

Status of Non-Conventional Sources of Energy in Colombia: A Look at the Challenges and Opportunities of the Electric Sector

Oscar Churio-Silvera, Marley Vanegas-Chamorro and Paola Barros Zarante

Energy Efficiency Research Group - kaí, Engineering Faculty
Universidad del Atlántico, km 7 antigua vía Puerto
081008 Barranquilla, Colombia

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Abstract

This article analyzes the current state of Colombia's energy matrix, analyzing aspects of energy policy, the current state of non-conventional sources of energy (NCSE), the challenges and opportunities that the country is having in order to promote the implementation and use of this type of energy as well as the existing barriers to it. It is known that the Colombian electricity sector is in a constant challenge, which has led the national government to look for new alternatives to face the increase in electricity demand through the NCSE, sanctioning Law 1715 of 2014, to leave the dependence on fossil fuels to produce electricity, as well as the generation of hydraulic energy that is affected by the climatic variability of the country. With the new normative guidelines of the electricity sector, the government intends to deal with Greenhouse Gas (GHG) emissions and reach the non-interconnected areas by generating energy from renewable sources, which allows the diversification of the national energy matrix and therefore guaranteed the energy supply in a sustainable and environmentally friendly way.

Keywords: Non-conventional sources of energy (NCSE), National Electric System (NES), Energy demand, Greenhouse Gas (GHG)

1. Introduction

At present, some countries have been affected by the energy model used due to the

volatility of oil prices, which means that there is no sustainable growth that allows a balance between the demand and supply of energy. On the other hand, there is a global concern related to the emission of Greenhouse Gas (GHG), which has motivated different countries to change the way they produce, transport and distribute energy. The Colombian government has opted for the consolidation of mining-energy development for regional equity, as one of the objectives of the National Development Plan 2014-2018 [1], assuming the guidelines established by Law 1715 of 2014 to develop and to promote the NCSE to such point of view the integration of these to the national energetic system [2].

The importance of the energy sector in the country leads to its positive contribution to the trade balance, backed by the National Energy Plan, NEP [3]; being one of the transcendental pillars of the economy is also the basis of welfare, peace and security, which leads to envision the use of new technologies that allow the generation of energy more efficiently [4]. Therefore, the country's energy policy is to have a secure supply of energy, in order to diversify primary sources of energy, reduce environmental impact and have greater competitiveness in state enterprises, which generate regional equity [1] [3] [5].

The incentives promoted by the government for the use of Non-Conventional Sources of Renewable Energy (NCSRE), is because of the amount of resources available to the country, due to its geographical location that gives it an advantage in terms of solar and wind resources. relation to other countries [6]; due to this the country faces new challenges and opportunities such as knowing the behavior of the energy sector, its policies and the availability of energy resources in order to project strategies for the implementation of advanced technologies [7], aimed at the implementation of NCSRE to expand the energy system and meet the growing demand for energy.

2. Overview of Colombia

Colombia is a country with great diversity and this is clearly reflected in its geography. It is constituted by 32 departments and a capital district. Although most of its extension is in the Northern Hemisphere, Colombia is equidistant from both ends of the American continent [8], bounded on the north by the Republic of Panama and the Caribbean Sea, by the East with the Republics of Venezuela and Brazil, on the south with the Republics of Peru and Ecuador, and on the west with the Pacific Ocean [9].

Due to the geographical position of Colombia, there is a great diversity of ecosystems and climates, ranging from the coldest, at 0°C in the cusps of the mountains, to the warmest, at 30°C on the Atlantic and Pacific coasts [10]. It is one of the countries with the largest number of water resources in the world and has great geological resource potential, which makes possible the exploitation of coal (fourth largest exporter worldwide), metals, precious stones (gold, silver, platinum and emeralds) and minerals [7].

Colombia is a social state of law and its economy is based, fundamentally, on the production of primary goods for export, and on the production of consumer goods

for the domestic market [11] [12]. The behavior of the exchange rate affects mainly the export sector, however, the other side of the coin shows that imports have recently registered growth, which is perceived as a clear indicator of the reactivation of the Colombian economy and the use of the appreciation of the currency [13]; positioning the Colombian economy as the fifth largest in Latin America, after Chile, Costa Rica, Panama and Mexico and in the international classification, is among the 66 largest in the world [11] [13].

3. Regulation of the Colombian electricity sector

For the Colombian electricity sector to function as efficiently as possible, a scheme has been established that involves the entities that produce, transport and distribute energy, those that coordinate all of the above, those that establish the general policies, those that do the rules to deliver good quality products at a reasonable price and those that ensure that all comply with existing standards [14]. The electricity sector is regulated by entities such as the Ministry of Mines and Energy (MME), in charge of designing sector policies; the Energy Mining Planning Unit (EMPU), which designs the National Energy Plan for the expansion of the sector; the Energy and Gas Regulation Commission (EGRC) who is in charge of regulating, through legal norms, the behavior of users and companies with the aim of ensuring the provision of these public services in conditions of efficiency, coverage and quality of service; the National Dispatch Center (NDC) operates the market, planning, supervising and controlling the operation of generation resources, transmission and interconnection; the National Operation Council (NOC) who adjusts the technical aspects to ensure that the integrated operation of the National Interconnected System (NIS) is profitable, unequivocal and reliable and the Superintendence of Public Utilities (SPU), in charge of monitoring the behavior of agents and punish violations of laws and regulations [14] [15].

4. Generation of the National Interconnected System (NIS)

Colombia in 2016 had a generation capacity of 16,594 MW, while the maximum demand was 9,904 MW, which means that the system is able to generate 40% over the requirements of maximum demand [16] [17]; This allows the electric sector to occupy the first place in reliability in Latin America and the tenth position in the world in terms of environmental sustainability. Of this capacity, 69.93% corresponds to hydraulic energy, 20.78% to thermal (gas and coal) and 9.29% to generation from Minor Plants and Cogeneration projects (See Figure 1) [17].

The Colombian electricity market consists of 53 generators, 94 trading companies, 31 network operators and a dozen transmitters [18]. The consumption of electricity in the country is concentrated in the transport (40.2%), industrial (28.9%) and residential (16.5%) sectors. The tertiary sector has a consumption close to 5%, which, despite being low, presents important opportunities for improving energy efficiency in segments such as commercial, public entities and public lighting (See Figure 2) [19].

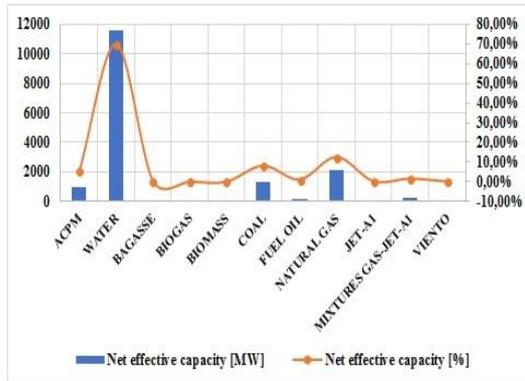


Figure 1. Capacity Installed by Technology and Resource
 Source: UPME data. Author's own elaboration

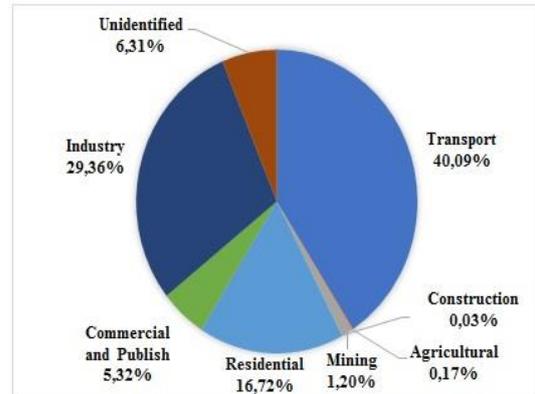


Figure 2. Distribution of Final Energy Consumption
 Source: UPME data. Author's own elaboration

5. Growth of the Electricity Sector in Colombia

The growth of the electricity sector has been greater compared to the population growth; currently, the population growth and electricity generation rates are 0.9% and 3.2%, respectively [20], as shown in Figure 3, the generation of energy by fuel for the period from 1971 to 2015, where the growth of electricity generation is clearly observed, as well as the contribution of hydroelectric power plants to supply the energy demand.

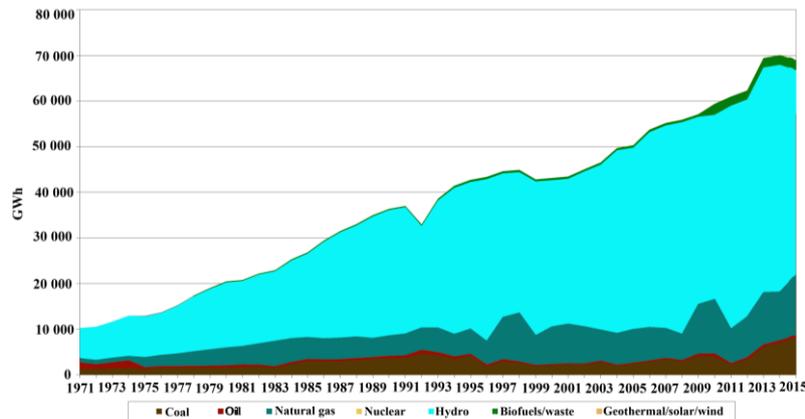


Figure 3. Generation Electric power from 1971 to 2015
 Source: XM, UPME

The total projection of the demand for electric power for the year 2030 [21], show the same behavior; however, population growth can be affected by the problems of neighboring countries such as Venezuela. For this reason, a total projection of the electric power demand is presented to meet the expected demand where by the year 2030 an increase in the demand for electric power greater than 105,000 GWh is expected.

6. Emissions of the Electricity Sector in Colombia

Carbon dioxide (CO₂) emissions from the electric sector are produced especially by thermoelectric plants. The amount is variable taking into account the size of the plant, the type of fuel used and the amount of energy generated [21].

The country's emissions increased by 15% (36 million tons of CO₂eq), from 245 Mton in the year 1990 to 281 Mton in the year 2012; the sectors that generate the greatest amount of emissions in the country are the forestry sector with 36%, the agricultural sector with 26%, the transport and manufacturing industries with 11% and the mining and energy sector with 10%. All these statistics reflect the increase of the country's emissions with respect to global emissions from 0.37% to 0.42 in recent years. In Figure 4, the behavior of CO₂eq emissions from 1990 to 2015 is observed.

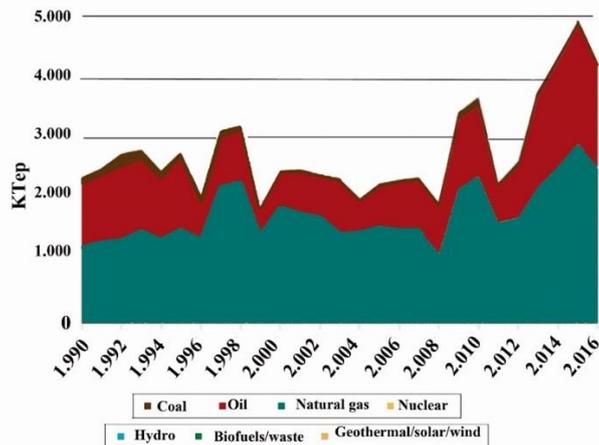


Figure 4. CO₂ emissions from the NIS between the years 1990 to 2016
Source: XM, UPME

It is worrisome the tendency of the growth of these from 2008, where it is appreciated greater level of the emissions of the thermal plants; therefore, the maximum CO₂ emissions corresponding to coal and natural gas are 1,955 kTep and 2,929 kTep, respectively, for 2015 [22].

7. Niches of Renewable Energies in Colombia

The generation of energy from wind projects in La Guajira (the area with the greatest potential in the country) would represent an environmental benefit measured in terms of savings in GHG emissions, representing an energy potential with installed generation capacity of up to 18,000 MW. In addition, benefits would be obtained such as the decrease in installation costs compared to thermal plants, since cheaper energy would be delivered, increasing the generation capacity of the Caribbean Region. Currently, there is the Jepírachi Wind Farm, located in the

northeast of La Guajira, on an area of 1.2 km², with 15 wind turbines of 1.3 MW, resulting in an installed capacity of 19.5 MW [23].

Biomass combined with modern technologies allows both the production of electricity and the production of heat and its use for transport purposes. This is the most developed renewable source in Colombia, specifically the use of bagasse from sugarcane. The energy potential of biomass in Colombia is high, especially from waste, reaching the order of 450 PJ / year which corresponds to approximately 41% of the national energy demand, and can be used both for electrical and thermal purposes [23].

In Colombia, hydroelectric plants are the largest source of renewable energy generation. This type of energy is ideal for generating low-cost electricity, taking into account the location of the hydroelectric power plant. They are widely developed in the country with a large participation in the energy matrix with a contribution of 84.93% for 2016 [16].

Colombia is not one of the countries with the greatest potential for the use of geothermal energy. However, it has specific areas such as the volcanic area of Nevado del Ruiz and the region of influence of the Chiles, Cerro Negro and Azufral volcanoes on the border with Ecuador, where the resource can be used to generate dozens of MW, at a very low cost of production and operation [23].

In recent studies it has been concluded that the greatest potential for the development of seawater energy is found in the peninsula of La Guajira with a value of 11.67 kW / m but does not reach the minimum required flow (15kW / m), similarly the area near the San Andres and Providencia Islands have speeds that can be exploited in the long term. The Pacific region does not present usable thermal gradients or adequate depths to obtain energy. Despite meeting the necessary tidal ranges, certain areas of the Pacific Coast such as Bahía Málaga have low speeds of tidal currents, which makes this potential unusable in the medium term [3].

In Colombia there are no power generation plants with this technology, however, there are already guidelines that guide the management of reactive waste in the territory, which indicates a beginning to constitute a future regulatory framework in Colombia. The small nuclear power plants could be a long-term alternative to diversify the electricity generating park in the country. Nuclear energy is a reliable, safe and free source of GHG emissions [3].

The second modern source of renewable energy with the highest penetration in the world is solar energy, after wind power; the country has an average radiation of 4.5 kWh / m²day [8], which exceeds the world average of 3.9 kWh / m²day and is well above the average received in other parts of the world such as Germany that counts with a resource of 3.0 kWh / m²day.

In addition to the good average resource available, it is considered that there are particular regions of the country such as La Guajira, a good part of the Atlantic Coast and other specific regions in the departments of Arauca, Casanare, Vichada and Meta, that have levels of radiation above the national average, which can reach the order of 6.0 kWh / m², comparable with some of the regions with the best resource in the world, such as the Atacama desert in Chile or the states of Arizona and New Mexico in the United States [23].

8. Energy Regulations in Colombia

The national government has opted for the development of regulations for control and implementation of projects related to the development of NCSRE, supporting entrepreneurs, companies, foreign investors and educational centers; having as a regulatory framework Law 1715 of 2014. Likewise, everything related to this law has been disclosed through the regulation of the small-scale self-generation power limit (UPME Resolution 0281 of June 05, 2015), that shows the guidelines for the application of incentives of Law 1715 (Decree MME 2143 of November 04 of 2016) and indicates the procedure and the requirements to access tax benefits (UPME Resolution 045 of February 03 of 2016). Likewise, the national government has established the public policy guidelines for efficient energy management and delivery of small-scale self-generation surpluses (Decree 348 of March 01, 2017). In Resolution 121 of August 28 of 2017 of the Commission of Regulation of Energy and Gas (CREG) where it is ordered to make public the draft resolution regulating small-scale self-generation and distributed generation activities in the national interconnected system and finally in February of this year, the CREG published Resolution 030 of 2018, which regulates the activities of small-scale self-generation and distributed generation in the national interconnected system.

9. Challenges and Opportunities to implement NCRE

Since the restructuring of the Colombian electricity sector in 1994, it has been able to meet the energy demand of the population. However, from that period to date, different climatic variability phenomena such as the El Niño Phenomenon have been presented, affecting the energy matrix since there is a dependence on hydroelectric and thermoelectric plants. Therefore, the challenge for the country's electricity sector is to develop projects that take advantage of the potential of renewable resources that facilitate their development due to the privileged geographical position of the country. For the implementation of the different technologies of renewable energies there are challenges that directly do not favor their development, among which the following can be mentioned: a) Licensing processes, b) Absence of technical requirements and c) Development of infrastructures for the connection of networks [23].

10. Conclusions

The generation of electric power corresponds to 69.93% to hydraulic energy, 20.78% to thermal generation (gas and coal) and 9.29% generation from Minor Plants and Cogeneration projects; where the consumption of electricity in the country is concentrated in the transport (40.2%), industrial (28.9%) and residential (16.5%) sectors.

The sectors that emit emissions the highest amount of CO₂eq emissions in the country are the forestry sector with 36%, the agricultural sector with 26%, Transport and Manufacturing Industries with 11% and the mining and energy sector

with 10%. CO₂eq emissions from the country are related to coal and natural gas with values of 1,955 kToe and 2,929 kToe, respectively, for 2015.

The country's energy policies are focused on the use of NCSRE, which offer great opportunities to make the electrical matrix more robust and versatile that can reach the non-interconnected areas of the country; likewise, the national regulation is in favor of business development and remuneration through incentives, as established by Law 1715 of 2014.

References

- [1] D. N. de Planeación, Plan Nacional de Desarrollo 2014-2018, Bogotá, (2014).
- [2] MINMINAS y UPME, Incentivos Tributarios - Ley 1715 de 2014, Informe no. 5, (2014).
http://www1.upme.gov.co/Documents/Cartilla_IGE_Incentivos_Tributarios_Ley1715.pdf
- [3] UPME, Plan Energético Nacional de Colombia: Iderario Energético 2050, Bogotá, (2015).
- [4] O. Churio, G. Valencia, M. Vanegas y E. Villacaña, *Cálculo De Las Radiaciones Total, Directa Y Difusa A Través De La Transmisibilidad Atmosférica En Los Departamentos Del Cesar, La Guajira Y Magdalena*, PhD Tesis, Universidad del Atlántico, Barranquilla, 2016.
- [5] M. R. Vivos, Política energética colombiana y propuestas para su transformación, (2016).
https://defensaterritorios.files.wordpress.com/2016/08/doc_rios-vivos_propuesta-mea_2016_rf2.pdf
- [6] C. V. d. Noticias, Colombia una potencia en energías alternativas, Ministerio de Educación Nacional, Republica de Colombia, Bogotá, 2016.
- [7] Y. Castillo, M. Castrillon, M. Vanegas, G. Valencia and E. Villicaña, Role of Non-Conventional Energy Sources in the Colombian electricity sector, *Prospect*, **13** (2015), no. 1, 39-51. <https://doi.org/10.15665/rp.v13i1.358>
- [8] A. G. Martínez, Toda Colombia: Geografía de Colombia, (2015).
<http://www.todacolombia.com/geografia/geografiacolombiana.html>
- [9] S. C. d. B. d. l. República., Posición astronómica y geográfica de Colombia, (2015).
http://www.banrepcultural.org/blaavirtual/ayudadetareas/geografia/posicion_astronomica_geografica_colombia

- [10] Colombia-sa, Mapas de Colombia, (2013).
<https://colombia-sa.com/geografia/geografia.html>
- [11] Colombia.com, Informe Económico, (2016)
<http://www.colombia.com/colombia-info/informacion-general/economia/>
- [12] E. Espectador, Economía colombiana crecería 1.8% en 2017 y subirá al 2.6% en 2018: Cepal, (2017). <https://www.elespectador.com/economia/colombiana-crecio-18-en-2017-y-seguira-haciendolo-en-2018-en-26-cepal-articulo-728414>
- [13] B. Mundo, ¿Cuáles son los países más competitivos de América Latina según el Foro Económico Mundial?, (2017).
<http://www.bbc.com/mundo/noticias-america-latina-41428239>
- [14] CREG, Estructura del sector, (2017).
<http://www.creg.gov.co/index.php/sectores/energia/estructura-energia>
- [15] GrupoEnergíaBogotá, Sector energético en Colombia, (2014).
<https://www.grupoenergiadebogota.com/eeb/index.php/transmision-de-electricidad/sector-energetico-en-colombia>
- [16] UPME, Subdirección de energía eléctrica – grupo de generación. (2016). Informe mensual de variables de generación y del mercado eléctrico colombiano, (2016).
http://www.siel.gov.co/portals/0/generacion/2016/Segui_variables_dic_2016.pdf
- [17] M. Saavedra, Generación eléctrica en Colombia está holgada ante la demanda, *El Mundo*, (2017).
- [18] XM, Descripción del sistema eléctrico colombiano, (2014).
<http://informesanuales.xm.com.co/2013/SitePages/operacion/1-4-Agentes-del-mercado.aspx> [Último acceso: 24 abril 2018].
- [19] UPME, Plan de Acción Indicativo de Eficiencia Energética 2017 - 2022: Una Realidad y Oportunidad para Colombia, (2016).
http://www1.upme.gov.co/DemandaEnergetica/MarcoNormatividad/PAI_PROUR E_2017-2022.pdf
- [20] DANE, Proyecciones nacionales y departamentales, (2010).
https://www.dane.gov.co/files/investigaciones/poblacion/conciliacenso/7_Proyecciones_poblacion.pdf
- [21] XM, Pronóstico de Demanda, (2017).
<http://www.xm.com.co/Paginas/Consumo/pronostico-de-demanda.aspx>

[22] S. d. I. E. colombiano, Estadísticas y variables de generación 2016, (2017).
<http://www.siel.gov.co/Inicio/Generaci%C3%B3n/Estad%C3%ADsticasyvariablesdegeneraci%C3%B3n/tabid/115/Default.aspx?PageContentID=1191>

[23] UPME, Integración de las energías renovables no convencionales en Colombia, (2015).
http://www.upme.gov.co/Estudios/2015/Integracion_Energias_Renovables/resumen_ejecutivo_integracion_energias_UPME2015.pdf

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