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A SWOT Analysis for Wind Energy Potential Assessment in Colombia.

Análisis DOFA para la evaluación del potencial de energía eólica en Colombia

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Resumen

La demanda y oferta energética en Colombia ha venido en aumento, aunque teniendo en cuenta que las producciones de energías renovables en el territorio no tienen porcentajes altos, se puede observar un mercado económicamente viable para la inversión y obtención de capital, es por esto que, en Colombia en zonas específicas, como lo son las áridas, se puede implementar el desarrollo de plantas y parques eólicos a corto plazo, con apoyos económicos y sociales de parte del Gobierno. Sin embargo, las capacidades que tiene Colombia deben ver comparadas con las experiencias que tienen países con altas producciones de energía eólica como los países miembros de la comunidad Schengen, y conocer de esta forma en qué se puede mejorar y cómo aprovechar las oportunidades que brinda el territorio colombiano con sus fortalezas y debilidades en un mercado variable como lo es el de energías renovables actualmente. Por otra parte, uno de los objetivos fundamentales de este trabajo es evaluar técnicamente el proyecto, así como el costo nivelado de energía para cumplir con los requerimientos de demanda energética.

Palabras clave: energía eólica, análisis DOFA, Europa, Colombia, simulación técnica y financiera

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Abstract

The energy demand and supply in Colombia has been increasing, although considering that renewable energy production in the territory does not have high percentages, it is possible to observe an economically viable market for investment and raising capital, which is why, in Colombia in specific areas, such as arid areas, the development of wind farms and plants can be implemented in the short term, with economic and social support from the government. However, Colombia's capacities should be compared with the experiences of countries with high wind energy production, such as European countries. Thus, know how to improve and how to take advantage of the opportunities offered by the Colombian territory with its strengths and weaknesses in a variable market such as the renewable energy market today. One of the main objectives of this work is to technically evaluate the project, as well as the levelized cost of energy to meet the energy demand requirements.

Keywords: Wind energy, SWOT analysis, Europe, Colombia, Technical and financial simulation

1. Introduction

According to the WEC (World Energy Council), Colombia is in tenth place in Latin America in sustainable energy production, evaluated according to its energy production capacity in factors such as security, equity, and sustainability [1-3]. Represented by 80.61% in hydraulic capacity, 19.25% thermal sources, and other sources with 4.63% [4]. However, the production in 2016 of electricity from wind energy was only 51GW according to International Energy Agency (IEA) representing 0.14%, today this reflects a problem of diversification of sustainable energy sources [5,6]. As the main cause of the low energy representation by wind energy are the high technological costs [7-8]; although Colombia recently seeks the implementation of new technologies for electricity generation, such as 294 projects from solar and wind plants, hydroelectric plants and biomass in 25 departments [9-10].

The global energy production from sustainable sources according to IEA in 2018 is approximately 2 million Ktoe, 14.3% of the world energy production, of which Colombia provides about 10 thousand Ktoe. But with a low figure for wind and solar production of only 6 Ktoe; today wind production is led by energy powers such as (China, United States, Germany, India, and Spain) both in offshore and onshore production [11-16].

This study will be evaluated through a SWOT matrix model, to characterize the strengths and weaknesses as well as opportunities and threats of wind energy development in Colombia, supported by data collected from research, projects, and existing literature. Showing the capacity that Colombia may have and the imminent need for energy production, as well as the social, political, and environmental problems. On the other hand, this work also presents a technical-financial simulation of a wind project in the Colombian Guajira.

2. Methodology

To achieve the initial objective of the work, the methodology was divided into two large areas: SWOT analysis and Numerical Simulation. In the SWOT analysis, identifying the analysis criteria requires setting out the strengths in the matrix, defining the opportunities, describing the weaknesses, and finding the threats. On the other hand, the numerical simulation is done through the SAM simulator (System Advisor Model) of the National Renewable Energy Laboratory (NREL). This simulator combines geographic information with computational models of energy efficiency.

2.1. SWOT Analysis

The SWOT analysis is a tool designed to know the real situation of an organization, company, or project within the market. It consists of making a list of strengths, weaknesses, opportunities, and threats, to facilitate future decision-making.

For the development of this analysis, a bibliographic survey was initially made on the political, economic, and social context of Colombia and member countries of the European community. In the same way, categorical parameters were identified that allow for defining key aspects in each of the levels of the SWOT evaluation.

2.2. Numerical Simulation

The objective of the numerical simulation is to know the technical and economic details of the implementation of an offshore wind farm in the Colombian Guajira. This preliminary study will provide considerable elements to evaluate the feasibility of this type of energy undertaking. The reason for choosing the Colombian Guajira is due to the potential of the wind resource in the area. The lack of electricity in the region and the ability to attract foreign investment.

To ensure the repeatability and confidence of the simulation, a vertical methodology was developed and divided into 4 parts. First, the wind resource of the area was evaluated, knowing the wind map of the Colombian Guajira, and modeling the wind speed as a function of categorical parameters linked to energy production. Subsequently, the wind turbine power curve was modeled. Subsequently, the most adequate wind farm arrangement to produce electric energy was arranged. Finally, the financial analysis of the project was carried out.

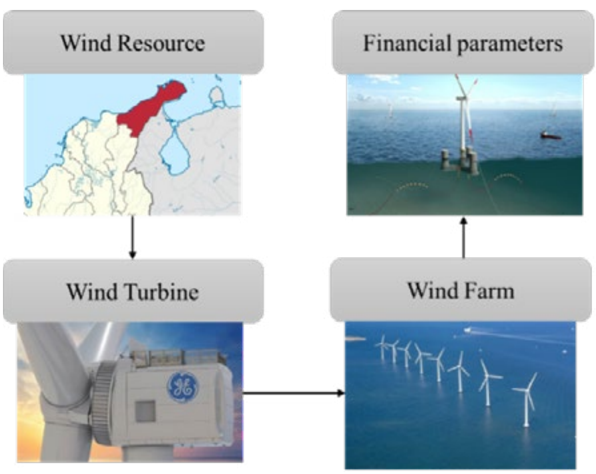


Figure 1 Methodology developed for the technical and economic simulation of the wind farm. Source. The authors.

Initially, the wind resource was arranged, and the value of the annual average wind speed is specified concerning the measurement height and the Weibull factor K (Figure 2). It can be observed that there is a peak energy production when the wind speed ranges between 6 and 9 (m/s).

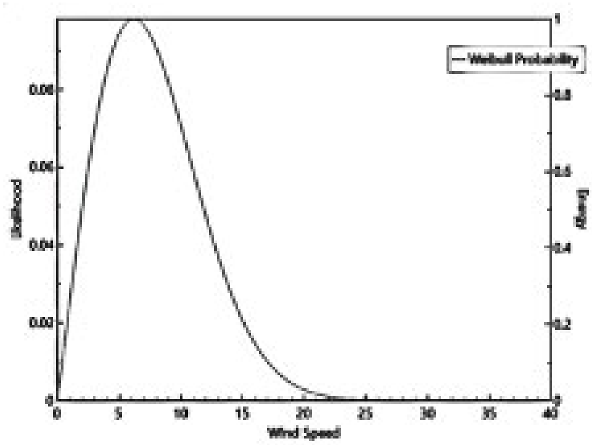


Figure 2. Likehood and energy load curve as a function of wind speed. Source. The authors.

Figure 3 shows the performance of a GE 1.5 SLE brand turbine in terms of energy production as a function of wind speed. It is constituted by a Rating of 1500 kW, a rotor diameter of 77m, hub weight 80 m, and a shear coefficient of 0.4. The maximum power of the turbine is reached in the range of 8 m/s – 25 m/s

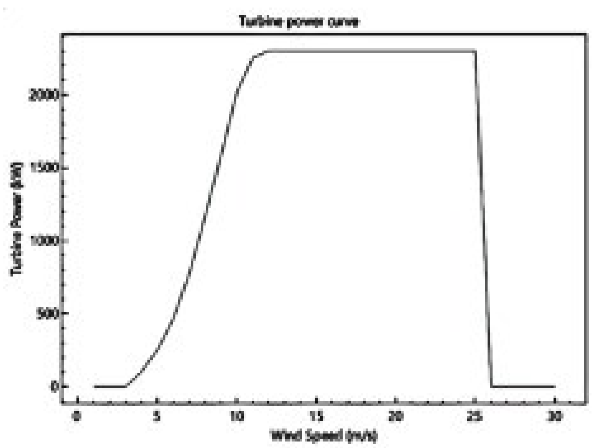


Figure 3. Turbine power as a function of wind speed

On the other hand, it is essential to know the layout of the number of turbines. The position of each wind turbine in the wind farm allows us to understand the wake effect losses resulting from the variation of time. In the same way, the configuration of the wind farm will help reduce the turbulence coefficient, which represents the variation in wind speed caused due to thermal effects and air masses that impact the wind farm.

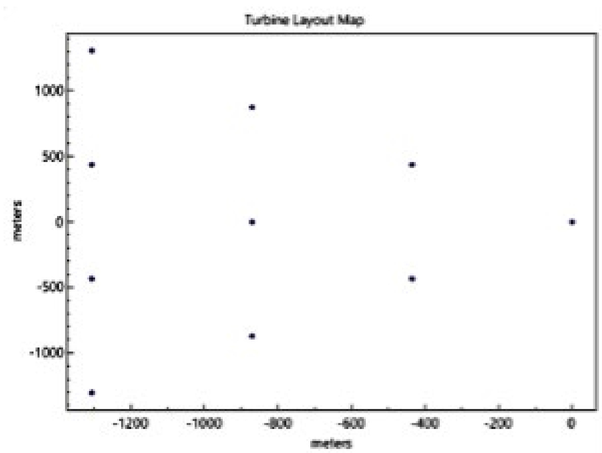


Figure 4. Likehood and energy load curve as a function of wind speed. Source. The authors.

Table 1 specifies the financial parameters that were used in this simulation.

Table 1. Financial parameters used in the simulations.

Financial Parameters	
System Capacity	48,000.00 kW
Capital cost	1695 $/kW
Fixed operating cost (annual)	51.00 $/kw
Analysis period	20 years
Inflation rate	2.5 % year
Internal rate of return (Nominal)	13 %/year
Project Term debt	60%
Nominal debt interest rate	8%/year
Effective tax rate	40%/year
Nominal construction Interest rate	8%/year

Source: the authors

3. Results and discussions

3.1. SWOT Analysis

Considering the possibilities of production and market of sustainable energies in the Colombian territory, focusing on current global policies and economy, especially with the production of electricity from this type of energy in some European countries and their sustainability strategies. Figure 5 shows the history of electricity generation in Colombia from 2004 to 2019.

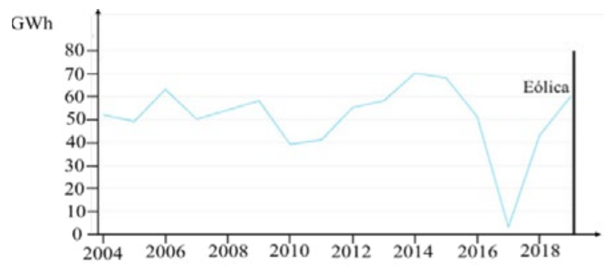
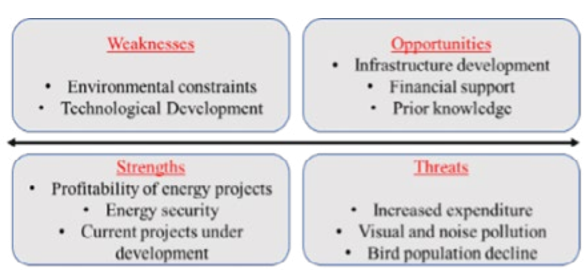


Figure 5. Wind power generation in Colombia 2004-2019 [15].

Colombia has abundant potential for energy production from hydropower and coal [17]. along with possibilities for energy production from solar and wind sources [18] Although, before being able to design strategies for the use of renewable energies, mathematical modeling of the construction and installation of the systems is necessary [19]; in Colombia, the development of wind and solar energy is minimal and is represented by the Jepírachi wind farm located in the La Guajira department [19-21] but opportunities are also evident in urban parts of Colombia such as Manizales, Pasto, Cúcuta and Bogotá [22]. While globally in 2015, India had a production of 2.3 GW surpassing Spain in total capacity [23]. In terms of turbine production Europe uses around 40 thousand turbines [24]. A key factor influencing wind power generation are large-scale changes in wind patterns and climate models [25]; wind power generation sites are found around the Baltic Sea and in Western Europe [26]. For Europe as a whole, wind fleet developments estimated at one-third more than today and increases in underlying wind speeds are planned [27,28] (Figure 6).

Figure 6. shows the Weaknesses, Opportunities, Strengths and Threats.



3.1.1. Strengths

3.1.1.1. Profitability

In Colombia for the generation of wind energy there are several points in favor such as financial options which is a title that grants the right to sell or buy an asset subject to specific conditions therefore there is a yield that can never be less than zero regardless of the underlying asset call options can be of European or American type, when it can only be exercised on a specific date it is European and when it can be exercised at any time until an expiration date it is American projects have been considered for the production of wind energy in the region of La Guajira for its wind potential in which cash flows of around 145 thousand dollars can be considered with an initial investment of approximately $208 thousand although the NPV of the project is negative this is approved because market conditions are favorable and a 5-year term option is considered [29- 32].

3.1.1.2. Current projects

The first wind energy project was the Jepírachi wind farm located in the department of La Guajira and built by the public companies of Medellín (EPM) giving energy to the Wayuu reservation, construction that was carried out over the years 2002-2003 with an investment of 28 million dollars, this project did not have great effects on the fauna and flora due to the arid zone where it is located and taking into account that the Colombian coasts provide the greatest air flows of the territory [33-35].

The Mining and Energy Planning Unit (UPME) has also registered projects, most of which are in La Guajira, with the production of at least 200 MW, according to Banmericas, in 2020; 21-year cash flow projections are made, which in turn refer to the useful life of the wind turbines [35-37].

The Cerrito wind farm project is currently being developed and is expected to be completed by the end of 2023 with a production of 378 MW. According to Banamericas, it was approved in 2017 by the Ministry of the Interior and will contribute economically to the Wayuu indigenous people and will not have a high impact on the ecosystem [38-40].

3.1.2. Weaknesses

3.1.2.1. Environmental constraints

One of the main weaknesses in wind energy production is the geographical location of the country where the wind farm is planned to be built because in certain places the wind speed is not enough. In the case of Europe wind speeds allow obtaining between 3.51 and 22.81 PW [41-43]. This allows European plants to generate around 403390 GW in 2018 (IEA) while Colombia has only a potential of 0.51 PW. [44-46].

The energy potential also depends on climatic conditions due to terrestrial formations, high mountains near the seacoasts [47-48,66,67]; unlike the scarce rock formations near coasts in Colombia (La Guajira). The El Niño and La Niña phenomena cause climatic variability in the Pacific Ocean coasts; this alters the thermal structure of the ocean and weakens the easterly winds [48].

3.1.2.2. Development

In most European countries legal regulations allow companies to market electric energy directly to the consumer, taxes of 1.5% are promoted for the construction of power plants and discounts for onshore and offshore energy production are granted to countries belonging to the European Union [49]. In Colombia, the investments that must be made for the construction of a wind plant are very high and the government does not grant large benefits. This is reflected in the fact that in the department of La Guajira the national energy demand could be satisfied but not enough wind power plants have been installed [50-52].

On the other hand, indirect social resistance to the implementation of wind energy in Colombia is generated, that is, residents are in favor of the renewable source but not of the development of projects derived from this topic, this logic is known as NIMBY, in addition to the insecurity of Colombians due to the fear of reducing job offers in the field and negative beliefs of the impact of self-generators on wildlife and ecosystems [53-55].

3.1.2.3. Technology

The last commercial turbines of the past decade had a diameter between 65-80 meters and generated between 1.5-2.5 MW, with production costs too high for Colombian industries to acquire them; in turn, the blades are made of carbon fiber which would give them advantages to avoid resonance and corrosion damage [53]. Despite the high costs, the cost of generation in the European Union is relatively low so it is economically viable, unlike Colombia [56-57, 66].

3.1.3. Opportunities

3.1.3.1. Infrastructure

Although Colombia geographically has few viable locations for the implementation of a wind farm, the winds along the Colombian coasts can be classified as the best in South America, classified as class seven with sufficient speed to produce electricity. In turn, the coastal locations of the Colombian Pacific harbor winds originating in the branches of the Andes Mountain range; considering the Colombian capacities, projects such as the Guajira II wind farm with a capacity of 325 MW planned for 2022-2023 can be implemented, according to Bnamericas [58-60].

3.1.3.2. Financial Support

The Colombian government has generated several financing and economic support options for the development of planning to produce electricity from renewable energies, such as the Financial Support Fund for the Energization of Non-Interconnected Zones (FAZNI), the General Royalties System (SGR), and the Financial Support Fund for the Energization of Interconnected Rural Areas (FAER) [69]. Which provides support from the Colombian government with both benefits and monetary support. Other opportunities for the future are established from the orange economy, for example, the support of the Inter-American Development Bank (IDB) with an investment in projects of 600 million dollars [60,63].

3.1.3.3. Previous knowledge

Wind power plants in European countries such as Poland provide jobs to more than 5 thousand people and with expectations from 2020 to reach around 60 thousand people, which in Colombia could be considered as an opportunity to generate jobs and thus draw the attention of the government and propose more support and financial benefits. Also, the government could bet on offshore wind plants as Poland does, bringing benefits to the economy and generating 6 GW and with this follow a model that is successful in other countries. Additionally, the development of renewable energy facilities that in Poland reach 37500 in the future and considering that the economy is based on product innovation (The Act on Renewable Energy Sources, 2015). Considering what has been presented, Colombia could use it to its advantage and generate enough energy as Poland does [60,63,66,70].

3.1.4. Threats

3.1.4.1. Increased costs

In wind projects it is necessary to implement advanced technology for its optimal development, therefore to meet the scarcity of Colombian resources would involve costly imports of equipment, due to this it is necessary to hire foreign trained personnel; this represents a high cost, also the implementation of technology involves difficulties in accessing the area where the wind turbines will be placed; although the Jepirachi wind farm had support from qualified personnel Colombia has not managed to invest enough to develop turbines to be used on a large scale [71]. The Jepirachi wind farm has represented economic risks because after being built with a World Bank credit of 21 million dollars it was reflected in an increase in this price due to the inflation of the value of the Colombian peso against the dollar and delays in the construction of the project. [64-65,69,71,73]

3.1.4.2. Pollution

The construction of a wind farm has direct effects on air quality, soil alteration and contamination, and increased noise (EMP). However, these are not the only type of contamination because we can find effects on fauna such as the destruction of the habitat of birds that circulate in the area [74]. Despite the effects described, environmental impact studies in wind farm areas are not sufficiently rigorous, so it is not known what other types of contamination can be generated**.**

3.1.2. Countermeasures and suggestions for wind energy development in Colombia

Economic Sustainability

Considering that Colombia has geographical areas with high speed winds suitable for the operation of wind farms, the Colombian government should promote the implementation of power plants from renewable energies, decreasing taxes and extra payments that must be made at the time of raising a project, in turn allowing the support of international companies in terms of technology and knowledge to solve the lack of government investment in technology and training of professional staff; however, the energy generated through wind farms should be supplied on Colombian power tracks and with a percentage of the profits generated sent to national institutions so that in this way the use of renewable energies is further promoted throughout the country. Although a strong economic control should be provided in the projects by reviewing the investments and money expenditures so that they do not increase exponentially due to external factors, such as delays or political situations. This would promote the use of wind farms not only in coastal sites such as La Guajira but also in locations such as Norte de Santander and Risaralda, which are potentially attractive for investments and development of wind energy [71,72].

Environmental Management

The environmental problems caused using wind farms, despite not generating high CO2 emissions, lead to changes in the ecosystem by the simple fact of installing large propellers, so that bird species can be injured and lead to a population decline of the species [69]. Which is why the installation of multiple propellers must be done carefully, which in turn generates an impact on local communities, as in this case the Wayuu ethnic group located in the department of La Guajira, changing their customs and agricultural activities due to soil contamination, which would limit their activities, which is why the inclusion of the communities in the projects and the distribution of electricity generated in the plants to places of residence that are difficult to access for these communities is proposed [74].

Finally, if the installation of wind farms in Colombia is sought, the large plants located in Europe should be taken as an example and from their operation and distribution, it should be possible to maximize the use of wind energy in Colombia in a fast and efficient way, increasing the production of energy in a sufficient amount to cover part of the Colombian energy demand in this type of geographic areas; and knowing that wind farms can be supported with other types of renewable energies.

3.2. Wind energy potential assessment

As can be seen in Figure 7A, there is a constant production of energy, this is due to the generation potential that exists in La Guajira, Colombia. Winds with a high probability of being converted into electrical energy remain throughout the year in the region. The response to power generation is positive from a technical point of view, due to the possibility of obtaining cash flow.

Similarly, when analyzing the daily energy production, it can be seen in Figure 7C that at the beginning of the morning between 8:00 AM and 9:30 AM. As well as from 18:00 to 19:30 there is a drop in energy production, which can be explained by the wind speed, which can exceed 26 m/s, triggering the intermittency of the energy process, because the wind turbines stop generating energy when the operating speed of the equipment is extrapolated.

From the above, it can be observed in Figure 7B and Figure 7E that the electric power generation capacity declines from the 200th day of the year and lasts for a little more than 30 days. This happens due to the wind intensity that occurs in August, allowing the turbine brake to be activated continuously, clearly affecting electric energy generation.

Besides, it can be inferred that the average wind speed is 9 m/s, according to the histogram of data collected in the simulation (Figure 7D). This information is also explicit in Figure 7F, which shows the latent wind intensity during the whole period of electric power generation, counting cycles of one year.

Consequently, the technical data predict a constant energy production, which allows supplying a large part of the population of the Caribbean coast. The capacity and system indicators were the Levelized Cost of Energy was 5.15centUSD/kWh, Annual energy (1 year) 201.541.760 kWh, Capacity factor 47.9%. Which places the wind resource as a strong candidate to supply the energy demand in Colombia.

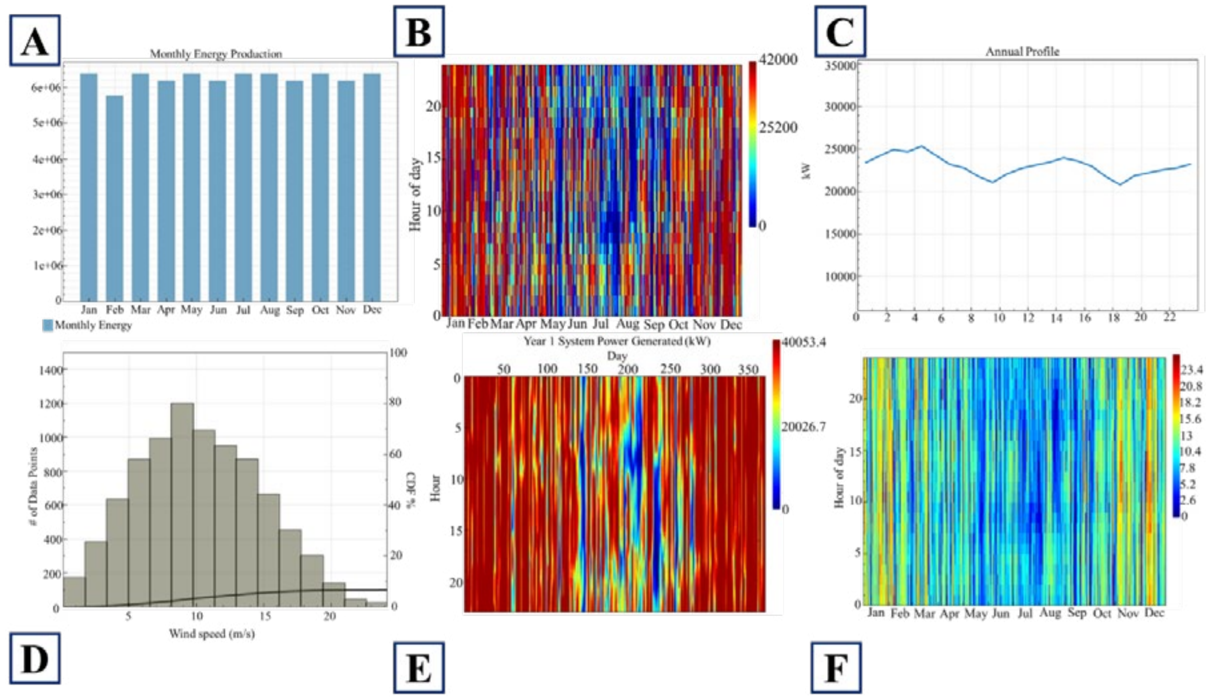


Figure 7. A) Monthly Energy Production, B) Heat map of annual electric power generation. C) Annual electric power generation profile. D) Annual wind distribution in La Guajira, Colombia. E) Heat map of daily power generation. F) Heat map of annual winds in La Guajira, Colombia.

4. Conclusions

The study is conclusive in showing that Colombia has a high potential for wind energy implementation, this can be verified in the SWOT analysis. Weaknesses can easily resolution by a state policy that encourages the importation of wind turbines. In addition, tax exemptions that would allow the entry of qualified companies to promote this type of energy project could also be considered.

According to the technical simulation, La Guajira, Colombia has a high potential for electricity generation. The annual availability of its winds makes it a perfect candidate for the massification of wind farms that generate and distribute electricity for the entire country. On the other hand, the generation of electric energy presents an adequate economic value, therefore, there is a high possibility of having profitable projects to attract capital and interested companies.

Colombia is currently debating the diversification of its energy matrix, and this work provides more elements for the debate, presenting wind energy as an energy alternative in the Colombian Caribbean region.

The projection and execution of an energy model are recommended to evaluate the possible energy distribution routes. On the other hand, it is vital to identify the industries that would most support these ventures to guarantee the supply of raw materials.

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