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Colombia towards an electricity generation matrix using renewable energies

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Abstract.

The purpose of this paper is present a review about to the currently legislation in Colombia with respect to renewable energies. The mainly goals are: (i) to explain the energy policy regulation related to renewables energy; and (ii) to characterize using descriptive statistics renewables projects based on wind, small hydro and photovoltaic. In addition, the analyses allow to understand the existing potential in the different regions of the country. This information was collected through of the procedures developed by UPME and CREG agencies in Colombia.

Key words

Renewables energies, Colombian legislation, renewable capacity.

1. Introduction

Colombia is Latin America's fourth largest economy measured by gross domestic product (GDP) at purchasing power parity (PPP) in 2010 of 349.22 billion USD. Colombia has a population of approximately 47.8 million, according to the National Administrative Department of Statistics (DANE). Currently, the electric power in Colombia is based on large hydro-power close to 64% and thermal generation 33% and the participation of small renewable sources.

The structure of the Colombian energy market is based on Laws 142 and 143 of 1994 [1], which established the rules governing public utilities and the regime for provision of electric power, respectively. The Unit for Mining and Energy Planning (UPME)[1] is responsible for the mid-term and long-term planning of the country and The Energy and Gas Regulatory commission (CREG)[2] is in charge of regulating the market related to gas and electricity.

In 2008 the government of Colombia issued a national policy (Decree 570) according to which the power sector should achieve the following objectives: (i) to strengthen the resilience of the power matrix to larger shocks associated to climate change (like El Niño event); (ii) To promote the competition and increase price efficiency through the long term energy contracts; (iii) To mitigate the effects of climate change by the harnessing of renewable energy resources; and (iv) To reduce greenhouse gas emissions (GHG) from power sector in order to achieve the country's commitments signed at COP21 conference in Paris [2] .

[1] Unidad de Planeación Minero Energética (UPME)
http://www1.upme.gov.co/Paginas/default.aspx

[2] Comisión de Regulación de Energía y Gas (CREG)
http://www.creg.gov.co/PORTADA_STREAMING.html

A. Aim of the study

This article aims to explain the energy policy developed by Colombia. The study has the following two goals to achieve: (i) to explain the energy policy regulation of Colombia related to renewables energy; and (ii) to characterize using descriptive statistics renewables projects based on wind, small hydro and photovoltaic.

2. Legislation in Colombia in renewable energies

The congress of Republic of Colombia through the law 1715 [3] regulates the integration of non-conventional renewables energies into interconnected network. Project registrations must be carry out with the Mining and Energy Planning Unit (UPME). The projects are focused on renewables energies such as: solar photovoltaic, wind small generation, biomass and geothermal generation sources. The registration is divided into three stages: (i) Stage 1: corresponds to the pre-feasibility of the project and includes environmental study of the project, technology, information about energy resource and installed capacity; (ii) Stage 2: corresponds to the feasibility of the project and includes technical, economical, financial and environmental assessment. Nevertheless, not includes the environmental permission and (iii) Stage 3: corresponds to the project must already technical, economic and environmental designs and environmental permission approved.

A. Colombian law for renewable energies

Colombia has enacted many laws and regulations about sustainable development and the use of renewable energies. However, until 2014 most of them have just enunciated principles and established functions that need to be developed by governmental entities. Laws 142 and 143 of 1994 determined that the Ministry of Mines and Energy would be responsible for defining criteria for uses of conventional and unconventional energy sources. MME was charged with these main functions: to regulate the delivery of surplus power from FNCER to the grid, and to develop guidelines for accessing the incentives.

Law 697 of 2001 [4] promotes rational and efficient use of energy and instructs the MME to formulate policies, strategies and instruments for the promotion of unconventional energy sources and Law 1450 of 2011 [5] reiterated that it is the responsibility of the national government to design and to implement a national policy to promote research, development and innovation in renewable energy sources. Only Law 788 of 2002 [6] established a concrete incentive, it provided a 15-year exemption from income taxes for revenue derived from electric energy generated from wind, biomass or agricultural residues.

Unlike the laws enunciated above, Law 1715 of 2014 [3] proclaimed the promotion of unconventional sources of energy as a matter of public policy and national interest, and established specific actions to promote energy resources like biomass, geothermal, small-hydro, wind and solar, which were named FNCER. In line with this, Law 1715 added responsibilities for the MME and mandate new incentives.

The incentives created by Law 1715 [3] are: (i) income tax reduction until 50% of investments in in research, development, production and distribution of energy from unconventional sources; (ii) VAT exemption for domestically produced and imported equipment, machinery and services for investment in unconventional renewable sources; c) tariff duties exemption for the importation of machinery, equipment, materials and supplies not manufactured domestically and exclusively destined to projects with renewable energy sources; d) accelerated rate for the amortisation of investments made in generating energy from FNCER, and; (v) the creation of a fund to finance unconventional energy sources and efficient energy management called "Non-conventional energy sources and energy efficiency management fund" (FENOGE).

B. Regulatory framework of renewable energies

Following a Law 1715 [3], Colombian government has established policies and regulations for FNCER. The major regulatory challenge for Colombia is auto-generation and distributed generation activities, which the financial viability depends on energy surplus sales as well as the possibilities to export electricity. Government defined "auto-generation activity" and energy surplus export policy [3]; in this point, it differentiates between small scale and large scale auto-generation, power plants above 1 MW belongs to the last group [7].

The detailed regulation for Small Scale Auto-generation (AGPE) has been issued by CREG; this includes the general rules for accessing to the national interconnected grid, and specific regulations for distributed power plants under 5MW. For its part, UPME developed the guidelines for accessing to the financial incentives created by Act 1715 of 2014 [3].

FNCER large scale systems financially viable using or not financial incentives are supposed to compete in the wholesale energy market under the same conditions of conventional power plants. In order to apply the policies of Decree 570 of 2018 [8], the MME has regulated long-term energy auctions [8]. The very first auction will be held on February 2019, and it is intended to achieve that at least 500MW of new power plants using FNCER will be in operation by 2022.

C. Regulation for renewables small scale Auto-generation and Distributed Generators (AGPE)

For small scale projects on auto-generation systems (AGPE) and distributed generation (GD)**,** regulation establishes to utilities to make a Geo-Referenced Information System (GIS) and to publish it in their websites showing to users availability power for connection and availability energy that can be exported to grid in each network. Regulation also establishes that amount total power installed of AGPE and GD at the same

circuit must be less than or equal to 15% with respect to nominal circuit power, transformer or substation where is requested the connection. The total sum energy exported to a level 1 circuit (circuit with 1kV or less) must be less than or equal to 50% in respect of annual average of minimum energy demand hours of each day during year before the connection request date. Information of installed power and exported energy must be shown through a color code as follows in the Tables I and II:

Table I. Percentage installed power AGPE.

% of installed power AGPE o GD in circuit or substation	Color
<= 9%	Green
> 9% y <= 12%	Yellow
> 12% y <= 15%	Orange
> 15%	Red

Table II. Percentage of exported energy of AGPE.

% of exported energy of AGPE o GD to a level 1 grid's circuit	Color
<= 30%	Green
> 30% y <= 40%	Yellow
> 40% y <= 50%	Orange
> 50%	Red

Procedure for distribution utility AGPE and GD is development through following stages: stage (i) simplified connection request to utility; stage (ii) utility answer: if request is reject, utility must to explain the causes and to make recommendations; if request is approbated, utility must to explain connection conditions and schedule connection date; stage (iii) inspection and testing by the utility; stage (iv) connection to distribution grid by utility; and stage (v) verification of conditions by utility: anytime, utility can verify that AGPE installation stays according to the approval.

D. Payment of exported energy to distribution grid by AGPE.

According with Act 1715 of 2014 [3], regulation establishes that surplus energy of AGPE with FNCER will are payments through energy credits system according following rules: (i) AGPE less than or equal to 100kW: energy exported less than or equal that its energy imported of grid during invoice period will are exchanged and the energy seller will charge to AGPE the sale charge for each kWh exported. Energy surplus greater than energy import, during invoice period, will are charged at the corresponding hour price in stock energy market; and (ii) AGPE greater than 100kW and less than 1MW. Unlike the previous case, for each kWh exported, energy seller will charge to AGPE, in addition to sale charge, rate elements of transmission, distribution, recognized losses and restrictions. In both cases, energy seller must report to user with AGPE through energy invoice, the detailed charges and costs of energy uptake (import), surplus (export) and other charges applied.

3. Basic characterization of renewable projects

A. Renewable projects description by region

Project registrations must be carry out with the Mining and Energy Planning Unit (UPME). The registration is divided into three stages: (i) stage 1: corresponds to the pre-feasibility of the project and includes, environmental study of the project, technology, information about energy resource and installed capacity; (ii) stage 2: corresponds to the feasibility of the project and includes technical, economical, financial and environmental assessment. Nevertheless, not includes the environmental permission and (iii) stage 3: corresponds to the project must already technical, economic and environmental designs and environmental permission approved.

According to this scheme developed by UPME, have been registered in total 472 projects divided in different energy resources: solar 343; hydro 94; wind 22 and biomass 13 projects respectively. For a total installed capacity installed of 8,385 MW, which is composed of solar 4,002 MW, wind 3,352 MW, small hydro 993 MW and biomass 38 MW. In reference to section 2, the projects are divided into three stages: stage 1 (357); stage 2 (97) and stage 3 (19) projects.

Colombia is divided into four major regions: Caribbean, Andean, Pacific, Orinoquía and Amazon. These regions have different weather, economic and social conditions. The projects are concentrated thus Caribbean 6,046 MW, according to Table III the main resources are: Wind (53.4%) and Solar (46.6%). This region presents the greatest generation possibilities, mainly in solar and wind generation.

Table III – Caribbean region

Resource	Capacity (MW)	Percentage
Wind	3228	53.4%
Solar	2815	46.6%
Biomass	2	0.0%
Total	6045	100%

With respect to Andean region the projects are focused on Solar (49.4%) and Small-Hydro (44.7%), this region has a potential very large in the water resource applied to small hydro and solar in residential use.

Table IV – Andean region

RESOURCE	CAPACITY (MW)	PERCENTAGE
Solar	1074	49.4%
Small hydro	972	44.7%
Wind	125	5.7%
Biomass	4	0.2%
Total	2175	100%

The Orinoquía region has a potential mainly in solar resources, according to Table V, the participation is of 113 solar projects (78.8%).

Table V – Orinoquía and Amazon region

RESOURCE	CAPACITY (MW)	PERCENTAGE
Solar	113	78.8%
Biomass	30	21.2%
Total	143	100%

Finally, the Pacific region is the rainiest area of the world, therefore has great possibilities with water resource in small-hydro, as presented in the table VI.

Table VI – Pacific

RESOURCE	CAPACITY (MW)	PERCENTAGE
Hydro	20	95.8%
Solar	1	4.2%
Total	21	100%

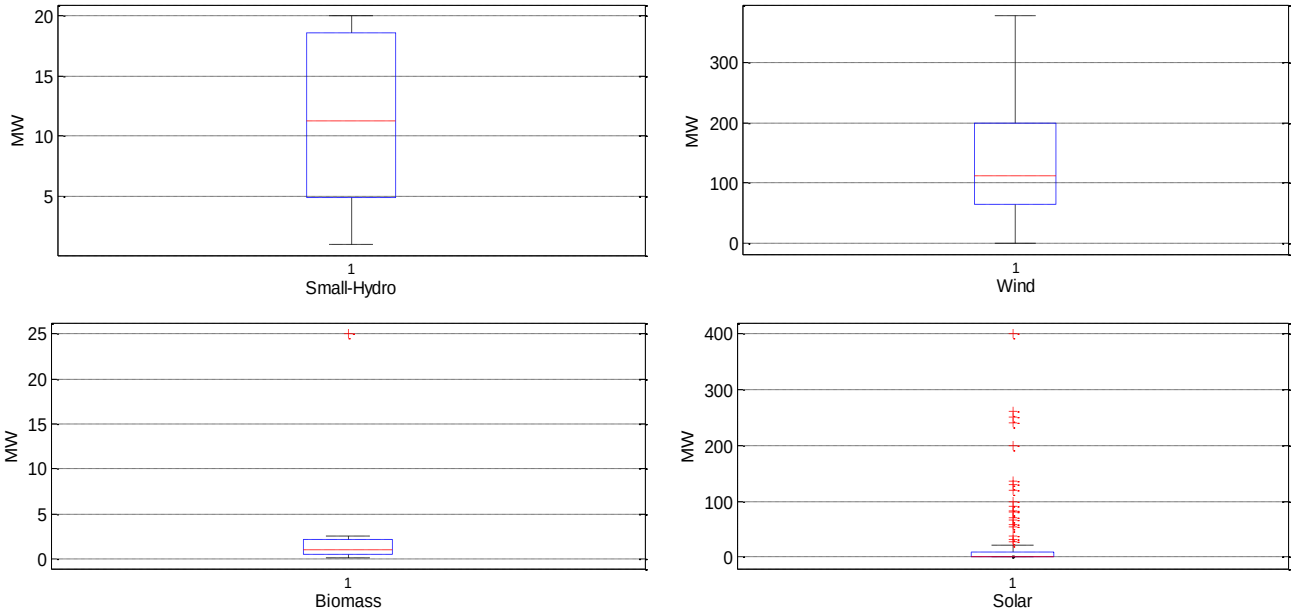

Fig. 1. Boxplot renewable projects by source: display distribution.

A. Distribution renewable projects by resource

Figure 1 shows the distribution of renewable projects registered by UPME using a boxplot distribution. The *x* label presents the name of the energy resource and the *y* label defines distribution of capacity in MW. The box plot contains five important data: minimum value, first quartile, median, third quartile, and maximum value. For small-hydro there are 81 projects, the projects analysed in this paper is from 0.1 MW to 20 MW, the mean is 11.31 MW, the deviation is 6.76 MW, the interquartile corresponds to is from 5 MW to 18 MW.

With respect to wind resource the mean is 139.67 MW, the deviation is equivalent to 104.34 MW and the interquartile is from 63.5 MW to 200 MW. For biomass the mean is 2.94 MW, deviation is 6.67 MW, related to interquartile is from 0.54 MW to 2.1 MW. Finally, with respect to solar, there are 344 projects with a high dispersion due there are small and large projects. The mean is 11.63 MW, the maximum value is for a project of 400 MW and the minimum is 0.01 MW, the deviation is 38.2 MW. The solar figure includes the interquartile from 0.1 MW to 10 MW and the first and third quartile.

Figure 2 presents the Kernel distribution, which is a non-parametric estimation, that probability density function. Kernel distribution is defined by a smoothing function and a bandwidth value. Each energy resource such as: small-hydro, wind, biomass and Solar. Is divided into steps with the objective to show power categories. In the *x* label is the capacity (MW) and the *y* label the number of projects. The results show that there is any specific distribution.

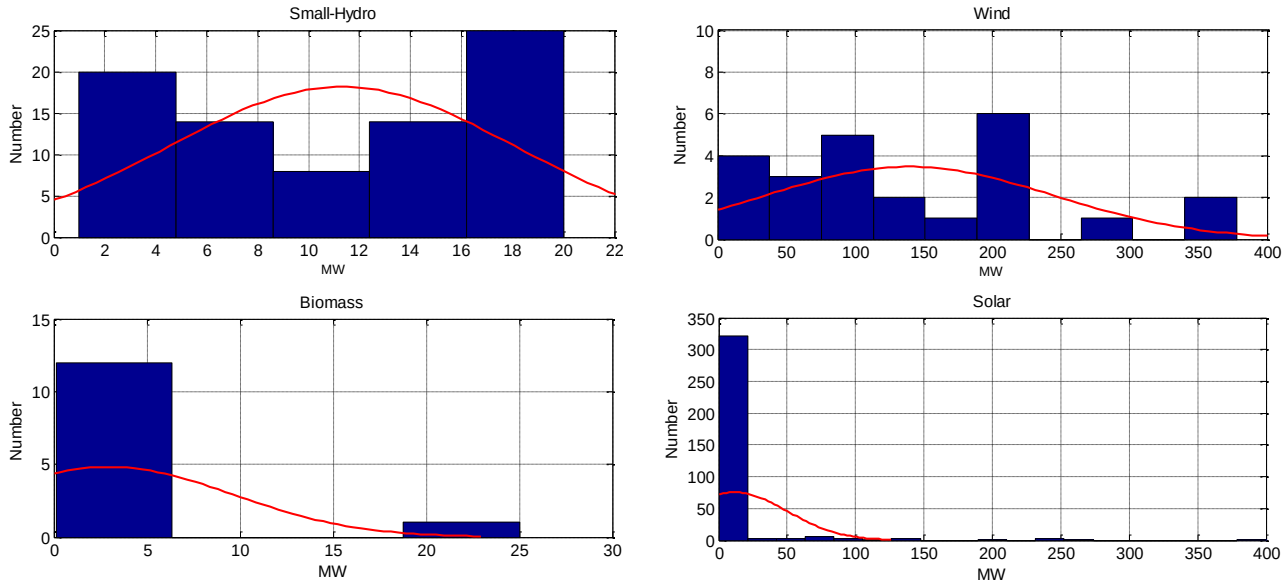

Fig. 2. Kernel distribution of renewable projects.

4. Conclusions

Colombia is one of the most important economies in Latin America. In terms of product (GDP) at purchasing power parity (PPP) is a fourth largest economy by gross domestic product (GDP) at purchasing power parity (PPP) in 2015 [9]. Between 2010 and 2016, the GDP per capita, on PPP basis constant to 2011 increased by 20.4% from 10,900 USD to 13,124 USD. In the same period, the population grew from 45.918 million in 2010 to 48.653 million in 2016. Based on the global development indicators,

Colombia wants diversify the energy matrix mainly two aspects: (i) to ensure the resilience of the electricity matrix generation to climate change and diversify the risk; and (ii) (iv) to reduce greenhouse gas emissions (GEE) related to power sector in accordance with World Summit on Climate Change in Paris (COP21) [2]. Therefore, the government through the UPME and CREG develops regulatory framework. That allows introducing other sources based on renewable resources such as: small-hydro, wind, biomass and solar generation. Hence, Colombia develops the regulatory framework to advance toward growing use of FNCER and diversify electrical generation matrix.

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