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A look to the Electricity Generation from Non-Conventional Renewable Energy Sources in Colombia

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ABSTRACT

This study discusses the potentialities and current situation of the electricity generation from non-conventional renewable energy sources (NCRES) in Colombia. In particular, three scenarios considering the increment of NCRES electricity based generation installed capacity are discussed. The three scenarios are compared to the 2020 forecast of the Energy and Mining Planning Unit ((UPME). Overall, it id shown that Colombia has a significant unused NCRES potential, which makes possible to realize the 6% target for NCRE based electricity generation capacity installed by 2020. In particular, the photovoltaic energy is foresee to account for over half of the NCRE mix. Even though the law 1715 is a progress towards integrating NCRE to the National Electric System, more policies and developments are required, to further the NCRE based installed generation capacities.

Keywords: Non-conventional Renewable Energy, Electricity Generation, Energy Policy
JEL Classifications: O, Q4, Q42

1. INTRODUCTION

The consequences of global warming and climate change and the possibility of running out of fossil fuels, have driven the growth of renewable energy sources (RES), which currently have the mayor growth rate (BP, 2017). In particular, the power generation sector has one of the fastest growing of RES (Sawin et al., 2017) where amount for 24% of the global electricity mix, it is estimated to increase to 30% in 2030 (IEA, 2017).

The RES using for power generation shows a rapid growth in industrialized nations, which is led by China, the United States, the European Union and India (IEA, 2017). Moreover, there is a significant potential for RES based electricity generation in developing countries that in some cases has a rapid economic expansion with significant energy demand increase (Kim et al., 2017). Even though some governments played a significant role in the expansion of RES technologies, new and improved policies are required to promote the renewable energy market (Gabriel, 2016).

The Colombian electricity generation mix main components are hydroelectric plants (66%) and gas and coal-powered thermoelectric plants. The country needs to diversify its electricity mix by incorporating non-conventional RES (NCRES) in order to reduce vulnerability to hydrological fluctuations and fossil fuels dependence (UPME, 2015). NCRES are defined in Law 697 (Gobierno Nacional, 2014) as "energy sources available worldwide that are environmentally sustainable, but which in the country are only marginally used and are not widely commercialized." Consequently, NCRES are solar energy, wind energy, energy derived from biomass, and geothermal energy.

Although the National Energy Plan (UPME, 2015) calls for the diversification of energy supplies through the use of NCRES and Law 1715 has established a legal framework to it implementation into the national electricity grid (NEG), including promotion mechanisms and incentives, its application 4 years later are marginal yet (Cardenas et al., 2017; Edsand, 2017; Jimenez et al., 2016). NCRES currently account for only 0.7% of energy generation capacity (EGC) in Colombia (UPME, 2018a). According to the scenarios studied by Medina et al., (2013) and the models developed by Chaves et al. (2018), renewable EGC would continue to remain low. In the worst-case scenario, wind energy would reach 474 MW by 2030, which would represent 2% of the EGC, and even in the best-case scenario, its total share would reach only 6% (Quijano, 2012).

This study provides a forecast of the increase in electricity generation from NCRES by 2020, in three scenarios, based on the current stage of development of the projects registered at the UPME. The forecast results are compared to forecasts made by UPME in 2015 in order to assess their feasibility.

2. THE COLOMBIAN ELECTRICITY SECTOR

In Colombia, national policies for the electricity sector are managed by the Mines and Energy Ministry (MME) through the UPME, which issues and monitors the national energy plan and the plan for the expansion of the electricity sector. the energy and gas regulatory committee (CREG) regulates the public utilities, and the public utilities services superintendence performs oversight and control. Other intervening agencies include the National Dispatch Center (CND), which is responsible for planning, supervising and controlling the NEG, and the national operations council (CON), which establishes technical standards to ensure that the integrated NEG operates in a safe, reliable and economic manner (Castillo et al., 2015). The Colombian electricity market comprises 62 power generators, 96 distributors, 31 network operators and 12 transmission operators (XM, 2018).

Since 1994 Colombian electricity sector adopt a liberal market based approach excepting the households where there are regulated rates (Jimenez et al., 2016). The market prices are set the previous day based on bids freely entered by the various operators (Olaya et al., 2016).

In 2017, the EGC in Colombia totaled 16,597 MW. Figure 1 shows the electricity mix by primary energy source, NCRES account for 2% of the total, of which 1% is from small hydroelectric plants (SHP) and the use of bagasse as fuel respectively, whereas wind power generation was very incipient, with only 18.4 MW, equivalent to 0.001% of EGC (UPME, 2017a).

In 2016, total electricity generation in Colombia was 66,593 MWh. Figure 2 shows the load balance of the NEG.

Because of the high share of hydroelectric energy in total electricity generation, Colombia is an advanced country in terms of clean energy, with an average annual growth rate in electricity generation of 2.7%, in line with growth in demand. However, it is also highly vulnerable to hydrological variability, which makes it necessary to have thermal energy capacity in reserve in order to ensure the NEG's stability and reliability (Caspary, 2009; Macías, 2013).

Figure 3 shows the behavior of energy generation by primary energy source between 2007 and 2016, fluctuations of the shares in the periods 2009-2011 and 2014-2016 are a result of meteorological events such as the El Niño El Niño-Southern Oscillation and La Niña (Gonzalez et al., 2017) phenomena.

During dry seasons hydroelectric generation is low because drops in water availability and thermal generation is increased provoking over cost for fuel consumption according fuel price and also increasing the country greenhouse gas emissions. The main intention of NCRES implementation promotion is contributing to satisfying the future growth in electricity demand and seasonal fluctuations avoiding this inconvenience (Macías, 2013).

Figure 1: Colombian Electricity Mix. EGC in 2017. Source of data: (UPME 2017a; XM 2018)

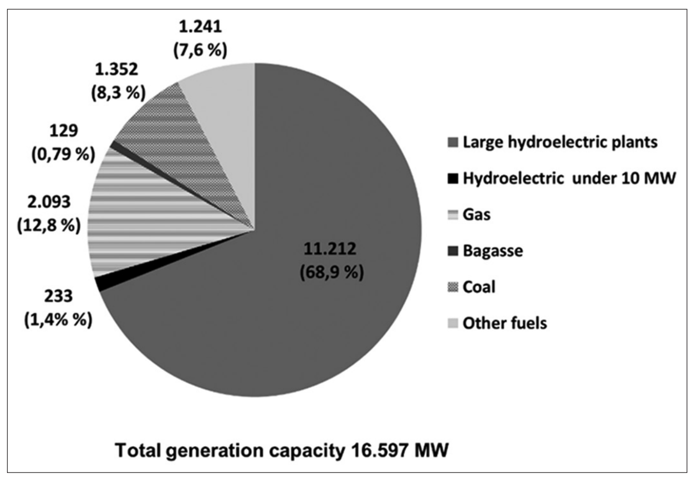


Figure 2: Load balance of the Colombian NEG in 2016. Source of data: Prepared by the authors based on data from: (UPME, 2017)

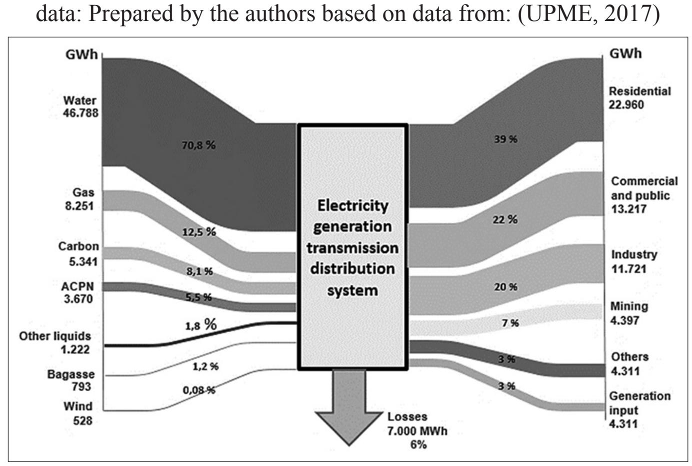
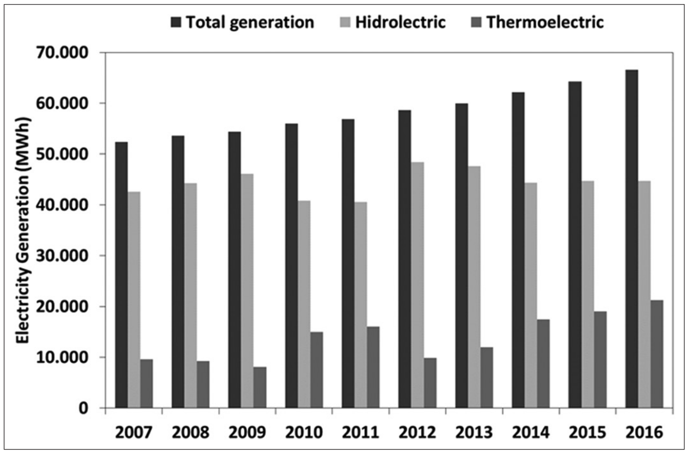


Figure 3: Electricity generation by primary source. 2007-2016. Source of data: Prepared by the authors based on data from: (UPME, 2017)



3. POLICY FOR PROMOTION OF NCRES IN COLOMBIA

The enactment of Law 697 (Gobierno Nacional, 2001) establishes the government throughout MME in formulating policy guidelines, strategies and instruments to promote NCERS creating incentives for companies and the market. Nevertheless, to date, the impact of this law has been very limited because the participation of NCRES in the Colombian NEG is almost negligible, with only 2% of EGC and 1.2% of electricity generation in 2017 (Figure 1).

In 2014 a policy to guidelines to enable the implementation of NCRES projects with attractive incentives for Colombian companies ensuring their inclusion in the national energy market throughout the enactment of Law 1715 (Gobierno Nacional, 2014) which set the procedure for the development of NCRES projects. Some of the most widely praised aspects of the law include: (a) Annual income tax deductions for projects that promote research, development, and investment regarding energy production and use of NCRES; (b) VAT exemptions to promote the use of energy derived from NCRES; (c) exemptions on import taxes for new investments in new NCRES projects, and (d) accelerated depreciation of assets for the generation of energy from NCRES (Gaona, 2015). The positive impact of Law 1715 was highlighted by Castillo et al. (2017), however, Olaya et al. (2016) point out several successful incentives applied in other countries have not been included. Pereira (2015) considers that its scope is limited in terms of their implementation into the NEG because several implementation mechanisms have yet to be fully established (Olaya, 2016). From 2018, 221 projects involving NCRES have been certified; they are in different stages of development and would add around 1,240.88 MW to EGC (UPME, 2017).

Since 2006, the shortcomings of the rules and the absence of adequate rates have been pointed out (Ruiz and Rodríguez, 2006), this situation remains because is still uncertainty regarding the implementation of NCRES (Edsan, 2017; Román et al., 2018). In addition, there is lack of regulations on their effect on the adoption rate and on prices and issues related to the security of supplies into the Colombian energy market (Jiménez et al., 2016).

The influence of rules weakness and the lack of adequate rates have been highlighted since 2006 (Preira, 2016), this uncertainty remains over NCERS implementation (Edsand, 2016; Román et al., 2018). Additionally, there is a lack of regulations on prices and security of supplies into the Colombian energy market (Jimenez et al., 2016). NCRES haves others disadvantage in front of conventional energy sources because of lack a clear methodology for calculating the electric generation based in NCRES which reduce its competitiveness because frequently reliability charges are applied it (Botero et al., 2010).

Even though an indicative national plan exists (PEN, 2015), which establishes actions and measures to fulfill the goals of the energy sector by 2022, no mandatory targets have been set for NCRES. For this reason, Román et al. (2018) emphatically recommend following the example of countries such as Chile, Mexico and Argentina, which have set a law mandatory target to generate 10% of their electricity based on NCRES (Chavez et al., 2018).

According to MME the current status of NCRES in Colombia is still in the early stages of technical development and regulation still far from maturing, with a slow technical learning curve because lack of capacity and experience, which delays the implementation and impact of Law 1715 (Medina et al; 2013). IRENA (2015) reviewed the RES policies of Latin American countries in terms of 49 aspects related to 5 topics: National policy, tax incentives, access to the NEG, regulatory instruments and finance. In the results, Colombia was pointed was lagging behind other countries in the region (IRENA, 2015).

4. NCRES IN THE COLOMBIAN ELECTRICAL SYSTEM

There are great natural resources in Colombia. It comes in sixth place worldwide in terms of renewable water resources (Gonzalez et al., 2017), and it uses them for large-scale electricity generation. However, it also has great potential in other RES that are not adequately utilized: A potential for 25,000 MW in SHP, potential solar energy of between 5 and 6 kWh/m^2 per day, annual production of over 5 Mt of sugar cane bagasse, 457000 tons of rice straw and a total of 29 Mt of residual agricultural biomass, great wind farming potential in the northern region of the country, with average density of 1,530 W/m^2 at 50 m, and potential for using geothermal energy in several departments. The estimated potential of energy from tides is around 500 MW, and that from waves is of 30 MW, on the two coasts (Castillo et al., 2015; Radomes and Arango 2015).

4.1. Wind Energy

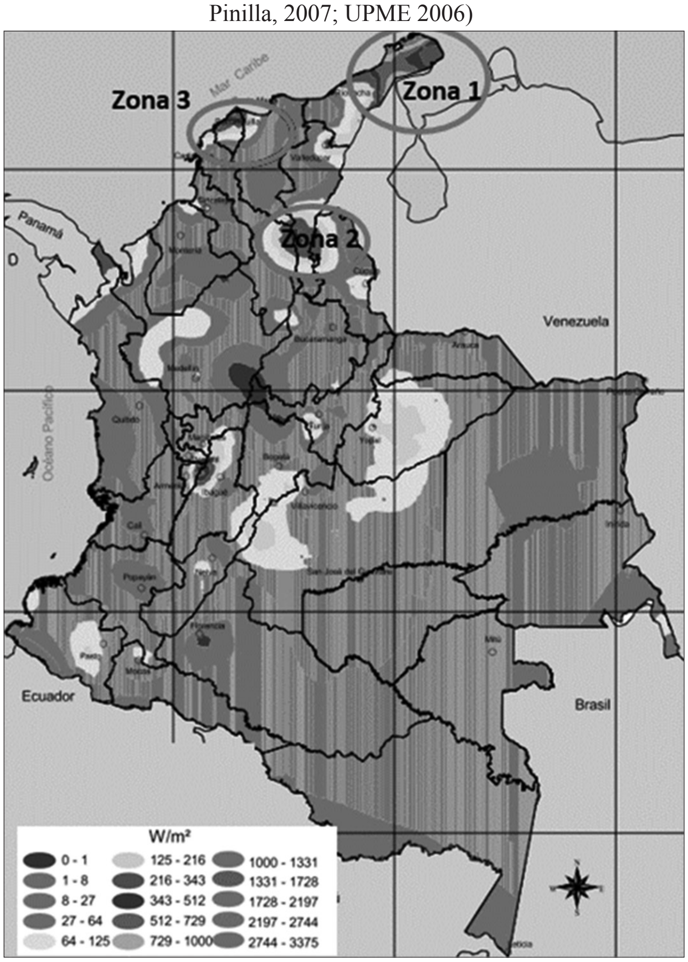
Wind energy is expected to experience a high growth in Colombia, although has not yet been massively implemented. Its potential is concentrated in northern of the country, as shown in Figure 4. The energy potential is 27,000 MW, distributed in the Guajira Peninsula with 18,000 MW, the Santander region with 5,000 MW, the northern coast with 1,000 MW and other regions 3,000 MW. The total potential of wind energy is 60% greater than the country's current EGC (UPME, 2015b; Huertas and Pinilla, 2007). However, Pabón (2017) and Ceballos and Ramos (2018) highlighted that further assessment is required in order to review technical, economic, social and land use restrictions for the installation of wind farms, which could reduce such potential by between 15 and 35%.

Currently, there is in Colombia one wind farm of 19.5 MW, which is 2017 generated 520 MWh (UPME, 2017). There are 11 projects between 2015 and 2017 in licensing process by MME with1510 MW of total capacity (UPME 2017; SIEL 2018), which would indicate over-fulfillment of UPME expectations on wind generation capacity. If these projects are successful, wind generation would total between 1,117 and 1,338 MW to 2025 and 1,322 to 1,658 MW in 2030, which is substantially greater than the UPME forecast of 543 MW between 2015 and 2029, 776 MW from 2020 to 2025 and 320 MW between 2025 and 2030 (UPME, 2015b).

The implementation of this wind energy projects would be highly beneficial for the country because they would enable substituting some of the natural gas used to generate electricity high operating and maintenance costs. Wind energy would also supplement hydroelectric power by minimizing the impact of the hydro-meteorological cycles (Olaya, 2016).

Edsand (2017) has identified several barriers that may limit the wind energy penetration: Scarce human resources in remote rural areas; low institutional and organizational capabilities; few political support for the large turbines introduction; decision-making hampered by bureaucracy and institutional rigidity; low prices of hydroelectric power and the absence of pricing policies; lack of specific subsidies to import equipment; insufficient resources to extend NEG into not connected areas; low level of government interest and the absence of a specific entity to disburse funds for wind energy projects; market dominated by a few large hydroelectric companies, and the opposition of thermoelectric companies.

Figure 4: Average inter-annual wind speed at a height of 50 meters and wind energy potential in Colombia. Source of data: (Huertas and Pinilla, 2007; UPME 2006)



UPME has also identified barriers for increasing the penetration of wind energy: Non-existence of specific references to environmental studies on non-conventional sources; the lack of specific technical requirements to connect and operate wind farms to the NEG; and the remoteness of areas with high wind potential, which would require major investments in order to connect them to the NEG.

From the perspective of social acceptance, Rosso and Kafarov (2015) found 80% of favorable perception of wind energy. However many problems have occurred in the main wind potential region, "La Guajira," because indigenous communities largely reject this technology (UPME, 2015b).

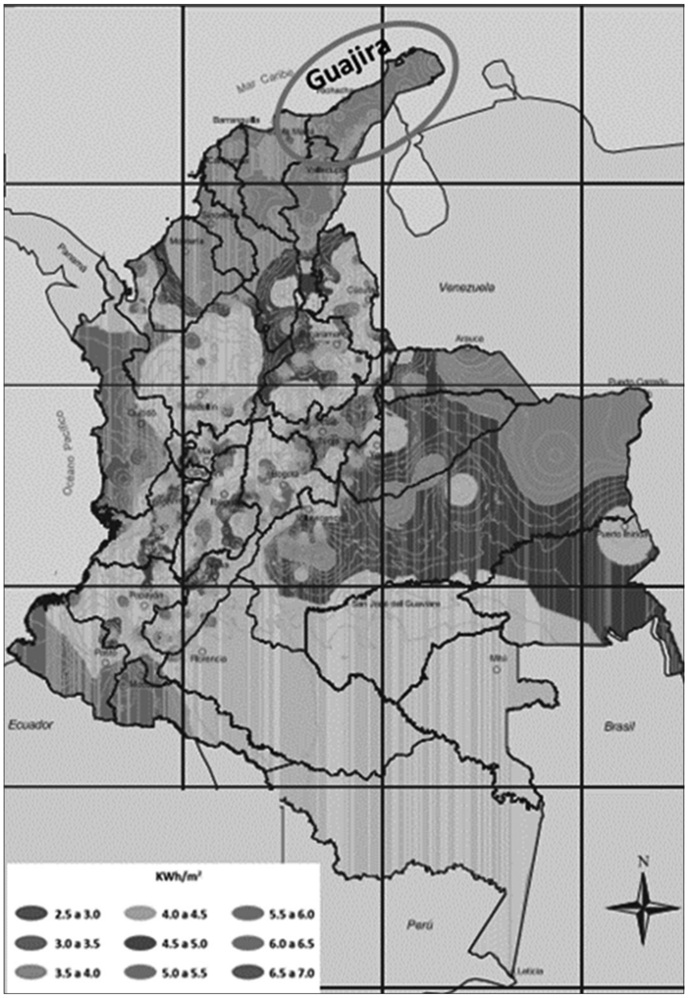
4.2. Photovoltaic Energy

Average solar radiation in Colombia is 4.5 kWh/m^2/d, above the world average of 3.9 kWh/m^2/d, also because the country is near the Equator sunlight remains stable throughout the year (Muñoz et al., 2014). Figure 5 shows a average solar radiation in Colombia, the greatest potential is concentrated in the northern coast, in the same areas with highest wind energy potential, the Guajira Peninsula, where solar radiation around 6.8 kWh/m^2/d are registered. In other zones, average radiation is up to 6.0 kWh/m^2/d, which is comparable to the worldwide higher solar potential zones, such as the Atacama Desert in Chile or the states of Arizona and New Mexico in United States (NREL, 2008).

Penetration of photovoltaic technology (PV) in Colombia has been very limited to date and mainly restricted to isolated regions (Castillo et al., 2015). Nevertheless fast expansion is expected because the gradual reduction of investment costs with reduction in generation costs, (Caspary, 2009; Flórez et al., 2017; IRENA 2018); and the enactment of Law 1715 which has sparked substantial interest in this technology. To date there are 26 projects in different stages of the licensing process with a total capacity of 2,644 MW (UPME, 2017; SIEL, 2018). This should receive a further boost with the enactment of Resolution 30/2018 of the MME, which establishes the conditions for the synchronization of small generation plants with the NEG. As a result, the forecasts of UPME indicating that PV generation would be from 35 to 63 MW in 2020, between 148 and186 MW in 2025 and from 163 to 216 MW in 2030, could be overly conservative (UPME, 2015b).

The way to connecting small PV (0.25 to 5 MW or even less) to the NEG and export surplus was established by Resolution 30/2018 (CREG, 2018) become PV in an excellent business opportunity for the possibility of the using rooftops of industrial and office buildings in urban areas for PV farms. However, preliminary

Figure 5: Overall solar radiation in Colombia. Multi-year average. Source of data: (UPME, 2005)



assessment of the potential of this modality in Colombia's 20 largest cities, taking in account the use of 40% of available rooftops, finding a potential 1,866 MWp, 1,284 MWp in household and 600 MWp in productive facilities. Although this scenario would produce substantial benefits by 2030 the consequences over energy market must be taken into account because of reduction of energy demand in both sectors (Figure 2) and the increase of electricity availability consequence of exporting surplus electricity to NEG. The simulation of PV implementation in 40% of households in 2030 in two scenarios, using energy storage systems and without storage shown the risk of electricity market collapse was shown Jimenez et al. (2016), further studies are required on the policies to be adopted on the expansion of small-scale PV generation.

Despite some of the barriers to the expansion of PV have been resolved by Resolution 30/2018 (CREG, 2018), following still remain: The uncertainty surrounding the key development factors that would enable determining and quantifying its potential impact on the NEG [19]; the absence of technical standards for equipment selection, configuration and installation; difficulties to connecting small and large PV systems to NEG; the lack financials programs aimed at investment in PV and the absence of a regulatory framework focusing on the use of intelligent networks. The social acceptance of PV technology is favorable in 89% (Rosso and Kafarov, 2015).

4.3. Small Hydroelectric Plants

The definition of an SHP is not clear in Colombia, neither in legislation nor in official documents (Morales et al., 2015). The Law 697 (Gobierno Nacional, 2001) defines SHP as NCRE plants with <10 MW, whereas Law 1715 (Gobierno Nacional, 2014) is even more ambiguous, using the term "small-scale" without establishing a threshold for this category.

In several researches legal definition (Gobierno Nacional, 2001) are used (Caspary, 2009; Gallego et al., 2015; Morales et al., 2015; Ruiz and Rodríguez, 2006), However in others (Arias, 2017; Duque et al., 2016a; Duque, 2016b; Múnera et al., 2015) set the threshold for SHPs at 20 MW of capacity. Also UPME, contributes to the confusion when defines SHP as <20 MW (UPME et al., 2015), but in the study on integration of NCRES in Colombia (UPME, 2015) only includes forecasting and assessments for SHP lower than 10 MW exclusively applied for generation in areas that are not connected to the NEG. In addition, UPME establishes that SHPs must be <10 MW in order to be eligible for the incentives provided for in Law 1715 (UPME, 2017). SHP between 1 and 20 MW are included in the same group by Arias et al. (2017) without considering the particularities of those of <10 MW, which produces uncertainty in their results.

The <20 MW SHP electricity generation potential in Colombia is estimated at between 8,000 and 25,000 MW (Olaya et al., 2016). The EGC of the 121 plants in this category totals 1,001 MW, only 89 are classified as NCRES because their capacity is <10 MW, with a total of 233.7 MW (XM, 2018). The UPME expects that SHP capacity to 2020 will total 331 MW, rising in 2025 to 438 MW and by 2030 to 448 MW (UPME, 2015b), which implies that its share in NEG will remain small.

The development of SHP <10 MW is in zones not connected to the NEG, primarily in the Amazon and Orinoco areas where there are abundant water resources; with low potential for large-scale use in electricity generation. On the other hand, numerous opportunities exist for small run-of-river plants that make use of river currents, which do not require major investments and have a low environmental impact. There are currently 32 SHP projects of <10 MW in different stages of development, with a capacity of 170 MW (UPME 2017; SIEL 2017).

4.4. Energy from Biomass

Colombian electricity generation based in biomass totaled 793 MWh in 2017 (Figure 2), mainly from the use of bagasse from sugar mills (UPME, 2015b). However, there is available potential in other biomass types such as agricultural residues, forestry residues, energy crops, residual biomass from livestock farms, and biomass from urban solid waste (UIS et al., 2010). The need for a comprehensive policy on the use and development of biomass is widely acknowledged. Its priorities should include the promotion of their use for energy production (Jimenz et al., 2016; UPME 2015b) and increasing R&D from a very low level (González et al., 2015)

Several researches estimate the potential of biomass from the agricultural and livestock sectors and urban solid wastes around 110,000 MW (AENE 2003; Arias 2009; Corredor 2011; Escalante et al., 2011; Kline et al., 2008; Phillips et al., 2011), and Gonzalez et al. (2014a, 2014b) estimate 200.000 MW but only 16,000 MW would be technically usable. The significant differences in the estimates of biomass potential by the various researchers evidence the need to undertake more precise studies aimed at a more comprehensive assessment, such as that performed by Sagastume et al. (2017; 2018).

The electricity generation based in waste biomass is unlikely to be competitive in the near future because its development largely depends on the Colombian government undertaking R&D activities and the implementation of policies that promote its development. The most optimistic scenarios indicate may be competitive in the NEG in 15-20 years (Caspary et al., 2009; Quintero et al., 2015). There are only 12 biomass-based electricity projects registered in UPME totaling 50 MW, focused on the use of bagasse (UPME 2017; SIEL 2017). The forecast of biomass-based electricity shows low growth in EGC, from 287 MW to 296 MW between 2020 and 2030 in the most probable scenario, and from 438 MW to 701 MW in the most optimistic scenario. However, the potential in zones not connected to the NEG is height and would contribute to the competitiveness and development of the country's agricultural sector, and to job creation in rural areas, which are a priority in the context of the current post-conflict scenario in Colombia. This should be included in future studies (UMPE, 2015a), considering the results of the study by Rosso and Kafarov (2015), which indicates that the use of biomass to produce energy has a full favorable perception in Colombian people.

5. FORECASTS OF ELECTRICITY GENERATION FROM NCRES IN COLOMBIA

Two scenarios of EGC integration from NCRES were studied by UPME (2015): Pessimistic with regulations and price in similar conditions to before enactment of Law 1715 (Gobierno Nacional, 2014) forecasting EGC of 2,500 MW from NCRES in 2030; and optimistic where MME take specific and effective action to promote NCRES and all responses will share, adopt and positively respond to the policy guidelines established. In this scenario, EGC from NCRES is expected to reach 3,622 MW by 2030 (UPME, 2015b). Figure 6 shows the forecast of both scenarios.

In both scenarios, wind energy has higher ECG between 1,300 and 1,650 MW in 2030 (52% of the total in scenario 1 and 45% in scenario 2). Geothermal EGC would be between 325 and 600 MW, while EGC from biomass with 206 MW in 2015, would increase from 299 to 701 MW in 2030. Solar EGC would be between 163 and 216 MW in 2030, and generation by SHPs would increase from 194 MW in 2015 to between 398 and 448 MW in 2030. The share of NCRES in the NEG would be limited, accounting for <6% of total EGC.

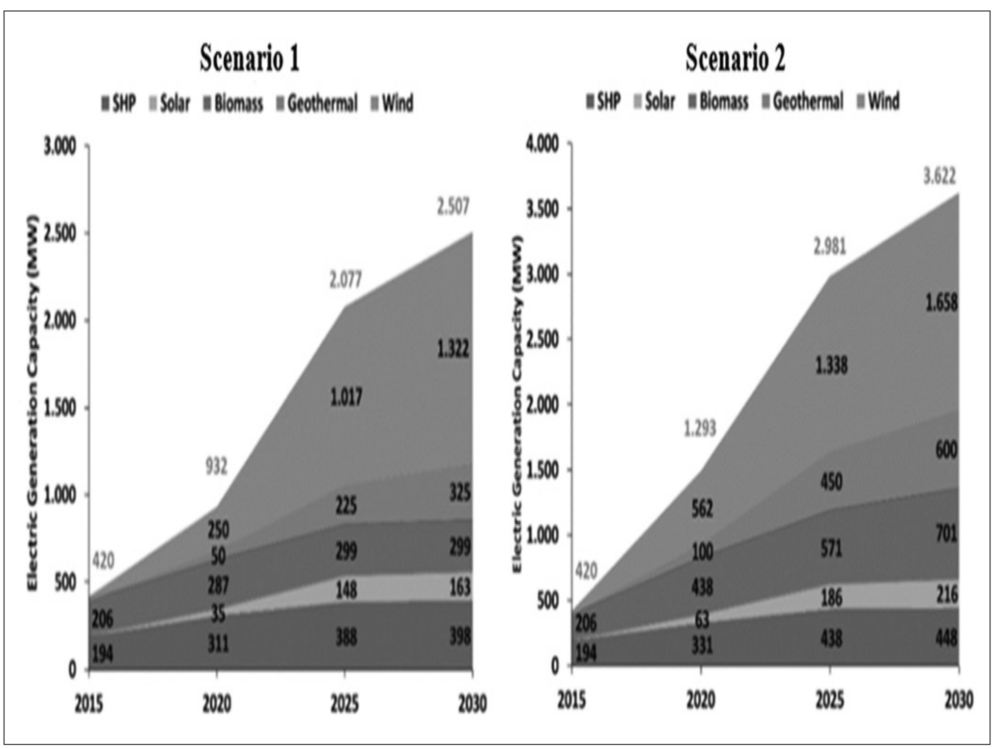
5.1. Registration of Electricity Generation Projects using NCRES in Colombia

NCRES projects in Colombia must be registered at UPME (UPME, 2007), and the approval process covers three phases with binding duration terms:

Phase 1: Pre-feasibility studies. 1 year

Phase 2: Technical, economic and environmental feasibility studies. 1 year.

Figure 6: Forecast of electricity generation capacity using NCRES. Source of data: UPME 2015b



Phase 3: Full designs and implementation timetable. The project will become ready for implementation. This phase takes up to 1 year.

The registry of NCRES projects began in 2016, the current phase of the project and general information each are in a free database (UPME, 2018b).

5.2. Forecasts of NGC Based NCRES through Projects Currently Registered at UPME

Based on registered projects in UPME and the current phase each, the number of projects going on to the phase 3 is estimated in three scenarios: 25%, 50% and 100% of them will be successfully implemented. Figure 7 shows the forecast results, compared to the UPME forecast made in 2015.

In all scenarios, the forecasts of PV to 2020 are higher than the UPME forecast (2015b). In the 25% success scenario, EGC would reach 430 MW, which is two times higher, whereas in the 50% success scenario would be around 860 MW, which is 400% higher. PV shows a significant growth trend because of the business opportunity it represents, the maturity of PV technology and its affordable cost. Consequently, by 2020 it could account for around 6% of EGC in Colombia, though its share in electricity generation would be less, because of PV is only operational during daytime hours, and it depends on the intensity of sunlight, which changes hourly.

The forecast of wind generation EGC increase to 2020 is lower than UPME (2015b) even in the 100% success scenario, reaching 240 MW, which is lower than the pessimistic scenario forecast by UPME (2015b) of 250 MW. In the 50% success scenario, wind generation capacity would total 130 MW, and in the 25% scenario, it would total 75 MW. In all cases, its share of the electricity mix would <0.1%, which is well below the potential of 9,000 MW found by Pabón (2017) and Ceballos and Ramos (2018).

Figure 8 shows the NEC based in NCRES forecasted by UPME and in this study. The UPME (2015) forecast between 880 and 1,400 MW would be reached if between 25 and 50% of succeeding in registered projects and the goal of 6.5% of EGC based in NCRES. However, the mix in terms of the breakdown by source is radically different from the UPME forecast, shown stronger growth in PV, and significantly slower growth in wind energy.

The impact on the energy market of a massive incorporation of PV generation must be studied more closely in order to avoid undesirable effects on prices (Jimenez et al., 2016). Further analysis is also required on its capacity to supplement the peaks in NEG (Paredes et al., 2017) because although contribute to cover the electricity demand secondary peak at 11 am not contribute to the main peak at 7 pm. However, the contribution of solar energy during average load hours would make it possible to accumulate water reservoirs during the day in order to later use it during peak consumption hours (UPME and CORPOEMA, 2010). In addition, Paredes et al. (2017) point out that wind farms represent a good complement to offset seasonal decreases of river water flows and hydroelectric generation (Paredes et al., 2017).

Since PV and wind are the FNCER of the more perspectives an estimation of yearly power generation each was carried out. The PV estimation was based in peak sunlight hours in Colombia average 1,944 hours per year, equivalent to 5.4 h of sunlight per day (UPME, 2005). The wind energy estimation was founded un the Jepírachi wind farm performance which has contributed an average of 147 MWh per day to the NEG, with a daily average

Figure 7: Forecast EGC by NCRES, based on registered projects. (a) Solar, (b) Wind, (c) Biomass, (d) SHP

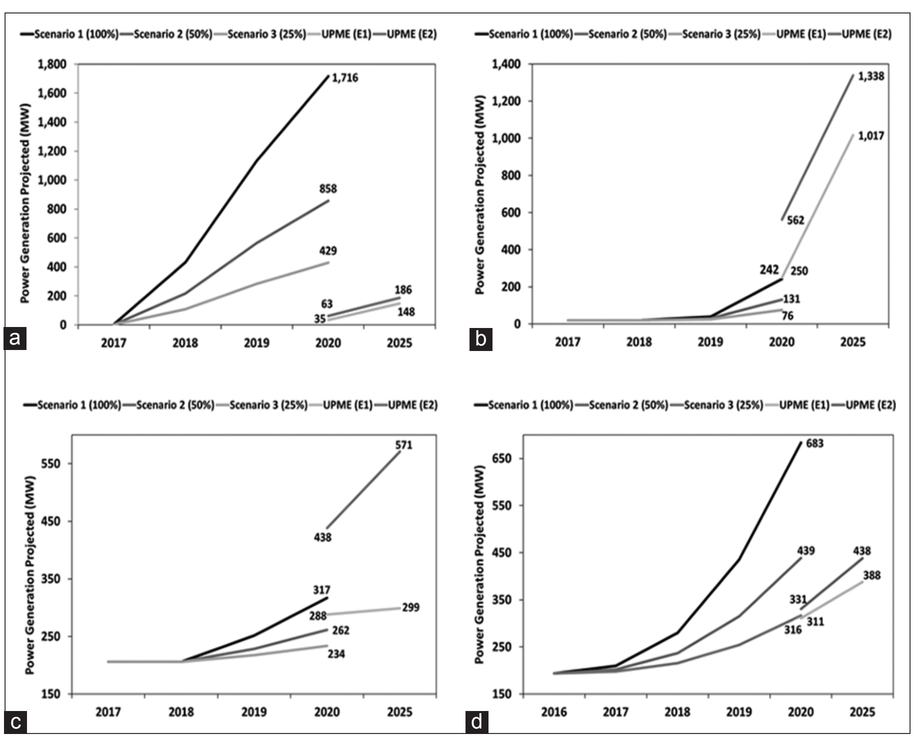


Figure 8: Forecast EGC based in NCRES in Colombia for 2020: Source of data: (UPME 2015b; SIEL, 2018)

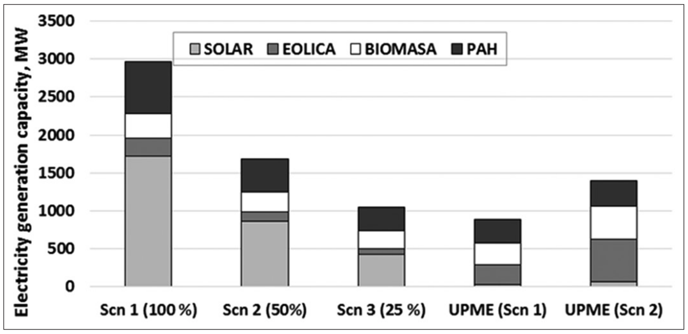
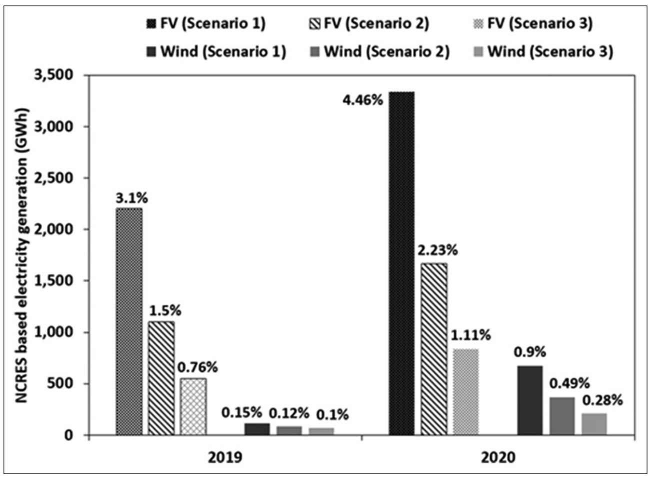


Figure 9: Forecast electricity generation based in NCERS (GWh), 2019 and 2020



plant factor (real energy produced by the plant/energy that would have been produced working at 100% capacity) of 31% (Moreno 2015; XM 2015).

At best forecast, NCFER could satisfy the 3.25% of electrical demand in 2019 and 5.5% in 2020, in the worst 0.9% y 1.4% respectively for what the share in electricity mix will continuous be low or insignificant en each year see Figure 9.

6. CONCLUSIONS

The potential of NCRES is significantly higher than the currently installed EGC of 16,700 MW. Biomass shows a potential of 16,000 MW technically usable, while wind energy has 27,000 MW. Solar radiation, which is higher than the world average has a potential over 20,000 MW and SHPs of <20 MW have from 8,000 to 25,000 MW potential.

The particularity that most of the solar and wind energy potential is concentrated in a single geographic region should facilitate the development of the infrastructure required to connect it to the NEG. Also, given that most thermal generation is concentrated in near zones, it should be easy to provide backup electricity generation to cover critical periods of low rainfall and low hydroelectric generation, with the overall objective of minimizing greenhouse gas emissions and thermal plant operating costs.

Although in recent years the national government increase actions to promote the implementation of NCRES, the current policy must be improved in order to the integration of NCRES can be further expanded. Even though it is feasible to have 6% of the electricity, generation capacity of the EGC based on NCRES for 2020, the share of NCRES will remain low as compared to its capacity. Even if 100% of the projects are realized, NCRES will share a low 4% of the generation mix, while in a 25% success rate scenario NCRES will account for <1%.

The share of solar energy in the NCRE mix will be over 50% for the three scenarios discussed. Therefore, specific policies to promote the use of wind and biomass energy are required to complement the NCRES mix, to stabilize NEG supplies during climatic events.

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