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Current Trends in Cuba on the Environmental Impact and Sustainable Development

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ABSTRACT

This technical note shows a summary of the current trends in Cuba on the environmental impact and sustainable development in the last five years. In this study, the country is sectioned in four regions, taking into account socioeconomic characteristics and similitude in conditions of development. In this paper, several elements are analyzed that have influence directly to the environmental impact, as, emissions of gases greenhouse effect, generation of electric power, water consumption, analysis of the air quality, implementation of renewable sources of energy, investments to mitigate the environmental impact, among others. The data set used in this material, was obtained from the report provided by the National Office of Statistic of the Cuba (ONEI). In this study is omitted the special municipality Isla de la Juventud.

1. INTRODUCTION

Cuba is a developing country, than even as the rest of the world receives the effects of the globalization and climatic change. At the present time, in Cuba it is worked up for the benefit of the sustainable development, guided to the reduction of gases of greenhouse effect, to the protection of waters and natural resources and to the proliferation of the use of the renewable sources of energy. For the purpose, the Cuban government has authorized the investment of over 2310 million of Cuban's pesos (MCP) in the last five years for works of environmental protection and mitigation [1].

Although previously studies were conducted on the use of electricity in Cuba, in none of these was considered the local effect of production, consumption and CO_2 emissions associated with it, (not including the adjacent keys). The production of electricity on the island of Cuba is highly dependent on fossil fuels. The fall of the socialistic block produced a severe crisis in the energy carriers in the country, since the main source of import of energy carriers was the Soviet Union [2].

In 2006, Cuba began a management of energy resuscitation, known as the "energy revolution". One of the elements associated with it is the entry into operation of power generation plants based on several units of low power generators, known in the country as an emerging generation.

In the last five years, the reanimation of the national economy has generated a sharp increase in electricity consumption; however, the national energy infrastructure has not been perfected. The degree of recapitalizations of the existing power plants has required that the emerging generation has been in charge of covering the new electricity requirements.

The Cuban state has undertaken the task of encouraging the use of renewable energy sources; however, the increase in generation with these sources does not compete with the rise in energy carrier needs [3].

The Cuban state has planned an investment that will allow the installation of 1650 MW of power based in renewable energy, (solar, wind and biomass), which represents 24 percent of the national energy matrix. of these, 875 MW correspond to 25 Biomass Power Plant (CEB) projects.

Recently, it was established law 124/2017, for the sake of protecting the subterranean and superficial waters; besides, there are several research projects and sustainable development, as they are, life, live coasts and energy efficiency.

In this technical note, is provided a brief overview of the state of generation and consumption of electricity in Cuba in the last five years. The study provides a focalization of each of the carriers for each of the country's fundamental regions. A relevant element to date does not have a similar material on the energy situation, the environmental impact and sustainable development in the country and the future prospects of this issue.

Additionally, several elements are analyzed that have influence directly to the environmental impact, as, emissions of gases greenhouse effect, generation of electric power, water consumption, analysis of the air quality, implementation of renewable sources of energy, investments to mitigate the environmental impact, among others.

2. METHODS AND VALIDATION

2.1 Brief description of the object of study

(1) The island of Cuba is made up of three fundamental regions, the occident, centre and orient. The Cuban capital (Havana) is considered in the present study as a fourth region, taking into account the conditions of very high population density that it presents. Figure 1 provides in detail the location of each of the provinces that make up the island of Cuba, in Table 1 the provinces that make up each region are detailed, while, in the Table 2 is given a summary of the demographics' distribution in Cuba for each region of study [4].

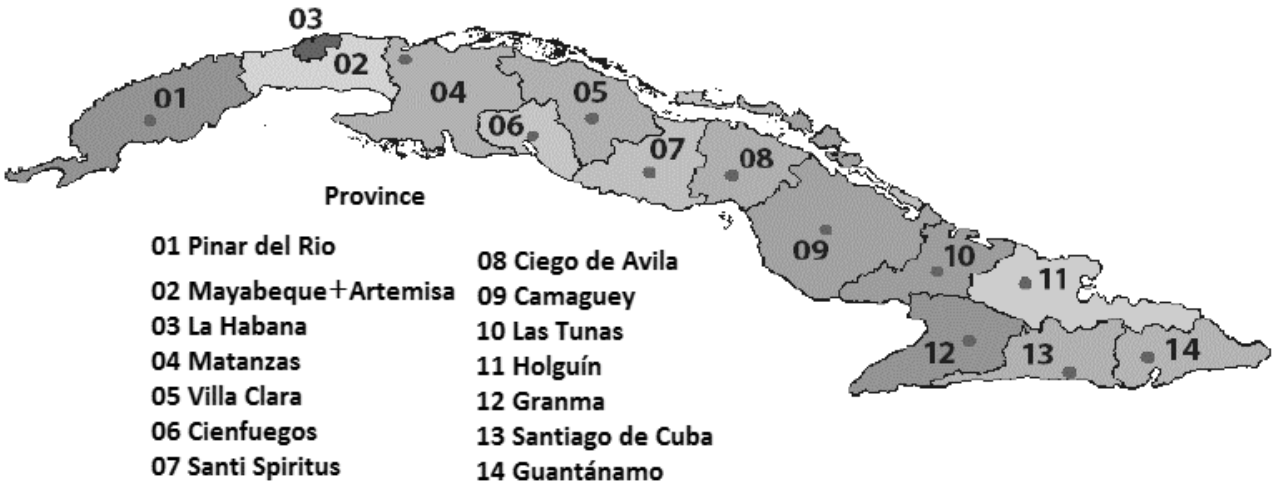

Figure 1. Location of the regional divisions of Cuba

Table 1. Location of the regional divisions of Cuba

Region	Province members
Occident	Pinar del Rio, Mayabeque+Artemisa and Matanzas
Centre	Villa Clara, Cienfuegos, Santi Spiritus, Ciego de Avila and Camaguey
Orient	Las Tunas, Santiago de Cuba, Granma, Holguín and Guantánamo
Habana	La Habana

Table 2. Demographics distribution in Cuba for region

Region	Inhabitants	Surface (km^2)	Populousness (inh/km^2)
Occident	2270520	28747	79
Centre	2870880	38739	74.1
Orient	3950830	36245	109
Habana	2256650	751	3004.9
Cuba	11348880	104482	108.6

2.2 Analysis of the consumption of electricity and water in Cuba

In the last five years, the consumption of electricity has experienced an increasing tendency in Cuba, this is fundamentally, for the incorporation thousands of new clients to the National Electro Energetic Systems (SEN) that recently have been benefited with the national programs of electrification, and the majority is located in orient zone. In the Table 3 show a summary of the electricity consumption in the analyzed period (in GWh/year) for each region of study, while in the Table 4 is given the average consumption by inhabitants (in kWh/year).

The water consumption in Cuba is regulated according to the standard NC-973-2013. The global crisis of water has exerted its impact on Cuba, for this reason, at this moment exist a total of 24 plants in operation to make sea water drinkable, (fundamentally in the orient zone), with a processing capability of 0.05 m^3/s each. The application of the law 124/2017 has established a control mechanism on the water use, for such motive the water consumption in the year 2018 is reduced with respect to the tendency to the consumption shown in prior years. In the Table 5 is given the global consumption of water in Cuba (in millions of m^3) for each region in the studied period, while, in the Table 6 is given the average consumption (in m^3 per inhabitants) in each region.

The data given in the tables 5 and 6, correspond to the global consumption of water, that is than include activities on industrial purpose, agriculture and human consumption. In the Table 7 is proportionate a global summary of the water consumption in Cuba by each activity in the studied period

Table 3. Summary of the electricity consumption in the analyzed period, (in GWh/year)

Region	2014	2015	2016	2017	2018
Occident	4043	4095	4148	4212	4284
Centre	4405	4447	4489	4532	4542
Orient	4250	4349	4450	4482	4511
Habana	4117	4185	4254	4440	4490
Cuba	16815	17076	17341	17666	17827

Table 4. Summary of the electricity average consumption by inhabitants in the analyzed period (in kWh/year)

Region	2014	2015	2016	2017	2018
Occident	1780.6	1803.6	1826.9	1855.1	1886.8
Centre	1534.4	1549	1563.6	1578.6	1582.1
Orient	1075.7	1100.8	1126.3	1134.4	1141.8
Habana	1824.4	1854.5	1885.1	1967.5	1989.7
Cuba	1481.6	1504.6	1528	1556.6	1570.8

Table 5. Summary of the global consumption of water in the analyzed period (in millions of m^3/year)

Region	2014	2015	2016	2017	2018
Occident	1430	1441	1468	1494	1407
Centre	1768	1781	1792	1808	1741
Orient	2538	2575	2598	2618	2458
Habana	1444	1489	1552	1555	1412
Cuba	7180	7286	7410	7475	7018

Table 6. Summary of the water average consumption by inhabitants in the analyzed period (in m^3/year)

Region	2014	2015	2016	2017	2018
Occident	629.9	634.6	646.7	658.2	619.9
Centre	615.7	620.3	624.3	629.9	606.5
Orient	642.3	651.8	657.5	662.6	622.2
Habana	639.8	660	687.7	689.1	625.8
Cuba	631.9	641.7	654.1	660	618.6

Table 7. Summary of water removal by destinations

Destiny	Water consumption (in millions of m^3/year)				
	2014	2015	2016	2017	2018
Gross freshwater extraction	7567	7919	7805	8024	7348
Water returned without using	387	633	395	549	348
Net freshwater withdrawal	7180	7286	7410	7475	7000
By industry water supply	1956	2627	2151	1773	1915
By other users	5224	4659	5259	5702	5085
Superficial freshwater extraction	4606	4573	4665	4558	4271
By industry water supply	793	1461	1006	567	830
By other users	3813	3112	3609	3991	3441
Groundwater extraction	2574	2713	2795	2917	2729
By industry water supply	1163	1166	1145	1206	1085
By other users	1411	1547	1650	1711	1644

2.3 Analysis of the generation of electricity in Cuba

In Cuba, the electricity generation is distributed throughout the country, although, the occident zone is the biggest producer of generation volume (approximately 40% of the total), however, it turns out to be the one with the lowest energy consumption.

The main sources of electricity generation in Cuba are:

1- Fuel Power Plants (FPP)
2- Energas Power Plant (GPP)
3- Fuel emerging generation (FEG)
4- Diesel emerging generation (DEG)
5- Biomass (B)
6- Renewable energy (RE)

Power plants are of two types, the first use liquid fuel and are based on the Rankine cycle, currently in the country there are 10 units, while the second type using gas turbines for the generation of electric power, currently have two units, one in Mayabeque and one in Matanzas.

The distributed generation considers the sites in which one or more generators with individual powers up to 1.5 MW are located, which consume fuel oil or diesel.

The main source of electricity generation in Cuba with biomass is the sugar industry, while the renewable sources used are three fundamental types, solar photovoltaic, wind and hydraulic [5, 6].

The consumption of electric energy in Cuba has shown a clear rise in recent years, a graphic representation of the consumption of the last four years is provided in Figure 2, and it can be found that it follows a linear growing trend [7, 8].

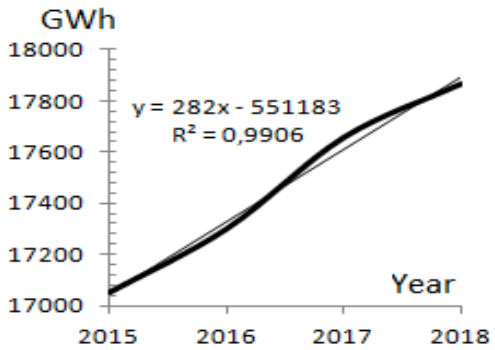

Figure 2. Growth of annual energy consumption in Cuba

This increase in electricity generation produces a clear increase in CO_2 emissions. Figure 3 shows the growth of emissions associated with the generation of electricity in Cuba [9, 10].

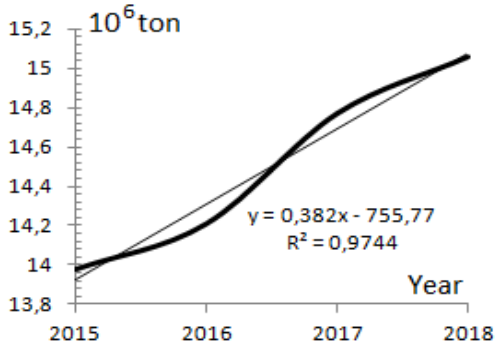

Figure 3. Growth of CO_2 emissions due to the generation of electricity in Cuba

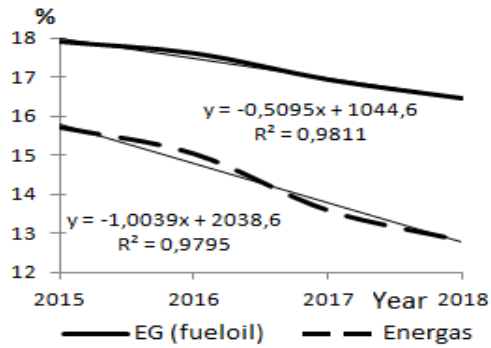

Figure 4. Percentage of participation in the electricity matrix in Cuba

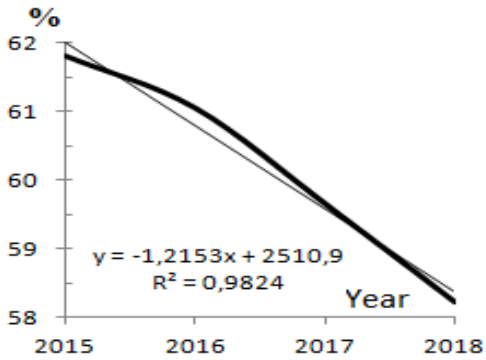

Figure 5. Percentage of participation of power plants in the electric matrix in Cuba

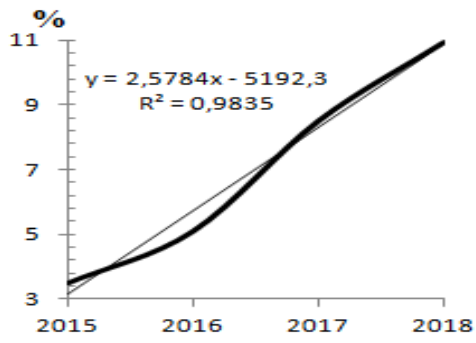

Figure 6. Percentage of participation of the emerging generation in the electricity matrix in Cuba

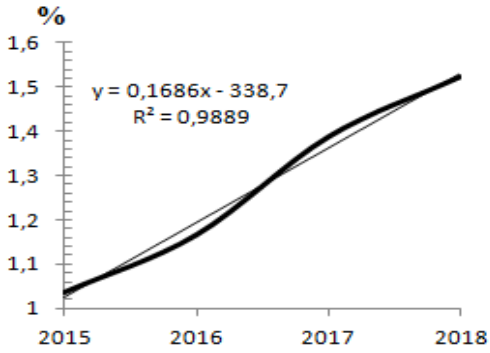

Figure 7. Percentage of participation of the renewable energy n the electricity matrix in Cuba

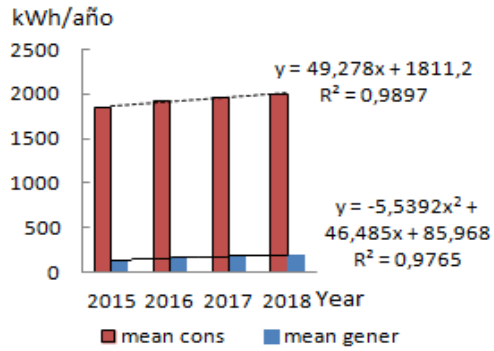

Figure 8. Consumption and the average generation per inhabitant in Habana

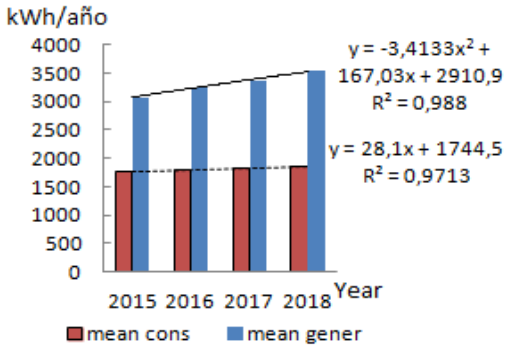

Figure 9. Consumption and the average generation per inhabitant in Occident

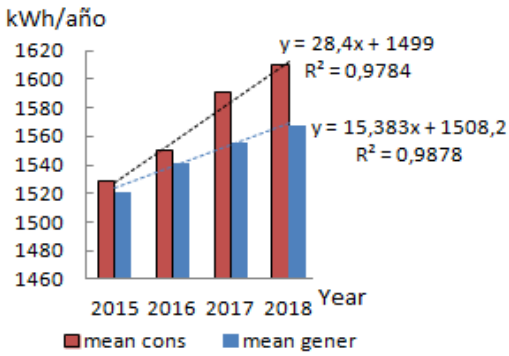

Figure 10. Consumption and the average generation per inhabitant in Centre

The individual participation of each generation source in the production of electricity in Cuba is given in Figures 4 to 9. In each of them, the percentage value represented by each individual source of the total generation delivered in the last 4 years is detailed. The accelerated growth of the presence in the energy matrix of the emerging generation can be verified.

In Cuba, consumption and electricity generation are not distributed equally in each of the regions. When establishing the average energy demand per inhabitant, it is found that in Havana, it turns out to be almost twice as high as in the Orient. In the case of generation, the Occident zone is the one that provides the highest average per customer; however, it turns out to be the second lowest consumption. In Figures 8 to 11 consumption and the average generation per inhabitant are plotted for each of the regions of Cuba.

In order to apply the given correlations in the Figures 10 to 11, the variable x refers to the year to analyze, taking the year 2015 as year 1.

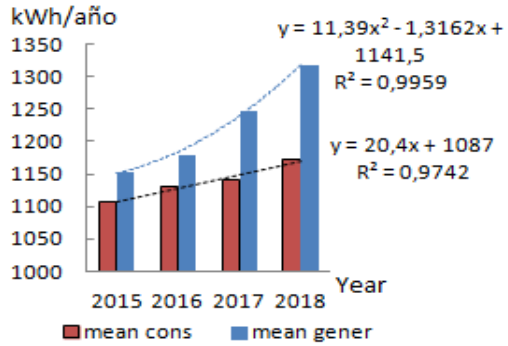

Figure 11. Consumption and the average generation per inhabitant in Orient

3. BRIEF ANALYSIS OF THE ENVIRONMENTAL CURRENT STATE OF CUBA

3.1 Summary of the main actions of mitigation executed in Cuba

At the present time, in Cuba it is worked up for the benefit of the sustainable development, guided to the reduction of gases of greenhouse effect, to the protection of waters and natural resources and to the proliferation of the use of the renewable sources of energy. For the purpose, the Cuban government has authorized the investment of over 2310 million of Cuban's pesos (110 million USD) in the last five years for works of environmental protection and mitigation. In the Table 8 is given in more details of this investment for environmental protection in Cuba [11].

Table 8. Expenses for environmental protection in Cuba, (in MCP)

Environmental sector	2014	2015	2016	2017	2018
Waters	226.4	239.4	243.9	245.7	258.4
Soils	17.5	18.1	18.5	23.6	32.2
Atmosphere	49.9	56.6	61.1	64.7	67.6
Forest resources	65.5	74.7	77.4	122.1	126.6
Solid resources	20.8	13.8	12.4	10.4	24.7
Others	24.7	26	22	3.5	64.6
Total	404.8	428.6	435.3	470	574.1

In the Table 9 are given the expenses for water protection by provinces, in MCP.

Correlating the average cost of water protection and its average consumption, it is obtained that the best fit is given by an exponential function, with an approximation coefficient (R^2=0,953), being described by [12, 13]:

$$G_{Usoagua} = 0{,}145 \cdot e^{0{,}0596\ (W_R)} \qquad (1)$$

In the Eq. (1), $G_{Usoagua}$ is the financial expense associated to the mitigation of the environmental impact, in \$/m^3 and W_R is the yearly consumption of water, in m^3.

Table 9. Expenses for water protection by province

Province	2014	2015	2016	2017	2018
Pinar del Río	9.3	9.4	8.7	10.3	15.8
Artemisa	1.1	0.8	3.4	2.1	16.6
La Habana	49.2	49.4	47.2	53.3	66.5
Mayabeque	1.2	0.2	0.6	0.8	5.7
Matanzas	15.5	14.7	65.6	47.5	15.6
Villa Clara	15.1	16.2	8.2	13.4	29.3
Cienfuegos	3.1	6.5	6.2	4.9	6.9
Santi Spíritus	5	10.8	6.8	6.4	5.4
Ciego de Ávila	4.2	6.1	7.6	9.2	9.5
Camagüey	8.1	7.9	7.8	9.6	9.7
Las Tunas	4	10.7	8.7	7.3	5
Holguín	40.4	35.4	40.3	34.3	30.8
Granma	11.3	13.6	15.5	17.5	10.6
Santiago de Cuba	48.3	47.6	8.4	18.8	18.4
Guantánamo	9.8	10	8.8	10.1	11.1
Total	226.4	239.4	240.9	245.7	258.4

The uses of Eq. (1) allows verifying that the average cost of mitigation required by each m^3 of water round the intervals given in the bibliographic analysis [5], however, due to the critical state of some local basins. the values determined with Eq. (1) can provide to be a 60 percent smaller than the real value.

In the Table 8 can check that nearly to 13 percent of the investment expenses for protection to the environment in the five year period 2013-2018 were dedicated to the atmosphere. For this reason, in the Table 10 is offers a summary of the main emissions of contaminating gases in the country in said period. according to the reports of ONEI [3].

Table 10. Summary of the main emissions of contaminating gases in Cuba, (in Gg)

Year	CO_2	CH_4	N_2O	NO_X	CO	SO_2
2013	27973.8	354.8	11.7	97.1	546.4	462.7
2014	26586.1	365.8	11.1	96.8	602.8	513.6
2015	24892.9	398.4	9.8	84.3	502.2	614.5
2016	24233.8	400.4	7.3	82.9	494.7	665.8
2017	26532.4	103.7	8.5	104.9	450.8	780.3
2018	30060.9	372.9	8.2	97.7	370.5	835.6

The correlation of the expenses for the concept of protection to the atmosphere with the estimated emissions in 2018 allows us to establish with an approximation coefficient (R^2 = 0.987) an expression for the determination of expenses based on greenhouse gas emissions, this expression is given by [5]:

$$G_{Emis} = 3{,}911 \cdot A \cdot e^{0{,}226 \cdot B} \quad \text{(MCP)} \qquad (2)$$

where,

$$A = Ln\left((CO_2)^{0{,}1} \cdot SO_2\right)^{0{,}1} + 0{,}252 \qquad (3)$$

$$B = Log\left[\frac{\left(CH_4 \cdot NO_X \cdot (CO)^{0{,}04} - (SO_2)^2\right)^2}{N_2O}\right] \qquad (4)$$

In Eqns. (3) and (4), the volumes of polluting gases are given in Gg.

4. CONCLUSIONS

In the last five years, in Cuba there is a clear tendency to increase the presence of the emerging generation within the national energy matrix. An unequal distribution of energy carriers between the different regions of the country was shown, being established that Habana consumes almost twice the average energy carriers per inhabitant than the rest of the country, and accompanied by a low rate of electricity generation.

In this paper, several elements are analyzed that have influence directly to the environmental impact, as, emissions of gases greenhouse effect, generation of electric power, water consumption, analysis of the air quality, implementation of renewable sources of energy, investments to mitigate the environmental impact

The application of the law 124/2017 has established a control mechanism on the water use, for such motive the water consumption in the year 2018 is reduced with respect to the tendency to the consumption shown in prior years.

Two expressions of calculation were developed for the analysis of the costs of mitigation by emissions of the greenhouse effect gases, as well as for the water uses.

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