Conglomerates of Latin American Countries and Public Policies for the Sustainable Development of the Electric Power Generation Sector

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Abstract. Due to the effects of greenhouse gases, countries have implemented policies to slow down their emissions. Latin America stands out as one of the regions that have seen these effects accentuated, among them, the vulnerability of its electrical systems to periods of drought. The objective of this paper is to classify the group of these countries that contribute more or less to the emissions of these gases, in relation to their generation of electric power. The data used to carry out this classification are those reported by databases such as: Latin American Energy Organization (OLADE, by its initials in Spanish) and the World Bank, for the period from 2006 to 2013. The big data are analyzed using data mining techniques: Grouping and Association. The results show that they were organized in three (3) clusters. In the efficient one is Brazil, with an average of 289.66 tons/GWh emissions. In the clusters, considered inefficient, they have an average emissions of 462.15 and 1137.10 ton/GWh.

Keywords: Greenhouse gases · Power generation · Clusters
Latin American countries · OLADE database · Grouping · Association

1 Introduction

The goals of reducing the generation of greenhouse gases (GHG), in order to slow down climate change, have triggered policies, which from the countries have been implemented to guarantee the sustainability of the planet [1]. The sectors with the highest production of GHG are due to the consumption of fossil fuels dedicated to the generation of electrical energy, transport systems and industrial processes, due to the burning of fossil fuels [2].

The effects of climate change are not similar in the different regions and country of the world. In Latin America, the last few years have been noticeably accentuated, as there has been an increase of 0.5 to 3 °C in the average temperature between 1901 and 2012 and reductions of 15 and 10% [2] in average annual rainfall. Due to the general dependence in this region on the generation of hydroelectric energy, additional effects

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are included, such as the vulnerability of the power plants, which have affected the stability of electrical systems [3, 4].

The policies that have been implemented or adopted by the countries have scope only in the energy sector, the information has been provided by the countries in the Intergovernmental Panel on Climate Change (INDCs) [2] for the Paris Summit of 2015. The information presented by the countries points towards development but with low carbon emissions, which are projected to 2030. Among these policies are [2, 5, 6]:

1. Diversification of the energy matrix
2. Promotion and increase of energy efficiency
3. Increase in the share of renewable energies (wind, solar, biomass and/or photovoltaic)
4. Increase the participation of alternative energies and other energies
5. The substitution of fossil fuels with biofuels or an increase of these with respect to the first ones
6. Reduction of energy intensity of consumption
7. Expand renewable energy sources other than hydroelectric power
8. Design a long-term energy development strategy
9. Mitigation action plans whose objective is to maximize carbon-efficiency
10. Possibility of using carbon markets mechanisms
11. Reduction of energy demand
12. Management of carbon sinks
13. Use of biofuels for final use (buildings, transport, industry)
14. Use of hydroelectric generation
15. Reduction of the emission factor of the electric network.

In this sense, the management of Sustainable Development Indicators (SDI) is necessary to evaluate the results of the policies implemented based on the results obtained in the environmental, economic and social spheres.

Since 1987, the Brundtland Report begins with the definition of the IDS, which is reaffirmed in the adoption of Agenda 21, of the Earth Summit, in 1992. Initially the indicators handled four (4) dimensions: environmental, economic, social and institutional. The latter was discarded, with the purpose of facilitating the adoption of measures and the evaluation of the results [7–9].

2 Methodology

Data mining (DM) [10], can be defined as a non-trivial process of valid, novel, potentially useful and understandable identification of understandable patterns that are hidden in the data, which in turn facilitates decision making and employs supervised and non-supervised learning techniques. The type of research to be carried out is defined according to the characteristics of the attributes that make up the database, as descriptive. The next step is the choice and application of knowledge extraction methods and the selection of validation measures to evaluate the performance and accuracy of the method (s) chosen by the DM analyst. The selected methods are [5]:

Grouping: Allow the maximization of similarities and minimization of differences between objects, through the application of some grouping criteria.

Association: Keep in mind that the association rules seek to discover existing connections between identified objects.

With the purpose of evaluating the measurements of the results of the IDS in the Latin American countries the present work is carried out. For this, a conglomerate of a set of 20 countries is made based on the electric power produced annually and the GHG emissions, both variables considered averages for the period of the year 2006 to 2013, both inclusive. The data is taken from the report published by OLADE [9] and the World Bank [2, 3], the software used is the SPSS V24®. Once the conglomerates are formed, a significant representative of each of these is analyzed based on the established policies and their results obtained.

3 Formation of Conglomerates

The purpose of establishing structures and associations in conglomerates is to suggest statistical models, perform diagnoses and for other purposes [11, 12]. In order to determine and classify, from the group of 20 Latin American countries, those that contribute more or less to the emissions of these gases, the data base of OLADE and the World Bank is used. From this, the data of the CO_2 emission are extracted by electric power generation (ton/GWh) and annual electric power generation (GWh), reported by each country, for the period of 2006–2013, both inclusive [14], they have been averaged. The correlation matrix between these variables is searched, the scatter plot is made [13] and, finally, the classification is carried out. The statistical program SPSS® is used to obtain the correlation.

Table 1 shows the correlation of the CO_2 emission variables by electric power generation (ton/GWh) and annual electric power generation (GWh), obtained from the SPSS V24®. A positive correlation can be observed (+0.596), being significant. Additionally, Table 2 shows the grouping of countries according to three (3) conglomerates, identified as A, B and C. From these, the most emblematic country is taken to describe the policies that have been implemented and the results obtained as a function of the IDS. These countries are Mexico, Venezuela and Brazil, respectively, for groups A, B and C.

Table 1. Correlation matrix and P-value

		Energy electric generation (GWh)	GHG/Energy electric generation (ton/GWh)
Energy electric generation (GWh)	Pearson correlation	1	0.596*
	Sig. (2-tailed)		0.006
	N	20	20
GHG/Energy electric generation (ton/GWh)	Pearson correlation	0.596*	1
	Sig. (2-tailed)	0.006	
	N	20	20

*Correlation is significant at the 0,01 level (2-tailed)

Table 2. Distribution of countries by cluster

Clusters	Definition	Countries	Number of countries	Average electricity generation (%)
A	***Inefficient*** Countries that have a total generation of electric power less than or equal to 300,000 GWh and GHG emissions greater than 800 ton/GWh	Argentina, Bolivia, Chile, Cuba, Ecuador, Guatemala, Haiti, Honduras, Mexico, Nicaragua and the Dominican Republic	11 (55%)	40,29
B	***Efficient Lower Level*** Countries that have a total generation of electric power less than or equal to 300,000 GWh and GHG emissions less than 800 ton/GWh	Colombia, Costa Rica, El Salvador, Panama, Paraguay, Peru, Uruguay and Venezuela	8 (40%)	22,75
C	***Efficient Higher Level*** Countries with an emission lower than 300 ton/GWh and with a total generation of electric power superior to 500,000 GWh	Brazil	1 (5%)	36,96

3.1 Mexico

In 2013, Mexico was the second largest electricity producer in Latin America, with a 19.63% share of the total electricity generated in the region. During that year the production of electricity reached 297,079 GWh, a figure that reflects an increase of 17% over the period 2002–2012 and represents an annual growth rate of 2.9%. It is the representative of Group A, considering that the energy matrix is mostly fossil, as shown in Fig. 1.

Among its defined policies are in the energy generation sector:

- Diversification of the energy matrix
- Increase in the share of renewable energies (e.g. wind, solar, biomass and/or photovoltaic)
- Increase the participation of alternative energies and other energies
- The substitution of fossil fuels with biofuels or an increase of these with respect to the first ones
- Expand renewable energy sources other than hydroelectric power
- Hydroelectric generation

Although its main source of electricity generation is based on fossil fuels, it increases the use of natural gas with respect to the others (from 20.9% in 1999–2002 to 52.2% in 2013), which is evident in Fig. 1 with the decrease in GHG emissions per generation unit and inhabitant. Unfortunately the share of renewable energies between 2002 and 2013 decreases from 10% to 8%.

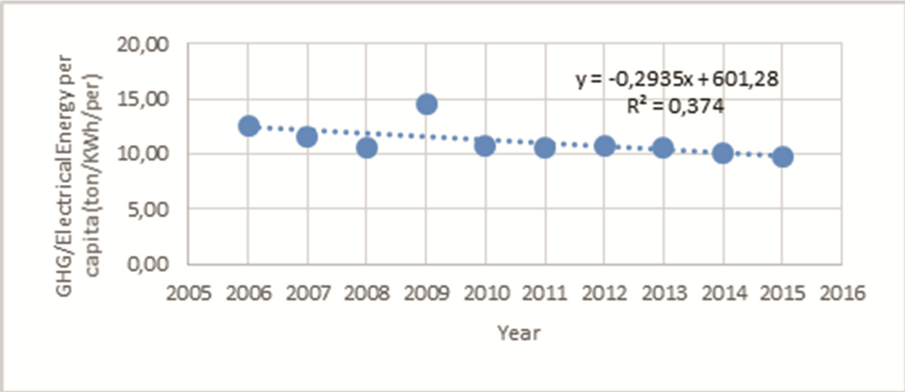

Fig. 1. GHG emissions/electric power generation per capita (ton/kWh/inhabitant) of Mexico for the period 2006 to 2013

3.2 Venezuela

Venezuela ranked fourth in Latin America in electricity production, behind Brazil, Mexico and Argentina, accounting for 8.76% of the region's total. However, it is the first consumer in per capita terms in Latin America [14–16], which is evidenced in Fig. 2. A country that generates 64.02% of its electric power in 2012 from renewable sources, specifically hydroelectric plants. This condition is the product of the country's

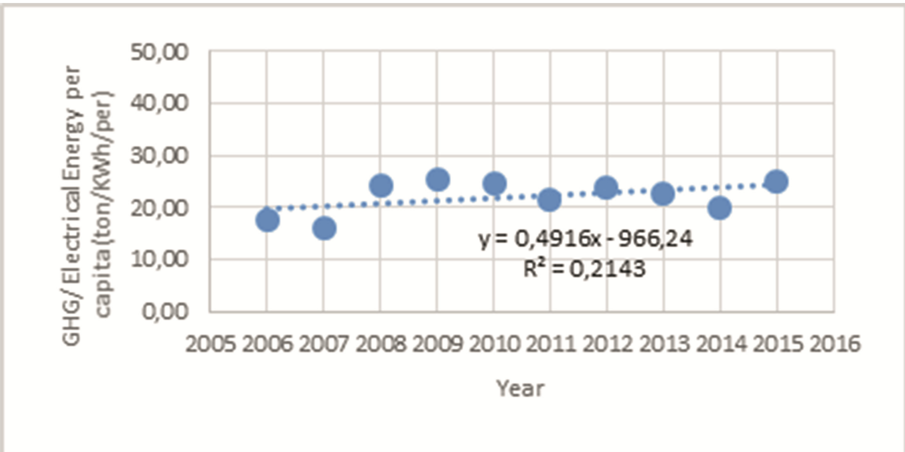

Fig. 2. GHG emissions/electric power generation per capita (ton/kWh/inhabitant) of Venezuela for the period 2006 to 2013

investment in the 1960s for the construction of reservoirs, motivated by the demand for water supply and hydroelectric power.

3.3 Brazil

Brazil is a rising player in the international energy scene due to the variety and abundance of energy resources available, the size of its domestic market and the dynamism of demand [16–19]. In this sense, it is the first electricity consumer in Latin America and is the ninth worldwide. The diversity of renewable resources that this country has, which account for more than 80% of electricity generation, make this country an efficient frontier. Although this country is a large producer-consumer of electricity, its GHG emissions are small compared to the rest of Latin American countries, as shown in Fig. 3.

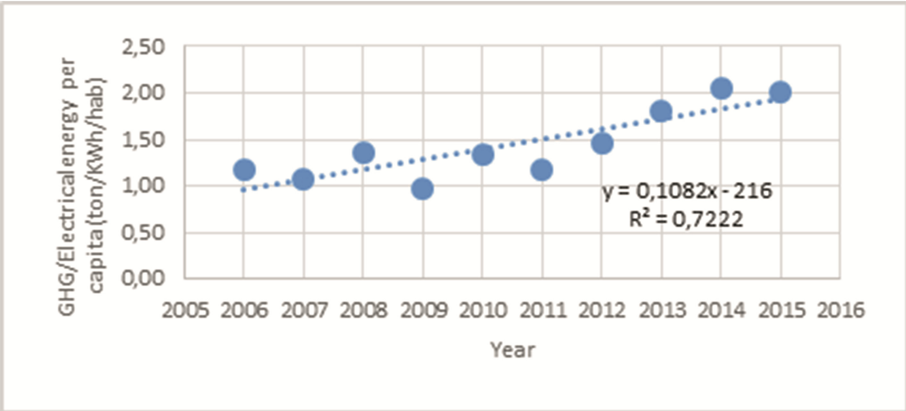

Fig. 3. GHG emissions/electric power generation per capita (ton/kWh/hab) of Brazil for the period 2006 to 2013

4 Conclusions

Figures 1, 2 and 3 show the trends in the generation of GHG emissions per generation unit and inhabitant for the period 2006 to 2013, both inclusive, for the countries of Mexico, Venezuela and Brazil, respectively. Two (2) observations valid for the study can be indicated from the equations:

(1) Mexico is the only one that shows a tendency to reduce the amount of GHG emissions, thanks to its policy of diversifying its energy matrix. On the other hand, Venezuela and Brazil have a positive trend, at 0.4916 and 0.1082 ton/kWh/per capita. This shows that Brazil's policies have served to slow the production of GHG emissions.

(2) The correlations are 0.3740; 0.2143 and 0.7222 of the trends of the countries Mexico, Brazil and Venezuela, respectively. This shows that the country that has

the most control over its emissions is Brazil and that is why it is located in the C cluster, which is the most efficient.

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