65th
Nova Andradina	0.545147	27th	Laguna Carapã	0.346022	66th
Sonora	0.543096	28th	Naviraí	0.336932	67th
Corumbá	0.540953	29th	Rio Negro	0.334412	68th
Inocência	0.534446	30th	Novo Horizonte do Sul	0.317834	69th
Bodoquena	0.533529	31st	Brasilândia	0.30686	70th
Maracaju	0.532483	32nd	Fátima do Sul	0.305024	71st
Água Clara	0.527542	33rd	Ponta Porã	0.29	72nd
Deodápolis	0.527122	34th	Japorã	0.267474	73rd
Aparecida do Taboado	0.526832	35th	Paranhos	0.229639	74th
Anaurilândia	0.520804	36th	Sete Quedas	0.202064	75th
Itaporã	0.514233	37th	Douradina	0.186243	76th
Figueirão	0.510624	38th	Santa Rita do Pardo	0.14476	77th
Antônio João	0.508492	39th	Ladário	0.144015	78th

Figure 7: Table 4 :

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