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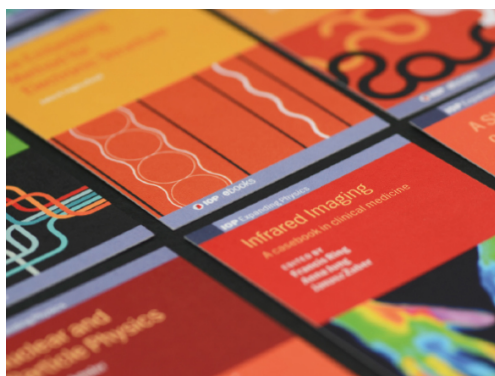
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PEST analysis of wind energy in the world: From the worldwide boom to the emergent in Colombia

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Abstract. This article presents the analysis of the political, economic, social and technological aspects of the countries with the greatest development and generation of wind energy in the world, with the aim of studying the successes and disadvantages over the years and serve as a reference to a country like Colombia, which is in full technological development and is very interested in investing in new alternatives to the imminent ecological disaster resulting from polluting emissions. Colombia signs the Paris Agreement and immediately creates a large number of opportunities supported by state policies and economic investment, specifically in the construction of wind farms that guarantee a real alternative to the country's energy demand. Wind energy supplies 5% of the world's electricity, a contribution in which countries such as the United States, China, and Germany are the main producers. For this reason, it is necessary to study and analyze the factors that prevent the technological development of wind energy in Colombia, if it is considered a country with abundant resources in renewable energy sources and zero cost, a country that aspires to be a protagonist in the next 5 years according to the Ministry of Mines and Energy.

1. Introduction

Environmental problems and the increase in the global temperature of the planet are the main consequences of the emissions of CO₂ and other pollutants generated by fossil fuels around the world [1,2]. This has caused collective concern due to climate change that is evident in different parts of the world, seriously affecting crops, vegetation, fauna and the balance of ecosystems [3,4]. In recent years, all efforts have been directed towards the protection and care of the environment by all organizations in the world, regardless of the area or scope of work [5]; this intention is reflected in the treaties and agreements signed throughout the world that allow for the regulation of the use of pollutants and the amount of emissions that seriously affect the environment (see Figure 1) [6].

To achieve this change requires commitment, dedication, and innovation from all entities and countries [8], understanding that the priority of the planet is the reduction of pollutants; therefore, the possibility of creating innovative technologies and methods for the creation of clean systems that provide a real alternative to the problems of climate change, such as wind energy, has been studied. Wind energy is a renewable energy source that uses the kinetic energy from the wind to generate electricity, it currently accounts for 32% of total renewable energy generation and supplies 5% of the world's



electricity demand [9,10]. It is important to recognize that renewable energy sources currently generate 25% of electric power as can be seen in Figure 2. It is clearly a high-potential alternative that over the years has provided electricity to meet the world's energy demand [11], given that the traditional energy sources responsible for generating electricity are among the causes of the increase in polluting gas emissions.

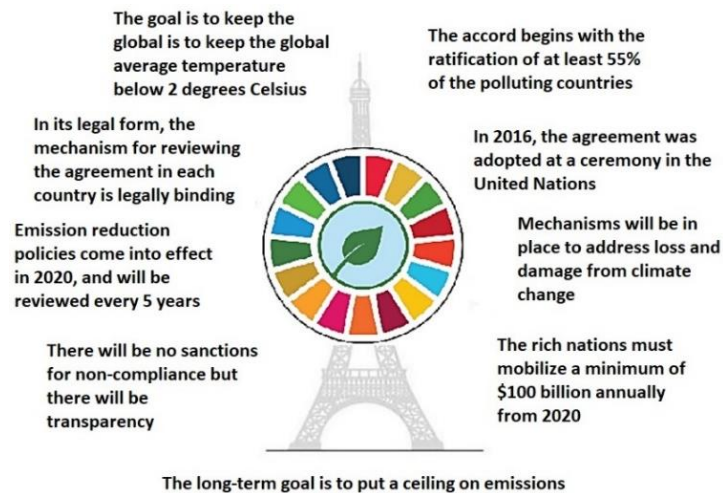


Figure 1. Summary of the Paris agreement. Adapted from [7].

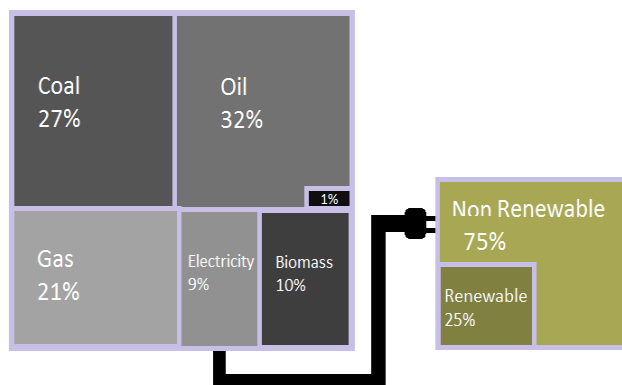


Figure 2. Energy generation and global electricity consumption in 2017.

The pioneering countries in wind power generation are the United States, China, and Germany with a total installed capacity of 89GW, 188GW and 56GW, respectively, and together provide 61.7% of the world's wind power (WWEA source) [12], guaranteeing the public the potential of wind power and its ability to supply conventional energy sources with fossil fuels [13]. Environmental issues have concerned the leaders of many countries, but above all, society [14]. Therefore, the public acceptance of this technology is crucial for its successful introduction into society [15]. For this reason, research on this type of energy has been generated for many years and has been of great importance for the analysis of the viability of a project that involves high investments and technologies unknown to any country [16,17]. It is necessary to use tools that allow society to visualize the current state of renewable energies in the world, specifically wind energy and compare our condition against countries that have found solutions through successes and mistakes in the development of new technologies [18].

The tool presented in this article is a PEST analysis, a tool that allows improving decision making on an issue, considering different criteria such as political, economic, social and technological factors (as its acronym indicates) that surround it [19]. Based on the above, it is possible to affirm that it is not enough to analyze the factors that directly depend on the subject under study, it is also necessary to know how the environment is and what impact it may have on the creation, development, and use of wind energy [20].

China, the United States, and Germany are protagonists because they are the countries that generate the most wind energy on the planet, although ironically they are countries with a high degree of pollutants; this causes uncertainty in society and, at the same time, causes concern due to the fact that emissions are not reduced considerably but the electricity demand in the world increases, this has made it useful to analyze the most unfavorable factors in view of the growth and development of wind energy [21]. In this sense, this article seeks to establish a comparison of the current status of Colombia in relation to the main producers of this energy in order to consider the existing gap and promote development in Colombia since the study of renewable energies is currently a priority research area in engineering [22].

1.1. Related work

In 2013, Kolios *et al.* [23] presented an analysis of Tidal energy in the United Kingdom, using the PESTLE approach (political, economic, social, technological, legal and environmental); the study highlighted certain potential risks in the political and economic sphere that would bring problems in the future of the project, particularly due to the technology used in the generation and other factors to be taken into account. The authors pointed out that the PESTLE analysis tool allows to visualize in a concise way the main risks and facilitated the decision making regarding the course of the Tidal Energy implementation project. A few years later, Igliński *et al.* [24] carried out a PEST analysis of the renewable energy sector both in the voivodship of Łódzkie, known as a renewable energy generating area, and in the Polish town of Leśmierz; the study sought to compare the current state of renewable energy in both locations and to analyze the factors that make the optimum development of energy generation more unfavorable than in another town or country.

2. Methodology

2.1. Review of concepts

This section presents the fundamentals of the PEST analysis, based on the integral position of wind energy in the world, its incidence and the characteristics that have led to its development and implementation. In addition, it is necessary to identify the technology used for electricity generation and then analyze its economic impact on the countries under study.

2.1.1. Global context of wind energy. Grid-connected systems are usually located in wind farms where considerable amounts of electrical energy are generated and distributed throughout the electrical circuit [23]. As shown in Figure 3, the vast majority of wind farms are onshore. On the other hand, stand-alone systems are those that satisfy the demand of remote sites where they do not supply conventional energy sources, these systems require backup wind turbines that store energy for periods when the wind calms down and electricity generation decreases [24].







Installed capacity in GW		539
Wind farms		18.732
Onshore		18.087
Offshore		645
Wind turbines		341.320
The % global electricity consumption		5

Figure 3. Current state of global wind energy development [22,23].

2.1.2. Wind energy technology. Wind energy is one of the renewable energies that currently has more production thanks to the installed capacity worldwide. In 2017, it has exceeded the figure of 500 GW of wind power installed in the world according to the European Renewable Energy Observatory.

There are different wind machines that are responsible for transforming the kinetic energy of the wind into mechanical energy; these are classified in different ways, according to the position of its axis of rotation, number of blades, electric generator used, control method, among others; in this article the purpose is the generation of energy to meet the electricity demand in the world so the different wind systems for the generation of electricity will be defined. These systems can be applied in micro-grid electric power systems, which are independent systems with generators and batteries (isolated) [23] or connected to the grid, as shown in Figure 4. These systems consist of a low complexity generation technology, such as the use of wind turbines connected to the electricity distribution networks.

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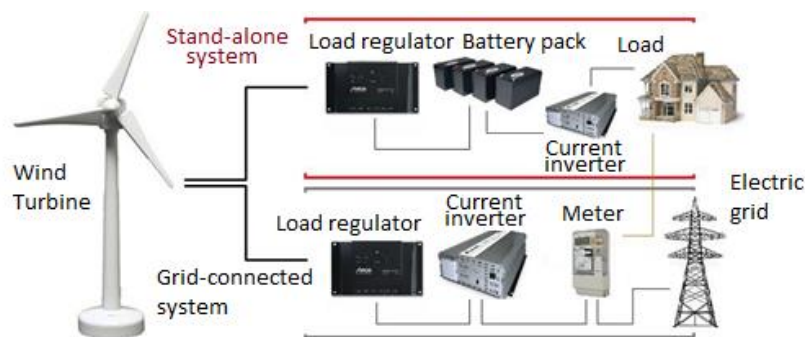


Figure 4. Basic scheme of the types of wind systems.

3. Results and discussion

3.1. PEST analysis of wind energy

Wind power is one of the fastest growing forms of electricity generation in the United States, with the largest share of renewable electricity generation capacity in the country according to the American Wind Energy Association [26]. The most favorable aspect is the political factor, due to the government's incentive for renewable energy and access to the electricity grid. In addition, the tax credit, sales, and production incentives play an important role in the promotion of wind energy.

In addition, China ranked first in 2016 in terms of new wind turbines, well above all other countries, so much so that it installed more than 50% of what everyone else installed [27]. This accelerated growth was due to government policies and the tariffs given to those entities that invested in the wind energy sector. The most unfavorable aspect is technological; regulators have tried to manage the pace of construction to give grids more time to expand transmission capacity, but 12% of the total wind power generated was wasted last year, according to official figures.

Germany is the country with the highest wind power generation in the European Union, although, like the other members of the European Union, it must urgently strengthen its efforts to deploy wind energy as part of a comprehensive renewable energy strategy and develop a roadmap for a near future of 100% renewable energy. It currently has 42% of installed capacity throughout Europe (6.58GW), and has the record achieved in 2017 as the European country that increased its production of wind energy more than the previous year (15% more than in 2016). The most unfavorable thing is the insufficient commitment from the government, due to political problems and wild overcharges; for example, the billions in maintenance derived from the excessive energy level of the national grid. Now, without nuclear power and without reforming the electricity grid, Germany continues to burn coal in the name of renewable energy. Today, the different varieties of coal still account for over 40% of the country's emissions, and they alone account for almost a third of the country's emissions.

In Colombia, the main disadvantage is the lack of guarantee that the system provides to investors who fear to lose their money, there are no political incentives to ensure permanence in the market for possible investments. All this problem is due to the fact that the country is going through a complicated period in terms of social and economic investment, which is why the World Bank has devised strategies to guarantee development and sustainability in the country. In terms of resources, the country is extremely privileged because it has the potential for wind energy in La Guajira, where an average energy density of 1530 W/m² measured at 50 meters high is estimated. Other regions with high wind potential such as Atlántico, San Andrés, among others, are also considered.

The results of the PEST analysis for the four countries mentioned are compiled and are shown below in Table 1.

Table 1. PEST analysis to United State, China, Germany and Colombia.

Standards	United States	China	Germany	Colombia
Policies	In 2015, the "Clean Energy Plan" and the creation of the "Environmental Protection Agency" were approved and implemented, under the guidance of the Department of Energy, which further enhanced the measures and projects underway by the federal administration and the states on wind energy, among others.	In 2009, China introduced a feed-in tariff for wind power generation that applies to the entire operating period. (Usually 20 years) of a wind farm. There are four types of tariff categories, ranging from CNY 0.51/kWh (USD 0.08/kWh) to CNY 0.61/kWh (USD 0.10/kWh), depending on the region's wind resources.	Germany's energy policy is framed within the framework of the European Union; in 2007 the Brussels European Council approved a mandatory energy plan requiring a 20% reduction in carbon dioxide emissions by 2020 and a 20% reduction in renewable energy consumption in the EU as a whole.	The Government has a decree ready to be signed with which it establishes the rules for the long-term contracting of wind energy generation projects, among others, where the norm establishes are the conditions to provide security to those who finance these projects, explained the Colombian Association of Renewable Energies.
Economic Aspects	At the end of 2009, installed wind power capacity in the United States was just over 35,000 megawatts (35 GW), making it the world leader ahead of Germany. In 2014, 8.3 billion dollars were invested in wind energy projects in 2014.	China will invest a total of 700 billion Yuan (\$102 billion) in wind energy over the period 2016-2020. The share of wind energy in the overall electricity mix should increase to 6% by 2020, compared to 3.3% in 2015, according to a plan by the National Energy Administration.	Germany was the largest investor in 2017. Its total investment was 6,700 million euros for the construction of new onshore and offshore wind farms. This large investment justifies 30% of the total investments in wind energy made in 2017.	Colombia will have an investment of 700 million dollars that will allow it to guarantee the electricity supply and increase its installed capacity in the next 15 years, and additionally, it will invest 167 million dollars in expansion works of its transmission network according to the Ministry of Mines and Energy.
Social Aspects	In 2008, surveys show that most Americans support wind energy in theory; although from Oregon to Maine, communities	Wind energy plans to create around 300,000 jobs by 2018, bringing the total number of employees to 800,000. However,	As people become accustomed to the visual impact, they have understood that the health effects are positive as wind farms replace dirty sources	The President of the Republic, Juan Manuel Santos, announced the implementation of a wind energy project in La Guajira, the

	are opposed to wind energy for several reasons. The sound, the visual pollution generated, as well as the potential impacts on migratory birds and wildlife in the name of global warming and energy security.	wind turbines also affect the community. Many complain about the sound and vibration of the turbines. Although the sound is minimal, it is still annoying to some inhabitants.	of energy. In the state of Baden-Württemberg in southern Germany, social barriers were removed that will facilitate the installation of wind turbines in mountains and forests.	construction of the Guajira wind power transmission line, which will allow the incorporation of wind energy into the National Interconnected System, thus benefiting energy costs in homes and other residential areas.
Technologic	According to the U.S. Geological Survey, Kern has more wind turbines than any other county in the country: 4,581 out of 57,636 wind turbines in the country, according to Energy Digital.	The Chinese government has continued to promote domestic manufacturing and technology development through a number of initiatives, including bids.	Since 2017, Germany has had more than 23,000 turbines for the production of electricity from wind energy.	The Jepirachi Wind Farm is the only known wind energy project in operation in Colombia to date. With approximately 15 wind turbines, it has enough power to power more than 12,000 homes in the Guajira.

4. Conclusions

This article presented in an organized and concise manner the political, economic, social and technological situation of the countries with the greatest electricity generation from wind energy, justifying the fact that these countries are in the top 10 in the production of articles and research for many years; a detailed analysis is made of the actions and activities that have allowed over the years the development and implementation of wind energy in the electricity grid of the countries with the intention of supplying the energy demand and reducing the use of traditional energy sources that cause damage to the environment, negatively affecting climate change on the planet. Colombia is in the development stage, but it is an attractive place for research due to its interesting resources, lacking a solid policy and investment on the part of the national government; many foreign entities have been interested in investing in order to take advantage of the resources available in the country. For this reason, this article is presented to analyze the current state of Colombia in the face the pioneer countries in wind power generation powers and to identify the most unfavorable factors in the face of the development of this new technology. The main problem for countries seeking to increase the production of this renewable energy are the political decisions and the laws that establish the limit of production without encouraging the demand for clean energy; that is, it is necessary to regulate the production of energy with non-renewable sources to encourage the increase in the generation of renewable energies. In this way, the development of wind power throughout the world will be promoted. Construction costs must be managed by government agencies to facilitate foreign investment and technological development, and the import and export of technology. Although the investment is high, maintenance and raw material costs are zero, the renewable energy source is unlimited and provides an air free of pollutants; sufficient reasons to opt for this technology as soon as possible and meet the objectives set out in the Paris agreement.

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