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Wind Farm Implementation Factors: A Bibliometric Analysis

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Abstract*—*Researches focused on identifying the factors that influence the implantation of wind farms have been found in the academic scope, considering the technical, environmental, economic and social points. The objective of this study is to map the scientific activity based on the theme "factors that influence the implementation of a wind farm", using in principle the entire period of coverage of the Web of Science - WOS platform, in order to compose a portfolio of bibliographical references on the subject. The process selected 9 relevant articles, aligned to the theme and present in several areas of study. A qualitative bibliometric analysis of the portfolio was also carried out in order to characterize and analyze the selected articles, also elaborating a SWOT Matrix with positive and negative factors on the researched topic.

Keywords*—Bibliometric, Renewable energy, Wind energy, Wind farm.

I. INTRODUCTION

Since the oil crisis in the 1970s, the search for alternative energy has been sought in order to achieve the energy security widely discussed today. According to Other factors motivated such demand, such as environmental, economic and social factors, giving rise to new sources of energy in the electric matrices of several countries, among them is wind energy [11].

Wind energy uses the wind for its generation. Brazil has advantages in the energy aspect, since it has relief, hydrography and tropical climate favorable to the use of several renewable sources of energy, such as wind energy [3] [14] [6] [18].

Brazil reached the end of 2018 with 14.71 GW of installed wind capacity, in 8th place in the world ranking, with 583 wind farms, which represents 9% of the Brazilian electricity matrix [1].

The Brazilian Wind Potential Atlas published in 2001 identified the Brazilian regions with great potential for the use of wind energy, with about 0.8% of the territory having winds with average speeds equal to or greater than 7 m / s, 50 m above of the soil, with potential of 143.4 GW, with capacity to generate 272 TWh / year [16].

Most of Brazil's wind potential is located in the Northeast, South and Southeast regions [19]. In order for such energy to be produced, it is necessary to implement wind farms, in Brazil the majority is located in the Northeast region.

With the increase of discussions regarding diversification of the energy matrix, renewable energies and energy security, and seeing the potential of wind energy in Brazil, the opportunity to generate scientific knowledge through a bibliometric analysis on the factors that influence the implementation of a wind farm.

The studies that are based on bibliometric analysis have been receiving prominence in the academic scope, since this is recognized for its relevance to quantify, classify and evaluate scientific works.

Thus, this work identifies the factors that are considered important when planning to implement a wind farm, using academic research tools. The objective is to map the scientific activity based on the theme "factors that influence the implementation of a wind farm", using in principle the entire period of coverage of the Web of Science - WOS platform.

II. MATERIALS AND METHODS

The present research is an exploratory-descriptive study, and it aims to provide a familiarity with the problem, making it explicit, through standardized techniques of data collection and treatment [20].

This work used as a database the Web of Science - WOS platform, which contains periodicals of great relevance to the academic and scientific milieu. Being initially selected the whole period available by the platform, from 1945 to 2019.

After defining the database, the keywords were determined that determine the focus of the research through topics. Since the theme is "factors that influence the implementation of a wind farm," the keywords chosen were: wind energy, wind farm and power plant.

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From the tags, the selection of the materials that will compose the portfolio of publications that form the theoretical reference and the results will begin. The first refining consisted of selecting an article-type document on the WOS platform itself. The materials resulting from this research were exported to Microsoft Excel in the form of a spreadsheet so that it could follow the selection.

A new selection was made, based on a cutoff number for the articles that were most cited, the articles were ordered decreasingly in relation to the number of citations, being selected the articles in which the quotations accounted for approximately 85% of the total obtained [13].

The Word Cloud tool was used to present the study areas in which the selected articles were published up to that stage in the analysis., Such a tool converts a given set of words into a word cloud, where each word is sized according to the number of occurrences and can be used as a data analysis tool [8] [24].

Due to the number of resulting articles plus a selection method was adopted, this time to define the sample number considered valid for analysis. The sample size (number of articles required) depends on the population size (total articles) and the degree of reliability desired for the results obtained [5].

For this study the size of the sample was established by the expression presented in Equation 1 [7], this calculation is necessary to guarantee the representativeness of the data collected and the legitimacy of the research:

$$n = \frac{Z^2.\left(\frac{x}{n}\right).\left[1-\left(\frac{x}{n}\right)\right].N}{(N-1).e^2+Z^2.\left(\frac{x}{n}\right).\left[1-\left(\frac{x}{n}\right)\right]} \quad (1)$$

Where: n is the sample size; N represents the size of the population; and is the sampling error; x / n is the estimated proportion of the item surveyed in the sample (%); and Z is the abscissa value of the normal curve associated with the confidence level [4].

An acceptable sampling error of 5% was considered, since no estimate was used, the value of 50% was used and the confidence level was 90%.

The selection of the articles published in the last 10 years was used, followed by the abstracts of the articles to exclude those that do not fit the research focus, so the theoretical reference portfolio was composed from this quantitative analysis.

In addition, the qualitative analysis of the portfolio, presenting a synthesis about the conclusions and perspectives of the authors of these articles on the theme, and based on the considerations collected in these articles, has been elaborated a SWOT Matrix, in order to evaluate the positive and negative for the continuation of research focused on the proposed theme.

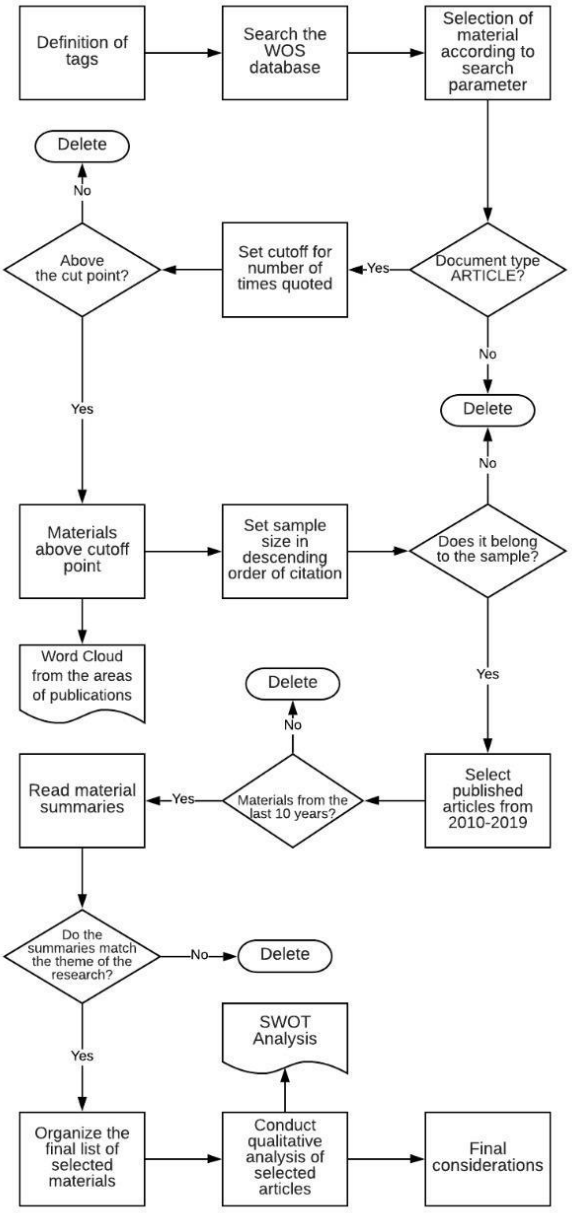

Fig. 1 shows a flowchart with the steps taken to select the portfolio for better understanding.
Source: Prepared by the authors

III. RESULTS AND DISCUSSION

When using the mentioned keywords, and considering the maximum time of publication of the data base chosen, were found 1,495 publications. Then the first refining was done, since only article type documents were selected, resulting in 777 publications, with the first work in 1995, until the year 2019, Chart 1 shows the evolution of the

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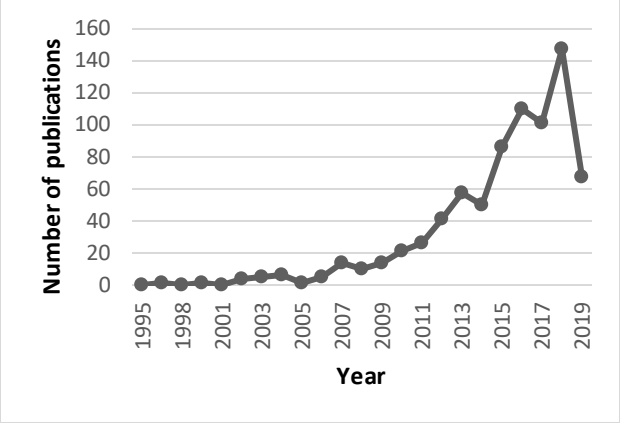
publication of articles of this theme to the logo of the years.



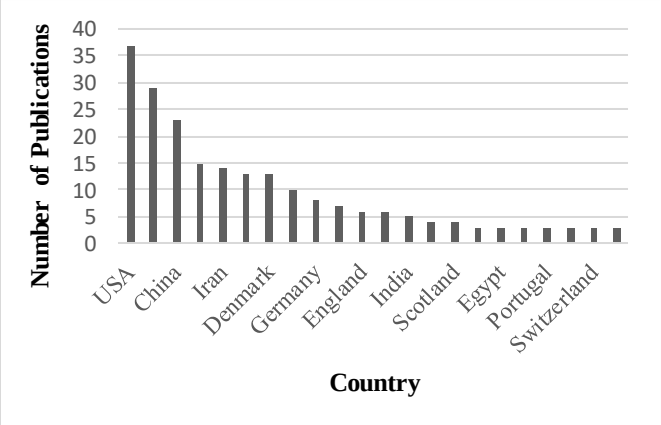
Graph 1 - Evolution of publications over the years
Source: Prepared by the author

The first published article is entitled "Wind Farm Economics" by Milborrow, D.J. [15], a publication in the journal Proceedings of the Institution of Mechanical Engineers Part A-Journal of Power and Energy.

It can be observed that from the year 2007 the growth of publications on the subject is of ascending form with a peak in the year 2018, the decline of the year of 2019 is justified by the research was carried out on 06/29/2019. But this year was not excluded in the total time span of the research, keeping the scope of the research the relevant papers published in the current year. Therefore, studies on wind energy have been showing an increasing interest on the part of researchers.

The sum of all citations of the 2,608 articles results in 13,606 citations, and with the cutoff method are 84.76% of the citations, being composed by articles that were cited 16 times or more, reducing the selection to 241 articles.

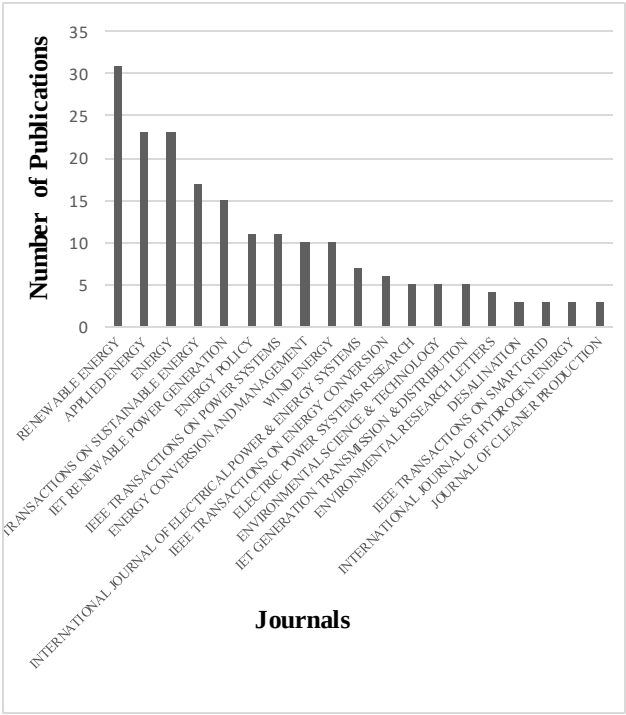
From these 241 articles it was possible to identify the countries that publish the most on the subject, Graph 2 presents the countries with three or more publications:



Graph 2 - Number of publications by Country
Source: Prepared by the author

It can be observed that the United States is the country that has published most on the subject, 37 publications, being an advanced country in scientific research. Brazil also has its share of contribution, however small, with a total of 3 publications.

One of the ways to evaluate the relevance of a scientific work in academic terms is the analysis of the journal where the work was published, the theme of this work has articles published in several magazines, each with a different evaluation and research themes. Graph 3 shows the journals with their respective numbers of published articles, only those that had three or more publications.



Graph 3 - Number of publications by Journals
Source: Prepared by the author

The journal Renewable Energy presented the largest number of publications, with 31 publications, which in turn has impact factor 4.9. Followed by Applied Energy magazines (impact factor 8.426) and Energy (impact factor 5.537) with 23 publications each. The impact factor is of great importance in measuring the relevance of journals, using the JCR (Journal Citation Report) platform to find this value [21].

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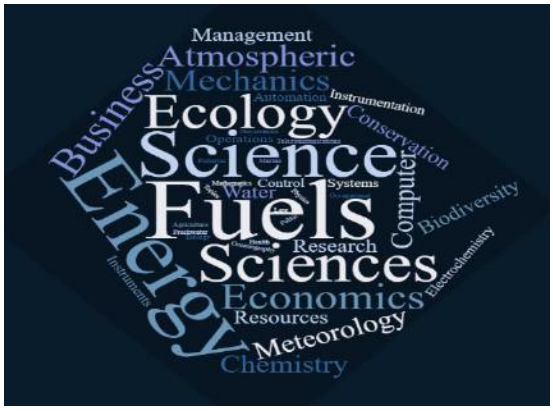

Fig. 2, which uses the Word Cloud tool for a better visualization, can be found in journals of several areas. Source: Prepared by the authors

It can be observed that the areas of the periodicals in which more articles have been published on the subject are Energy & Fuels, Science, Ecology and Economic Sciences.As a further refining was necessary, within the 241 articles, at a confidence level of 90% the sample of 129 articles was still selected according to the descending order of citation, resulting in articles cited 29 times or more.

In order to reach the desired portfolio, the articles published in the last ten years (2010-2019) were selected, obtaining 90 remaining articles. And from the reading of the summaries of the articles were excluded 82, resulting in the composition of the portfolio 8 articles as presented in Table 1.

Table 1 - List of articles in the portfolio

Title	Author	Year of Publication
Wind plant power optimization through yaw control using a parametric model for wake effects-a CFD simulation study	Gebraad, PMO; Teeuwisse, FW; van Wingerden, JW; Fleming, PA; Ruben, SD; Marden, JR; Pao, LY	2016
Environmental management framework for wind farm siting: Methodology and case study	Tegou, LI; Polatidis, H; Haralambopoulos, DA	2010
Study of decision framework of offshore wind power station site selection based on ELECTRE-III under intuitionistic fuzzy environment: A case of China	Wu, YN; Zhang, JY; Yuan, JP; Geng, S; Zhang, HB	2016
A multicriteria decision making approach for evaluating renewable power generation sources in Saudi Arabia	Al Garni, H; Kassem, A; Awasthi, A; Komljenovic, D; Al-Haddad, K	2016
A method for the assessment of the visual impact caused by the large-scale deployment of renewable-energy facilities	Rodrigues, M; Montanes, C; Fueyo, N	2010
Wind farm siting using a spatial Analytic Hierarchy Process approach: A case study of the Stadteregion Aachen	Hofer, T; Sunak, Y; Siddique, H; Madlener, R	2016
Climate change impacts on the power generation potential of a European mid-century wind farms scenario	Tobin, I; Jerez, S; Vautard, R; Thais, F; van Meijgaard, E; Prein, A; Deque, M; Kotlarski, S; Maule, CF; Nikulin, G; Noel, T; Teichmann, C	2016
Maximizing the overall production of wind farms by setting the individual operating point of wind turbines	Gonzalez, JS; Payan, MB; Santos, JR; Rodriguez, AGG	2015

Source: Prepared by the author's

From the selected articles it is possible to present a synthesis of the authors' comments on the subject. For example, present contributions for the optimization of energy in a wind power plant, for this the authors show elements that must be considered for such optimization process, which in turn, when considering the

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implementation of a power plant the optimization of energy will already be significant since the start of production of the wind power plant [9]. The elements studied extensively are: position of each turbine in the plant, wind direction, wind speed, turbulence and atmospheric stability and turbine type (generator torque, blade pitch angles or yaw angle). But consider the individual operating point of the wind turbines [10].

In a study to identify sites with potential wind farm installation in Greece, using a multicriteria analysis method mentioned that for such deployment includes environmental, economic factors, social constraints, and techniques [22]. In their research were identified and evaluation criteria for the choice of locality, these are presented in Table 2 below.

Table 2 - Criteria for evaluation of the article

Evaluation Criteria	Criteria Type\
Visual Impact	Environmental / Social
Visibility of settlements	Environmental / Social
Visibility of archaeological sites	Environmental / Social
Earth Value	Economic
Slope	Technological
Ground Cover	Environmental
Wind Potential	Technological
Distance fromElectrical network	Economic
Distance from the road network	Economic
Electricity demand	Environmental

Source: Adapted from Tegou et al., (2010)

Also uses a multi-criteria analysis method, but focuses on offshore installations involving wind resources, construction and maintenance conditions, ground support conditions, environmental impacts, economic and social benefits [25]. Table 3 shows the criteria established by these authors.

Table 3 - Criteria for evaluation of the article

Wind Resources	Construction and maintenance conditions	Ground support conditions	Environmental impact	Economic	Social benefits
Wind speed and its distribution status	Weather conditions	Traffic condition	Marine environmental impact	Total Investments	Employment
Wind energy density	Marine conditions	Electrical transmission and distribution system	Coordination of marine life	Total return period of the project	Benefit from the foggy climate
Effective wind hours	Underwater geological condition	Distance to load center	Bird co-ordination	Ratio of B / C	
Wind shear	Depth of sea water, distance from shore and width of the beach			Operation and maintenance costs	
Turbulence				Local financial subsidies	

Source: Adapted from Wu et al. (2016)

Used the multicriteria analysis in their research in their study as well, this time regarding the evaluation of renewable energy generation in Saudi Arabia from five different sources, among them wind [2]. As the criteria used for the generation of energy, these are considered important in the implantation of a power plant, such as socio-political, technical, economic and environmental factors.

Por large penetrations of renewable technologies, such as wind energy, the general visual impact can be substantial and can provoke a public reaction, ie a factor of fundamental importance when implementing a wind farm [17].

Also numbers criteria to determine the potential of a wind farm, but in Germany, and they are: Wind power potential / Wind speed; Distance from the road network;

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Distance from the power grid; Slope of the terrain; Distance from urban areas; Distance to places of interest; Distance from natural environments; Type of soil cover; and Landscape architecture [12].

In turn consider two important points in their studies, the climatic projections of the region and the force of the wind [23]. As they point out that the wind energy resource is subject to changes in the climate, in this way, they investigate the impacts of climate change on future European wind power generation potential.

Thus, based on the considerations collected in the articles that compose the portfolio, it was possible to elaborate a SWOT Matrix (Table 4), with pertinent information, thus evaluating the positive and negative points for the continuation of the photo survey in the topic addressed. With the SWOT Matrix it is possible to identify the strengths and weaknesses that are internal factors, and opportunities and threats that are external factors, in order to visualize advantages, disadvantages, contributions to achieve objectives and harmful to the execution of these.

Table 4 - SWOT Matrix based on the information collected by the articles

Positive	Negative
Strengths	**Weakness**
- Renewable and clean source; - Choice of a better location for the implementation of a wind farm.	- Give greater importance in technical and economic factors than environmental and social factors.
Opportunities	**Threats**
-Possibility of reducing environmental, social and economic impacts; - Possibility of studies for other types of generation and for hybrid plants.	- Lack of studies on social factors.

IV. CONCLUSIONS

With the bibliometric research carried out on the Web of Science platform, it was possible to identify the growth of scientific production regarding factors that influence the implementation of wind farms, and also to generate a portfolio to be the theoretical base of this study and future research.

Most of the publications are in the area of energy, which has been gaining its space in several discussions and studies, whether it is focused on technical, environmental, economic or social area.

This research used only one database (WOS), since it is a complete and rich database of academic works used by several countries of the globe, but it is suggested that other databases be used to make a comparison with others bibliometric studies in other languages.

The study brought to light the importance of the theme addressed from different perspectives, and to identify and list the factors that may contribute with other academic studies or real projects of wind farm deployments, thus generating a greater knowledge construction.

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