WIND POWER AND COMPETITIVENESS: a bibliometric analysis

ENERGIA EÓLICA E COMPETITIVIDADE:uma análise bibliométrica

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ABSTRACT
In the last few decades, the relationship between energy production through fossil fuels and climate change has been widely discussed, which has led to a significant increase in studies on new forms of energy generation, using clean and renewable sources. Among these sources, wind power is considered as one of the most promising, since it has exponential growth, economicity and guarantee of continuous supply. Despite this, given that fossil sources are already consolidated, both in economic terms and in technical knowledge terms, it is necessary to know the competitiveness factors that can be characterized as potentialities or restrictions for the full development of the wind source. In order to know these aspects, the central objective of this research was to analyze the evolution path of the studies related to the competitiveness factors pertinent to wind energy, using bibliometric analysis so that future research directions can be identified. The results showed that studies on wind power and competitiveness have gained prominence since 2006, remaining constant until the current period. It was also found, through analysis by keywords and qualitative assessment of publications, that these surveys were classified into nine aspects related to competitiveness: Economic Analysis, Competition, Technology, Operational Costs, Regulation/Government, Environmental Impacts, Competitiveness, Market and Hybrid Generation, thereby providing guidance for future investigations.
Keywords: Wind Energy. Competitiveness. Renewable Energy. Bibliometric Analysis.

RESUMO
Nas últimas décadas, muito se tem discutido sobre a relação da produção de energia por meio de combustíveis fósseis e as alterações climáticas, o que fez com que se aumentasse, significativamente os estudos sobre novas formas de geração de energia, utilizando fontes limpas e renováveis. Dentre essas fontes, a energia eólica é considerada uma das mais promissoras, pois apresenta crescimento exponencial, economicidade garantia de suprimento contínuo. Apesar disso, dado que as fontes fósseis já se encontram consolidadas, tanto em termos econômicos, como em termos de conhecimento técnico, torna-se necessário conhecer os fatores de competitividade que podem se caracterizar como potencialidades ou restrições para o pleno desenvolvimento da fonte eólica. A fim de conhecer esses aspectos, esta pesquisa teve como objetivo central analisar o caminho da evolução dos estudos relacionados aos fatores de competitividade pertinentes à energia eólica, empregando análise bibliométrica para que futuros direcionamentos de pesquisas possam ser identificados. Os resultados mostraram que os estudos sobre energia eólica e competitividade ganharam fôlego a partir de 2006, mantendo-se de forma constante até o período atual. Foi constatado também, através da análise por palavras-chave e avaliação qualitativa das publicações, que estas estavam classificadas em nove aspectos relacionados à competitividade: Análise Econômica, Concorrência, Tecnologia, Custos Operacionais, Regulação / Governo, Impactos Ambientais, Competitividade, Mercado e Geração Híbrida, fornecendo orientações para pesquisas futuras.
Palavras-chave: Energia Eólica. Competitividade. Energias Renováveis. Análise Bibliométrica.

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1 INTRODUCTION

In the last few decades, the interest in renewable energies has increased significantly due to emerging global issues, such as climate change, excessive exploitation of the environment and the search for sustainable development. Nevertheless, the generation of electric energy from renewable energies is still unable to compete economically with the electricity generated by fossil fuels, as it faces situations of uncertainty, problems of variability and performance (GAO et al., 2016; HAUSER; WERN, 2016; JÜLCH, 2016; NTANOS et al., 2018; PURKUS et al., 2018).

Even in countries like Brazil, whose share of renewable sources in the internal supply of electricity exceeds 60% (EPE, 2019), due to the use of hydraulic energy, other alternative sources, such as solar, wind and biomass have not yet been consolidated, especially, because of the competitiveness in terms of expenses presented by electricity production derived from traditional sources (FOGARASI; CORMOS, 2015; LINS et al., 2012; WANG et al., 2018b).

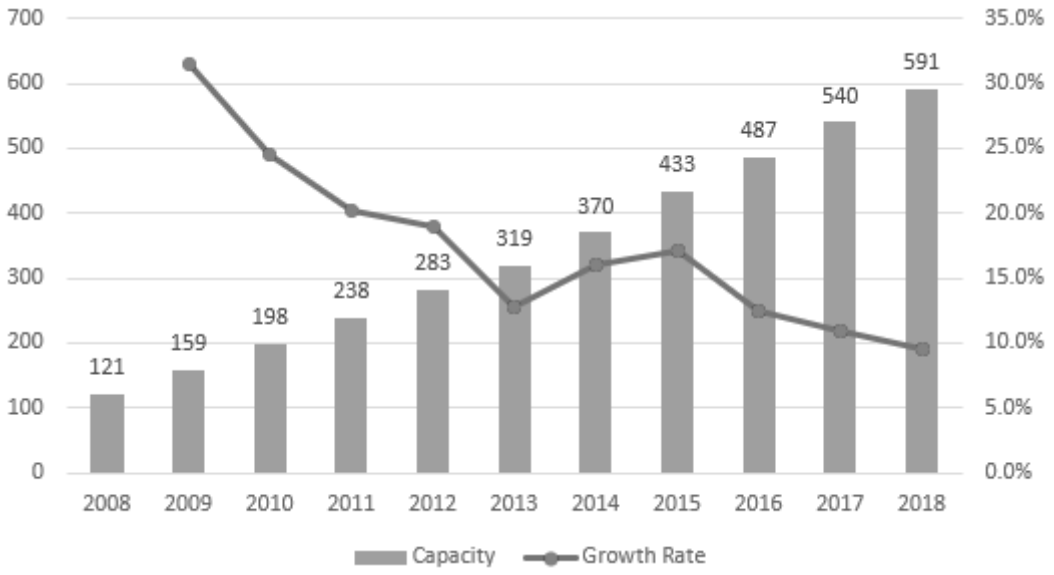
Despite these difficulties, renewable energies, due to the lower environmental impacts and CO_2 emissions (DONG; SUN; DONG, 2018; SOAM et al., 2016; XU; FAN; YU, 2014), have gained prominence in the socio-environmental agenda, mainly from December 2015, with the accomplishment of the 21st Conference of the Parties (COP 21) of the United Nations (UN), thereby being promoted to the level of key measures to cope with climate change (BORGES et al., 2016; MARTINS et al., 2019). Socio-political factors decrease the gap between the design of low-carbon energy policies and the proper deployment of renewable energy technologies to mitigate the effects of climate change (ABREU et al., 2014). Among the renewable sources available, wind energy is currently considered one of the most promising, since it presents exponential growth, scale and guarantee of continuous supply (DAS; KRISHNAN; MCCALLEY, 2015; DING et al., 2019; MADLENER; LATZ, 2013).

By the end of December 2018, the global wind energy production capacity expanded by 470 GW, that is, it increased from 121 GW in 2008 to 591 GW in 2018. Between 2009 and 2013, the production of wind electricity doubled; and, in 2018, wind energy represented 19% of the electricity generated by renewable energies (REN21, 2019). In the same period, the average annual growth rate was 17.4% (Figure 1). Accordingly, in order to make wind power even more viable, due to political, economic and social reasons, encouraged by the current sustainable development agenda proposed by the United Nations (UN) (COSTANZA et al., 2016), it will be necessary to achieve a greater integration between the process of generating electricity from the winds and the power transmission lines, better energy

planning in the countries and further research for the implementation of Offshore Wind Parks, because one of the major problems, both environmental and economic related to the generation wind power, is the need to use large areas to maintain its operation (ATAEI; SHAHSAVANY; MIKAEIL, 2013; HÜBLER et al., 2020; VAVATSIKOS; ARVANITIDOU; PETSAS, 2019).

Given these circumstances, it is important to establish a knowledge base on the competitiveness factors that influence and expand the development of wind power, thereby seeking to analyze and understand whether expectations of reduced equipment costs, such as, for example, wind turbines, will come to fruition (GIANNAKOPOULOU, 2018; MOHSIN; RASHEED; SAIDUR, 2018; REZAEI; NAGHDI-KHOZANI; JAFARI, 2020), as well as factors related to high investments, relationships with governments and suppliers, electricity costs and market demand (LAPPE; SPANG, 2014; SILVA et al., 2013; TROCHE-ESCOBAR; LEPIKSON; FREIRES, 2018).

Figure 1 – Global wind power capacity and growth rate



Source: REN21, 2019

With regard to competitiveness, Porter (1996) defines it as an analysis of competition among companies, considering that they are influenced by five competitive forces: rivalry among competitors, bargaining power among buyers, bargaining power of suppliers, entry of new competitors and substitute products. In other words, competitiveness is a broad term, which considers the environment as a whole, where agents are inserted and interact with each other by seeking to create competitive advantages.

In light of the foregoing, especially since 2006, a period in which there was a greater concentration of surveys on wind power and competitiveness, mainly due to a greater interest from China and the United States,

which will be better explained in a later section, several studies focused on different aspects of competitiveness. From 2006 to February 2020, 284 surveys were published, and the main ones will be listed below.

Zhang (2012) and Zhao, Hu and Zuo (2009) analyzed the Chinese wind industry, showing that this country is at an advanced stage of production of equipment essential to the process of generating electricity from the winds; however, it would still be necessary to evolve in terms of technical knowledge, thereby seeking to fill the gaps with the main foreign countries, especially the United States and Germany, with respect to technological research and development. Another competitive aspect exploited by publications in recent years is related to the financial return on wind parks. Macedo, Albuquerque and Moralles (2017) and Pinson et al. (2007) analyzed the return on investment of wind parks using economic engineering techniques such as Net Present Value (NPV) and Internal Rate of Return (IRR) in a situation of full knowledge of cash flow and also on an uncertain situation, which provides greater credibility to the projects. Thorough analysis of investment projects provides managers with reliability, whether public or private, for the correct decision making on future investments, thereby mitigating risks and increasing competitiveness (ASTARIZ; IGLESIAS, 2016b; LAZARO; GREMAUD, 2017; RAMOS; IGLESIAS, 2014).

Regional aspects and synergies with other sources of clean energy generation are also considered competitive factors. The best choice of locations for the implementation of wind parks, both onshore and offshore, can make a crucial difference in terms of expenses, thereby resulting in more competitive final sales prices. Astariz and Iglesias (2016b), (2016c), analyzed, in two documents, the best location of an offshore wind park associated with a wave generation park.

There are also works that addressed regulatory aspects. Pegels and Lütkenhorst (2014) analyzed the energy transition process in Germany, thereby demonstrating the barriers and opportunities that these changes presented and brought to this country. Bolinger and Wiser (2009), researched how the price of wind energy could remain competitive in the face of a situation of appreciation of the North American currency and increased consumption by electric power, in view of the existence of more consolidated energy sources and, therefore, more competitive in terms of sales price. Timilsina, Cornelis Van Kooten and Narbel (2013) and Twomey and Neuhoff (2010) carried out in-depth studies on the global potential of wind power generation and its influence on the electrical sectors worldwide, thereby highlighting competitive aspects that could entail impacts, such as costs, prices, production technology, besides macroeconomic factors, such as market demand, supply capacity and competition with other energy sources.

An important competitive aspect, which is present in studies on wind power, is the ability of an industry, market or sector to produce innovations. In the field of wind energy production, this factor is constant, whether in the use of winds to produce hydrogen and to assist the supply of electric cars, for example (ALAZEMI; ANDREWS, 2015; BROUWER, 2010; LE DUIGOU et al., 2013; LINNEMANN; STEINBERGER-WILCKENS, 2007), or to contribute to the mitigation of Greenhouse Gases (GHG), (DELARUE; LUICKX; D'HAESELEER, 2009; DELLANO-PAZ et al., 2015; SAFDARNEJAD; HEDENGREN; BAXTER, 2015).

In addition to specific works on aspects of competitiveness, articles were also published with the purpose of identifying and analyzing the critical success factors that significantly affect the development, potential and competitiveness of the wind sector. To that end, the modeling known as Porter's Diamond was used, which helps us to understand the competitive advantages of nations and to explain how governments can act as catalysts for development, by improving the economic environment and establishing conditions so that the four factors present in the theory (Porter's Diamond), company strategy, competition, support industries and demand conditions, can be correctly analyzed (IRFAN et al., 2019a, 2019b; ZHAO; HU; ZUO, 2009).

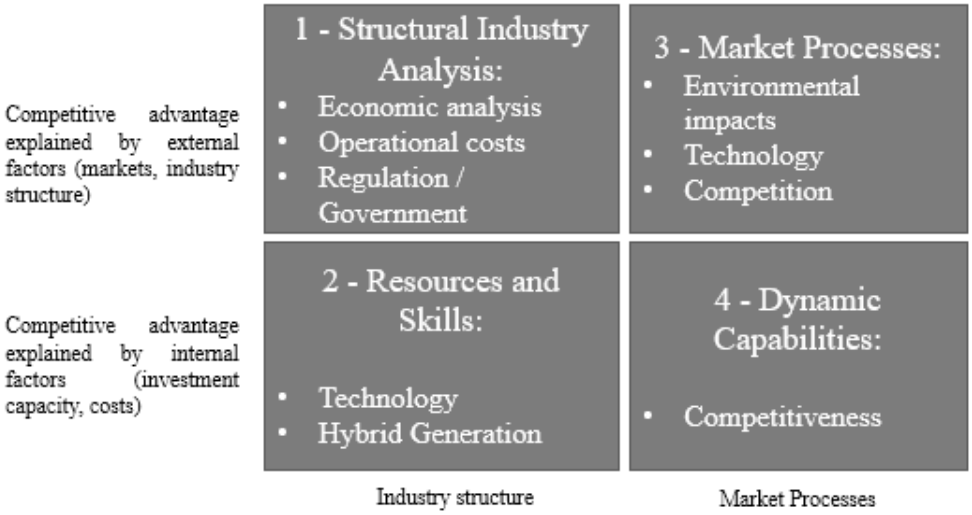
As you can see, from 2006, many works were published on competitiveness and wind power. Nevertheless, none of them presents a comprehensive, systematic and targeted view on the models of competitiveness and the factors involved in the process of generating electricity from wind energy. In addition, none offers a holistic and quantitative view of publications related to competitiveness and wind power, holding bibliometric analysis. Consequently, this study intends to fill this gap.

The main contribution of this research took place by means of the identification, through the articles of the analytical body, of nine focal points related to the competitiveness factors that can be observed in the wind energy sector: economic analysis, competition, technology, operational costs, regulation/government, environmental impacts, competitiveness, market, and hybrid generation. The focal points were chosen according to two reasons. The first one is related to the content of the discussions and analyzes held in the publications. Accordingly, when reading the surveys, they were divided by the similarity of their study objects, thereby constituting the first stage of identification of focal points.

The second reason is associated with the fact that these nine focal points are associated with the four main theoretical trends that deal with the phenomenon of competitive advantage, that is, the occurrence of different levels of structural, technical and economic performance above the market

average due to the different strategies adopted by different market segments. The main explanatory trends of competitive advantage are: Structural Analysis of Industry (Industrial Organization), Resources and Competencies (Resource Theory), Market Process and Dynamic Capabilities (THOMAS; POLLOCK, 1999; VASCONCELOS; CYRINO, 2000). Figure 2 illustrates the theoretical trends about competitive advantage with the focal points associated with them.

Figure 2 – Explanatory trends of competitive advantage associated with focal points identified from reading the articles of the research analysis body



Source: Adapted from Vasconcelos and Cyrino, 2000

The Structural Analysis of Industry in force, or Industrial Organization, supported by the pioneering works of Edward Mason and Joe Bain (BAIN, 1954; MASON, 1948), states that the strategic performance of companies within the industry depends on the behavior of sellers and buyers, pricing, research and development policy, cost competitiveness and analysis of antitrust policies through situations of natural monopolies or established by government regulation (JEDLICKOVA, 2018), that is, external and internal aspects to the company. Accordingly, the following focal points were associated with this trend: economic analysis, operational costs and regulation/government.

The second identified theoretical trend, Resources and Competencies, emerged in the 1980s, as an alternative to the dominant position of the Industrial Organization in force. The central proposal of this trend recommends that the core of competitive advantage is primarily found in the resources and competencies developed and controlled by companies (OYATERU, 2011; PEPPARD; WARD, 2004; VASCONCELOS; CYRINO, 2000). Accordingly, the focal points were selected: Technology and Hybrid

Generation for this strategic trend, since these factors, through investment in research and development, can be controlled by companies.

Market Process was the third identified trend. This theoretical trend was influenced by the works of Carl Menger and Shumpeter, two of the founders of the Austrian School of Economics, whose contributions are organized into four main objects: a) Market Processes; b) The presence and duties of the entrepreneur; c) The heterogeneity of companies; and d) A set of unobservable factors (BOETTKE; CANDELA, 2020). Considering these characteristics, especially the presence of innovation and uncontrollable factors, the market focal points, environmental impacts, technology and competition were allocated to this trend.

The last theoretical identified trend was Dynamic Capabilities, which formulates, especially from the theories of market processes and the theory of resources, a theory of the development of organizational competencies in environments with a presence of high complexity and constant changes (ALAM et al ., 2020; PARAST, 2020). This model aims to comprehensively study the relationships between the decision processes and the business actions carried out with their consequences in terms of formation, destruction or conservation of resources. Therefore, it deals with competitive advantage in a broad way, trying to address all its aspects. Accordingly, the competitiveness focal point was allocated to this trend.

It is clear that this adjustment of the focal points of the theory is not static. It was conceived based on the analysis of the publications present in this of analytical body, as well as the authors' evaluation, aiming to synthesize and organize issues related to wind power and competitiveness, as well as to contribute to discussions in this field. It is also important to highlight the presence of subjectivity in the allocation choices, since both the theoretical trends and the focal points can overlap or complement each other, thereby making the choice criteria difficult.

Given the general conceptual panorama, the central objective of this research is to analyze the evolution path of studies related to the competitiveness factors pertinent to wind energy, using bibliometric analysis so that future research directions can be identified. Specifically, the research intends to contribute to: a) evaluate the current research progress in the competitiveness of the wind sector, its applications and trends; b) present the characteristics of publications, highlighting the main journals, countries, articles and most cited authors; c) identify the distribution of keywords according to the purposes, methods, metrics and fields of research; d) discuss the results in detail, showing possible research directions in this field, by identifying focal points related to the content and analysis of the

publications and the characteristics of the different competitiveness models. For the study related to the competitiveness of the wind sector, a sample was taken of everything published in the period of analysis in English and indexed in the Scopus database.

It is important to highlight that publications from countries like Brazil, although the articles are not included in the Scopus database, have been developing a vast literature on the topic discussed in this research. Simas and Paccas (2013), for example, researched wind energy, job creation, and sustainable development, showing that environmental concerns have become the biggest driver in the search for cleaner alternatives to energy production. Magalhães et al. (2019), discuss in their article the objective of analyzing the competitive forces of the Brazilian wind industry, identifying the main actors involved in this environment, based on Michael Porter's model. Alves (2010), in his article on the regional analysis of wind energy in Brazil, where he proposes to present a diagnosis of wind energy, its regulatory frameworks and its position in the national scenario of renewable energy, emphasizing its importance for the consolidation of a sustainable energy matrix for Brazil, in line with the international literature on the subject.

This article is organized in three more sections, in addition to this introduction. The second section deals in detail with the research methodology, including data sources and treatment. The section three presents the results found and also discusses the results. Lastly, section four that presents the main conclusions of bibliometric analysis.

2 METHODOLOGY

•Bibliometric research is defined by Gautam (2017) as a quantitative and qualitative analysis technique that intends to assess the past contribution to science by research entities and researchers in order to predict its future potential for knowledge development. That is, bibliometric studies aim to demonstrate the direction of science in a given field of research during a pre-defined period of time, thereby examining bibliographic material from an objective perspective that proves to be useful in the organization of the required information (BARBOSE et al., 2016; MONTERO DÍAZ et al., 2018).

The analytical methodology used in this research followed that suggested by Castillo-Vergara; Alvarez-Marin and Placencio-Hidalgo (2018) and Zhao and Strotmann (2015), following the steps below: a) Definition of the keywords to be used in the research; b) Selection of database, formatting and cleaning; c) Coding of the selected material and; d) Analysis of the generated information.

• Definition of keywords and selection of the database (Steps a and b):

In the present study, the keywords "wind power" and "competitiveness" were used, which were searched in the title, abstract and keywords fields using the Boolean AND in the Scopus database of *Editora Elsevier*. The Scopus database was selected for its multidisciplinary and interdisciplinary character and for its scope. According to Thelwall (2018), this database indexes peer-reviewed academic titles, open access titles, conference proceedings, among others, in addition to having more than 22,800 titles from around 5,000 international publishers, and was released by *Editora Elsevier* in 2004, offering a wide variety of research fields, such as: engineering, social sciences, medicine, arts and humanities.

The collection took place in the last week of February 2020, between the 24th and the 29th, where only publications in English, the main scientific language, were selected. The period of analysis was from 1977 to February 2020, including Articles (179), Conference Papers (95), Reviews (18), Book Chapters (11), Conference Reviews (7) and Business Articles (4), totaling 314 publications. This number already excludes the articles removed at the time of qualitative analysis, where surveys that did not specifically deal with the two terms were excluded, as well as studies that addressed other sources of renewable energy, such as biomass and electricity generation from waves. Surveys on hybrid, wind-solar and wind-wave structures were maintained, since it was a highlight that will be better addressed in the discussion section.

The option to keep all types of publication, in addition to peer-reviewed articles, was due to the interest in providing a broad international perspective of research, considering that the discussed topic was dynamic and consistently discussed in conferences and debates around the world.

• Coding of the selected material and analysis of the generated information (Steps c and d)

After the data collection stage, a single information base was created in the form of a simplified file, in Excel, "CSV" format, encompassing the complete records of publications and variables used in the analysis: author, language, year of publication, search type and field, country of origin, main keywords and typed references. In order to avoid a common problem in bibliometric research and in systematic literature review works, the way in which the authors are cited, since they can be cited in different ways, causing, in some cases, double counting problems, was standardized, through of a "Thesaurus" file, thereby eliminating this difficulty.

Moreover, in order to identify the national property of the article, only the nationality of the first author was considered, when the authors come from different countries. If he has dual nationality,

the full address of the first author was considered as an identification parameter. Another difficulty is related to the fact that some keywords have different appearances, but the same meaning within the researched context, such as, for example, “Renewable energy” and “Renewable Resource”. In order to solve this problem, terms with the same meaning were treated as just one word. Lastly, references that share the same Digital Object Identifier (DOI) were considered only as a publication.

With the file properly formatted, the analysis indicators were defined. Quantitative indicators were used to measure the productivity of a researcher, journal or country in terms of the number of citations and publications, in order to measure the frequency with which an article, author or journal is cited, listing works, researchers, institutions and countries that more invest in this type of research in line with the chosen bibliometric method, mapping the units of analysis, which, in the specific case of this work, made use of the search metric through keywords.

The bibliometric methods selected for the present research were: Citation Analysis, Co-citation Analysis, Co-author Analysis and Co-word-Analysis. The first method uses the number of citations as a measure of performance and scientific reach, assuming that the most cited authors and journals have a higher level of influence (ZHAO; STROTMANN, 2015). The second method, Co-citation Analysis, intends to identify the groups of researchers that are systematically cited by a certain number of researches together, using this metric as a measure of similarity (MARTINS et al., 2019). The assumption in question is that the more a set of works is cited in an adjacent way, the more their content is related, inferring the most influential authors in the study area (ZUPIC; ČATER, 2015). On the other hand, Co-author Analysis provides the measure of approximation among authors, institutions and countries that work with the same theme, identifying the measure of collaboration between published surveys. Lastly, Co-word Analysis appears, which highlights the main keywords used in the period under study, the way in which they are used together and how the interest in research has been developing over time (CASTILLO-VERGARA; ALVAREZ-MARIN; PLACENCIO-HIDALGO, 2018; MONTERO DÍAZ et al., 2018).

In order to help in the construction of metric maps and the consequent analysis process, the VOSviewer software was used, an open access information technology tool developed by Waltman and van Eck (2012) for the elaboration and visualization of bibliometric maps. This software allows the design of so-called term maps. A term map is a two-dimensional map in which the frequency of occurrence of a specific term is defined by the size of the label. The distance between two terms can be interpreted as an indication of the relationship of these terms based on the number of co-occurrences between them (COBO et al., 2011). The analysis held in this program took into account countries, authors and most cited articles and keywords.

3 RESULTS AND DISCUSSION

This section covered the specific proposed objectives, thereby presenting the characteristics of the publications, the most cited authors and articles, as well as the countries and institutions most engaged in the discussed topic. In the end, the distribution and frequency of keywords in the period under study was also demonstrated, which sought to identify the main research trends in the area.

3.1 Performance of related publications and performance of countries

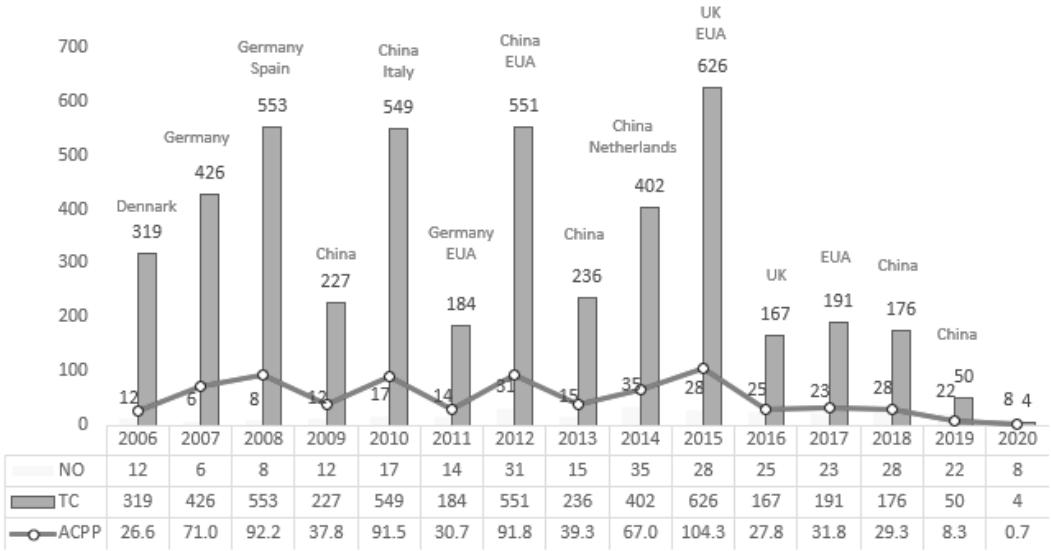
As detailed in the methodological section, the basic body of the identified literature corresponded to 314 articles. For the first 29 years, the average of publications was slightly higher than one article per year. The lack of interest in these first three decades in the competitive aspects of wind power can be explained by at least three reasons. The first is related to the technological issue. Despite having known for more than 3,000 years about the use of winds to generate energy, the efficiency of windmills during the 1980s and 1990s was still quite rudimentary (FRAENKEL; KENNA, 1984a, 1984b; LAPIN, 1977), thereby undermining the effectiveness of this process. Secondly, despite the fact that the world emerged from a world oil crisis (1973) and entered another just six years later, with oil prices remaining at high levels until 1986, there was still a time when the dominance of fossil fuels was little discussed and environmental concerns were not yet on the priority agenda (GROSSMAN, 2015; LOWRY; JOSLYN, 2014; MAY; JOCHIM, 2013; NOHRSTEDT; WEIBLE, 2010).

The probable third reason for the lack of interest in the wind energy sector, observed during the keyword research, which returned several publications that dealt with renewable energies, especially biomass, is also related to the oil crises. With a view to preventing future shortages, countries like the United States and Brazil, for example, started to invest in investigations with the production of fuels from biomass, especially ethanol, as a result of the specialization of these countries in the production of corn and sugarcane, respectively.

Only from 2006, the academic production on competitiveness in the wind energy sector was enhanced, growing at an average of 58% in the period from 2006 to February 2020. According to Gao et al. (2016), this happened because the group of the seven richest countries (G7), which includes the United Kingdom, United States, Canada, Germany, Italy, France and Japan, gathered to discuss and encourage the development of alternative energy sources, with the purpose of responding to possible external shocks in the price of oil. At the same time, China launched the program entitled “Renewable Energy Law of the People’s Republic of China” from February 2005, also intending to diversify its energetic and electric matrix, which is still based on the intensive use of mineral coal (KSENIA; RIFFAT;

JIE, 2010; PEIDONG et al., 2009; SHI, 2009). As a result, in this period, more studies were developed, 284 published surveys (approximately 90% of the production of the whole series). Figure 3 shows the performance of articles in the period from 2006 to February 2020, highlighting the number of published articles (NO), total citations (TC), average citations of articles per year (ACPP), in addition to the country or countries that more published in a given year.

Figure 3 – Performance of publications from 2006 to February 2020



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
NO	12	6	8	12	17	14	31	15	35	28	25	23	28	22	8
TC	319	426	553	227	549	184	551	236	402	626	167	191	176	50	4
ACPP	26.6	71.0	92.2	37.8	91.5	30.7	91.8	39.3	67.0	104.3	27.8	31.8	29.3	8.3	0.7

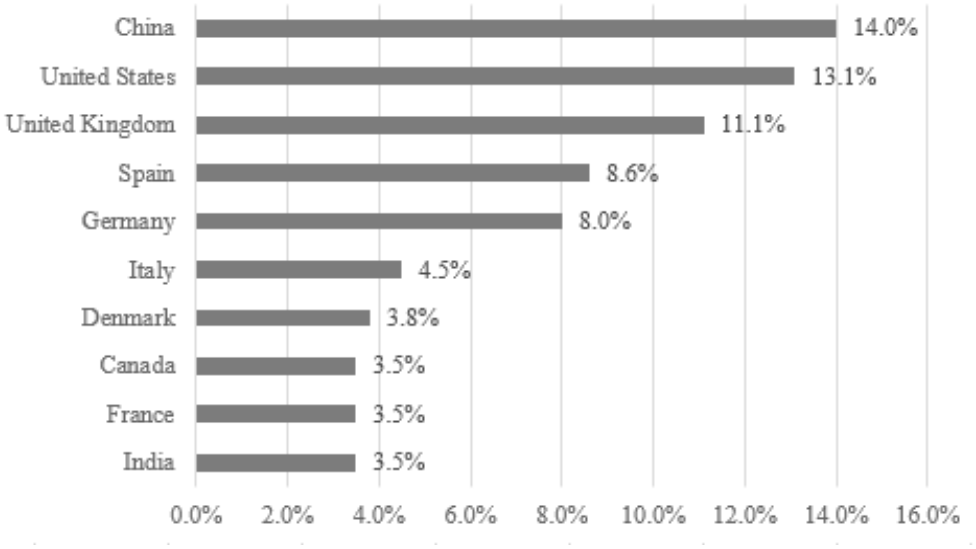
Source: Authors, 2020

The number of publications in a country reflects its degree of engagement with the field of study. The 10 most productive countries, considering the entire historical series (from 1977 to February 2020) and only the nationality of the first author, are illustrated by Figure 4. These 10 main countries published 231 articles, representing 73.6% of the total publications. The list is headed by China, with 44 publications (14%), followed by the United States, with 41 articles (13.1%), and the United Kingdom, with 35 publications (11.1%). In the middle of the list, Spain, Germany, Italy and Denmark appear, which have 27 (8.6%), 25 (8.0%), 14 (4.5%) and 12 (3.8%) publications, respectively and, finally, Canada, France and India, which have 11 articles each, representing 3.5% of the total number of publications. It is interesting to highlight that the 10 countries that most research on the competitive aspects of wind energy are also the ones that have the largest production capacities (REN21, 2019).

China, the largest producer in research on the topic of interest, also has the highest cumulative capacity in wind energy (GAO et al., 2016; WANG et al., 2018a), thereby reflecting the performance in surveys. Currently, the United States has an installed capacity of 89.07 GW. Despite being in second

place in the ranking of publications, it is the country with the largest magnitude of investments, around US$ 300 billion in 2018 (Global Wind Report, - GWEC, 2018; GIANNAKOPOULOU, 2018). It is also noteworthy to emphasize the participation of Europe in surveys related to the topic of interest: of the 10 countries present in the list of major research producers in the area, six are European.

Figure 4 – The 10 most productive countries on wind power and competitiveness



Source: Authors, 2020

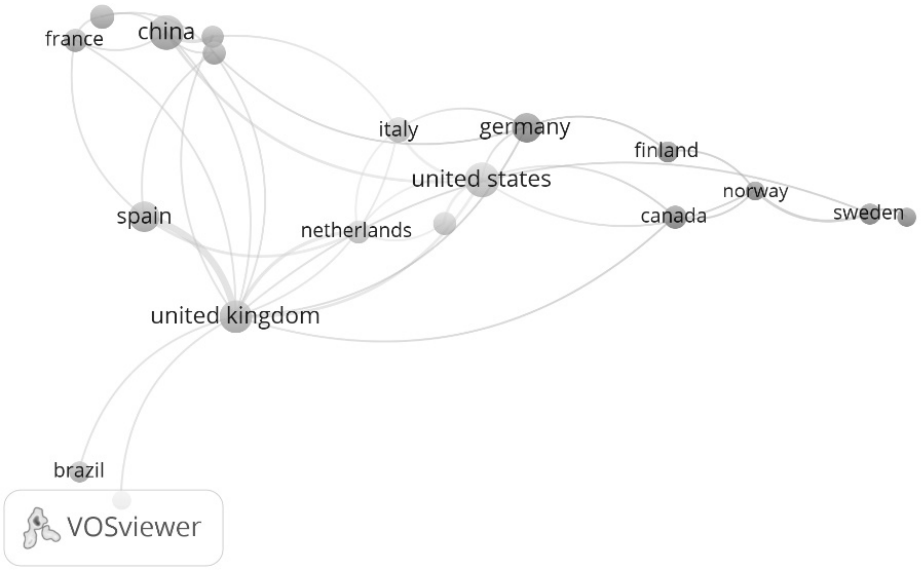
Concerning the collaboration among countries, considered academically as an important factor, as it allows integration between different authors and research, thereby enabling the technology transfer processes and the search for innovative solutions for the research area, it can be seen in Figure 5, which illustrates the scientific collaboration relationships during the period from 1977 to February 2020, which German researchers published most of the work co-authored with their partners in Finland, Canada, Norway and Sweden. For this analysis, a minimum of five joint publications for the countries were parameterized in the Vosviewer.

It is interesting to notice the presence of major oil producers such as Norway and Canada, showing interest in competitive aspects of wind energy, meeting the international agenda for Sustainable Development, which encourages the use of renewable energy. The main works deal with concerns about the cost structure of wind parks, especially in the late 2000s (LINNEMANN; STEINBERGER-WILCKENS, 2007; PAHLOW; MÖHRLEN; JØRGENSEN, 2009; WERNER; REMBERG, 2008), but also about strategy of using wind-solar hybrid parks to produce electricity, especially newer articles (HIRTH, 2015; KAEMPF; ERNST; BRAUN, 2019; RABE; KOSTKA; SMITH STEGEN, 2017).

The United States is also a prominent country in research in the area of interest. Its main collaborators are Italy and the Netherlands. The research presented was diversified, comprising economic studies on demand and prices of electricity from winds and cost reduction strategies for onshore and offshore wind parks (BARBOSE et al., 2016; BHATTACHARYYA; TIMILSINA, 2010; BOLINGER; WISER, 2009; TIMILSINA; CORNELIS VAN KOOTEN; NARBEL, 2013; ZARNIKAU, 2011) to surveys that talk about the GHG mitigation capacity in the energy sector (DELARUE; LUICKX; D'HAESELEER, 2009; DENHOLM et al., 2012; SAFDARNEJAD; HEDENGREN; BAXTER, 2015). The United Kingdom also has important and strong collaborations with other countries, especially Spain and Brazil. The main collaborative works were concerned with researching regional strategies for the implementation of wind parks and hybrid structures (ASTARIZ et al., 2015; ASTARIZ; IGLESIAS, 2016b; RAMOS; IGLESIAS, 2014; VEIGAS; IGLESIAS, 2013).

China also is highlighted in international academic partnerships. The main partner is France, but it also maintains research together with the United States, Australia and India. The main discussed joint themes were focused on the use of methodologies involving artificial intelligence to predict costs and wind speeds (KHARE; NEMA; BAREDAR, 2013; NIE; WANG; ZHANG, 2017; ZHANG et al., 2018). Figure 5 summarizes the status of international partnerships among authors, highlighting the cooperation of the United States, United Kingdom, Germany and China.

Figure 5 – Academic cooperation relationships among countries



Source: Authors, 2020

3.2 Performance of the main journals

The 314 collected articles are distributed in 11 areas of knowledge of Scopus (already included the class others), where the main classes are Energy (33.2%), Engineering (23.0%) and Environmental Sciences (15.5%). They were published in 105 different journals or conference proceedings, thereby indicating the diversified nature of surveys that address factors of competitiveness and wind energy. The top 15 journals are responsible for 38.1% of the total publications. Its particularities are analyzed in detail through Table 1. The most influential journal in this area of study is Energy Policy, with 29 publications (9.2%). Energy Policy is an international peer-reviewed journal that addresses the political, technical, economic and social implications of energy use and its planning. With an impact factor of 4.88, the articles cover global, national, regional and, in some cases, local topics, depending on the application and the political significance exercised by the findings. Another prominent journal is Energy, which, from 1977 to February 2020, featured 13 publications on the subject under debate, that is, 4.1%. The impact factor of the journal in 2018 is 5,537 and addresses studies on energy production, both renewable and non-renewable, in different aspects.

The only journal without a related impact factor is Applied Mechanics and Materials. This journal had seven related publications on wind power and competitiveness in the period between 2012 and 2014, with two editions dedicated to the International Conference on Mechatronics, Applied Mechanics and Energy Engineering (MAMEE) in 2013 and 2014. Most of the articles were concerned with analyzing competitive characteristics in relation to the availability of winds from certain regions, using different models to measure wind speed, occurrence and periodicity (HAN; ABUDUREYIMU, 2014; LIU, 2013; ZHANG; TAN, 2012).

Table 1 – The 15 main related journals and their main characteristics

Journals	TP	%	IF
Energy Policy	29	9.2%	4.88
Energy	13	4.1%	5.537
Renewable and Sustainable Energy Reviews	12	3.8%	10.556
Renewable Energy	12	3.8%	5.439
Applied Energy	8	2.5%	8.426
Applied Mechanics and Materials	7	2.2%	0
Energy Conversion and Management	7	2.2%	7.181
International Journal of Hydrogen Energy	6	1.9%	4.084
Energy Procedia	5	1.6%	0.44
Advanced Materials Research	4	1.3%	0.87
Energies	4	1.3%	2.707
Energy Economics	4	1.3%	4.151
IEEE Transactions on Power Systems	3	1.0%	6.807
Journal of Renewable and Sustainable Energy	3	1.0%	10.556
Ocean Engineering	3	1.0%	2.73

Source: Authors, 2020

Deepening the analysis a little further, starting with topics of interest to the journals, considering a minimum number of three publications per Journal, it was possible to identify five main clusters (Figure 6). The first cluster, led by the journal Energy, together with the Journals Renewable and Sustainable Energy Reviews and Energy Conversion and Management, were responsible for 32 publications on the topic of interest, that is, 10.19% of the total publications. The most cited articles were "Wind power integration using individual heat pumps - Analysis of different heat storage options" (HEDEGAARD et al., 2012), published in Energy, with 146 citations, which carries out a case study that analyzes the economic competitiveness of installation of heat storage pumps in Denmark as a way to integrate the wind system into the electricity generation process. The second most cited article was published in the journal Renewable and Sustainable Energy Reviews and featured 77 citations. The article "Automotive hydrogen fueling stations: An international review" (ALAZEMI; ANDREWS, 2015) was concerned with comparing the costs of hydrogen production for possible and eventual substitution of fossil fuels in public transportation in refueling stations worldwide, from different sources and routes of energy production. The aforementioned paper found that the most competitive source was still coal, through the gasification process, and the most expensive was wind energy. In general, the cluster was also concerned with strategic regional factors of wind parks (ASTARIZ; IGLESIAS, 2016b, 2016c; MESCHEDE; CHILD; BREYER, 2018), applications of wind energy for electricity supply in small spaces, such as buildings (HIMRI et al., 2008; LIU; HO, 2016), in addition to studies on new materials for the manufacture of turbines and the capture of energy (HAMDAN et al., 2014; JOSELIN HERBERT et al., 2007).

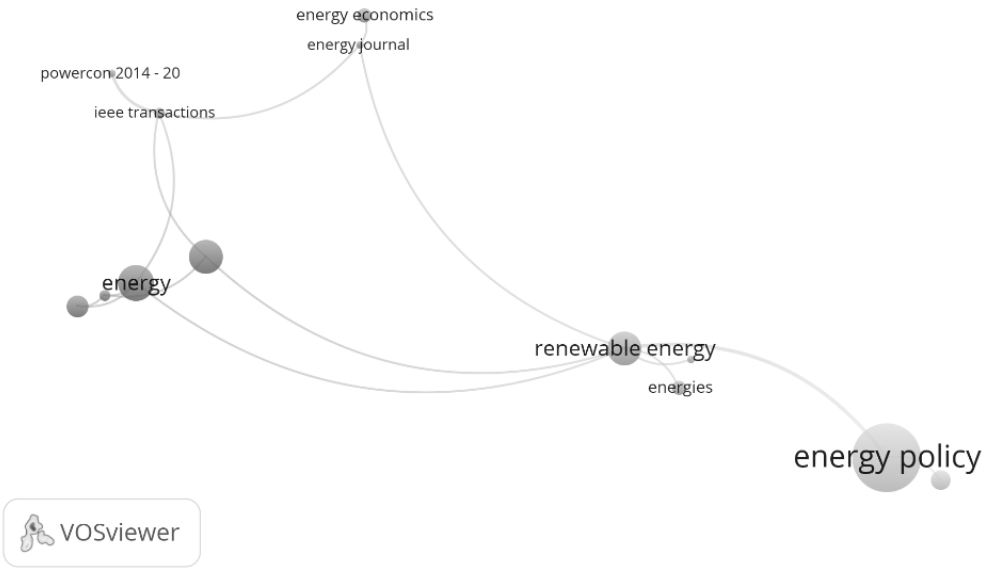
The second cluster, which was formed by the journals "Renewable Energy", "Energies" and "Economics and Policy of Energy and the Environment", covered 18 articles (5.7% of the total publications). The most cited article in this cluster was "Status and problems of wind turbine structural health monitoring techniques in China" (LIU; TANG; JIANG, 2010), which carried out a diagnosis on the monitoring techniques of wind turbines in China, in order to check its ability to operate over time, given the high costs of its implementation. The other publications in this cluster were also concerned with issues related to the cost of implementing wind parks, especially in relation to investments and costs of maintaining and operating this system (CORSATEA; GIACCARIA; ARÁNTEGUI, 2014; YU et al., 2017; ZHANG et al., 2019).

The journals “Energy Economics” and “Energy Journal” made up the third cluster, with six publications, four of which were from the first. The majority of the articles discussed the economic and strategic aspects of using solar and wind sources together. In this regard, they discussed the influence of price and the welfare of the generated energy (HIRTH, 2015; REICHELSTEIN; SAHOO, 2015), as well as the cost aspects of financing for flexible operations, including the challenges of modeling energy production for hybrid systems (BISTLINE, 2017; ODAM; DE VRIES, 2020). An interesting and unprecedented survey among the 314 selected articles was carried out by López Prol, Steininger, Zilberman (2020). The authors described how the constant entry of new technologies for electricity supply tend to drive the marginal cost to zero, raising the level of competitiveness among sources, but also causing a cannibalization effect among them. In this sense, according to the authors, only those sources that invest in greater cost mitigation, storage and internationalization technologies will be perennials.

The fourth cluster is composed by the journals “Energy Policy” (29 articles) and “International Journal of Hydrogen Energy” (six articles). The main articles were concerned with analyzing public policies to encourage wind energy adopted in some countries, such as Germany, United States and Sweden (BOLINGER; WISER, 2009; MABEE; MANNION; CARPENTER, 2012; PEGELS; LÜTKENHORST, 2014; WANG, 2006). Another primary concern of the cluster was the production of hydrogen through wind energy associated with life cycle analysis, comparing the economic and environmental costs generated from conventional sources with renewable sources (LEE et al., 2009, 2010; LINNEMANN; STEINBERGER-WILCKENS, 2007).

The fifth and last cluster was represented by two articles from two conferences quite distant from each other in temporal terms. The first was the “2000 IEEE Power Engineering Society”, which took place in 2000, where Gutierrez-Vera (2000), with the article Renewables for sustainable village power supply, discussed the implementation of electricity from renewable sources and in villages far from large urban centers in Mexico, among the discussed sources, highlighting wind power. The second conference was “Powercon 2014”, which examined strategic issues faced by the global energy sector. During this event, Reitenbach (2014) argued that the level of competitiveness of natural gas compared with other sources, in developing countries, is lower than other sources, including renewable ones, including wind power. Figure 6 illustrates the most cited journals in relation to the topic of interest, emphasizing the links among them.

Figure 6 – Most cited journals



Source: Authors, 2020

3.3 Performance of authors and collaborative relationships

The topic of interest, that is, competitiveness in the wind power sector, proved to be very specific. In this sense, according to the research data, the author with the largest number of publications was Astariz, Z. and Iglesias, G., with ten published articles. It is important to highlight that, in these ten publications, the authors worked together, always having Asterz, Z. as the main author and Iglesias G. as one of the co-authors. The most cited article of this pair was "Co-located wind wave farm synergies (Operation & Maintenance): A case study, which was published in the journal Energy Conversion and Management, in 2015, with 49 citations. In this article, the authors discuss how the operational process and lack of predictive and preventive maintenance can undermine the competitiveness of wind energy generated in offshore parks (ASTARIZ et al., 2015).

The most cited authors were Barbir, F., Sherif, S. A. and Veziroglu, T. N., who share only three publications on the topic of interest, but only one article that encompasses all 271 citations of the authors in this field. The research entitled "Wind energy and the hydrogen economy review of the technology", published in 2005 in the journal Solar Energy. In this article, the authors introduce a review of the technologies previously available for the production, storage, distribution and use of hydrogen to generate energy and electricity. In parallel, they discuss the possibilities of symbiosis between the use of wind energy to generate hydrogen, as well as how it can increase the competitiveness of wind power,

especially in terms of the storage of the generated energy (SHERIF; BARBIR; VEZIROGLU, 2005). Table 2 summarizes the main authors, emphasizing the total number of publications, citations and average citations on wind power and competitiveness.

Table 2 – Main authors, citations and averege citation per year

Authors	Publications	Citations	Average
Astariz, Z.	10	176	17.6
Iglesias, G.	10	176	17.6
Zhao, Z. Y.	5	132	26.4
Abanades, J.	3	94	31.3
Barbir, F.	3	271	90.3
Mirzaei, M.	3	46	15.3
Möhrlen, C.	3	9	3.0
Pahlow, M.	3	9	3.0
Pezez-Collazo, C.	3	94	31.3
Poulsen, N. K.	3	46	15.3
Sherif, S.A.	3	271	90.3
Veziroglu, T. N.	3	271	90.3

Source: Authors, 2020

In addition to specificity, another striking feature of the scientific production on competitiveness and wind power is the collaborative relationship, which is characterized by being very restricted. Considering the minimum number of three publications per author, it can be noticed that they work in seven main clusters (Figure 7), responsible for 29 publications, which represents only approximately 9% of the total articles in the entire historical series and 694 citations. The data show that most authors work in isolation, not interacting with each other. The main cluster, formed by Astariz, Z., Iglesias, G., Abanades, J. and Perez-Collazo, C., led by the first two[6], has 10 publications and a total of 176 citations. The main topic of interest to the group is the competitive aspects related to the implementation of offshore hybrid parks, with the combination of wind and tidal power generation. In this approach, the authors carry out studies related to cost reduction when there is the optimal use of these two systems, as well as the economic and financial evaluation of the implementation of hybrid parks with this profile (ASTARIZ; IGLESIAS, 2016a, 2016b, 2017). In addition, the group is also concerned with regional

6 The cluster leadership is indicated by the size of the circle formed after the data is rotated in the Vosviewer. That is, the larger the circumference, the more relevant the analyzed variable. In the specific case, the main authorship in scientific collaboration relationships (CHEN; XIAO, 2016).

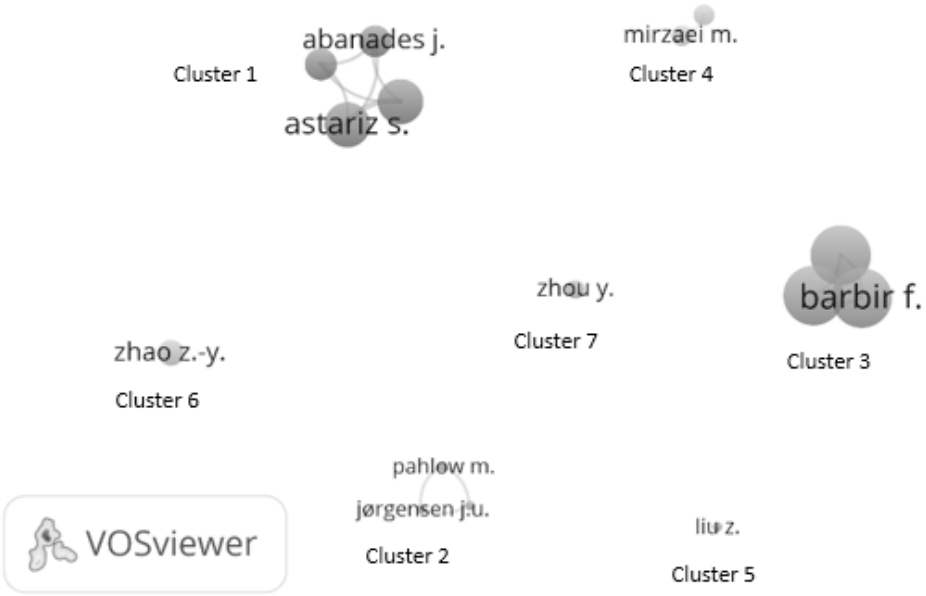
studies for the implementation of these parks, using location measures to define the best implantation sites (ASTARIZ; IGLESIAS, 2016b, 2016c).

Cluster two, made up by three authors (Jorgensen, J. U., Möhrlen, C. and Pahlow, M.), consists of two publications, with a total of nine citations. The main article, "Aplication of cost functions for large scale integration of wind power using a multi-scheme ensemble prediction technique", dated 2009, uses forecasting techniques to estimate the amount of winds from certain regions, with a view to integrating, in large scale, wind power to the electricity generation system. The optimization of the forecasts also intended to establish strategies to minimize the operational costs of wind energy, since it would balance the electric system and its use would be conditioned to production peaks, that is, to moments where there were lesser fluctuations in the occurrence of winds (ERNST et al., 2007; PAHLOW; MÖHRLEN; JØRGENSEN, 2009).

The third cluster presents a balance among the three authors belonging, Barbir, F., Sherif, S.A. and Veziroglu, T. N. The cluster is formed by two researches: a publication in the journal Solar Energy dated 2005, entitled "Wind energy and the hydrogen economy – Review of the technology" and a conference paper dated 2003 on the same theme, entitled "Wind energy and the hydrogen economy". Basically, the main research of this triad carried out a review of the main sources of energy for hydrogen production, which, according to the authors, will be the most used energy system in the near future. They argue that hydrogen should be primarily produced through clean energy sources and highlight the production of energy from the winds as an ideal technology for this process (SHERIF; BARBIR; VEZIROGLU, 2005).

Mirzaei M. and Poulsen N. K. make up cluster four. The authors worked together on three articles between the years 2014 and 2015. The developed research focuses on technical aspects related to the performance of wind turbines. The authors believe that the development of new technologies for equipment would provide an increase in competitiveness in terms of increasing the use of the wind potential of the regions and innovative solutions such as providing auxiliary services in the same way as is done in traditional energy plants, that is, at times when it is more economically advantageous to sell the reserve energy is more profitable than to produce at the limit of capacity. Accordingly, the authors suggest that wind turbines can be programmed, so that, at these moments, they can sell the differential capacity as reserve energy, optimizing the use of the parks, reducing operating costs and, consequently, increasing competitiveness (MIRZAEI et al., 2014).

Figure 7 – Cluster of scientific collaboration among



Source: Authors, 2020

The fifth, sixth and seventh clusters are led by just one author each. They are composed by: Liu, Z. (four publications and 10 citations), Zhao, Z. (five publications and 136 citations) and Zhou, Y. (three publications and 40 citations). It is interesting to highlight that these three clusters work with similar themes, but have no connection among them. The most important works, in terms of citation numbers, carried out a study on performance factors that affect the wind energy sector in China, including applying models of strategic competitiveness analysis, such as the Diamond Model and the Porter's five forces model (IRFAN et al., 2019b, 2019a; ZHAO; HU; ZUO, 2009).

3.4 Analysis of keywords and focal points

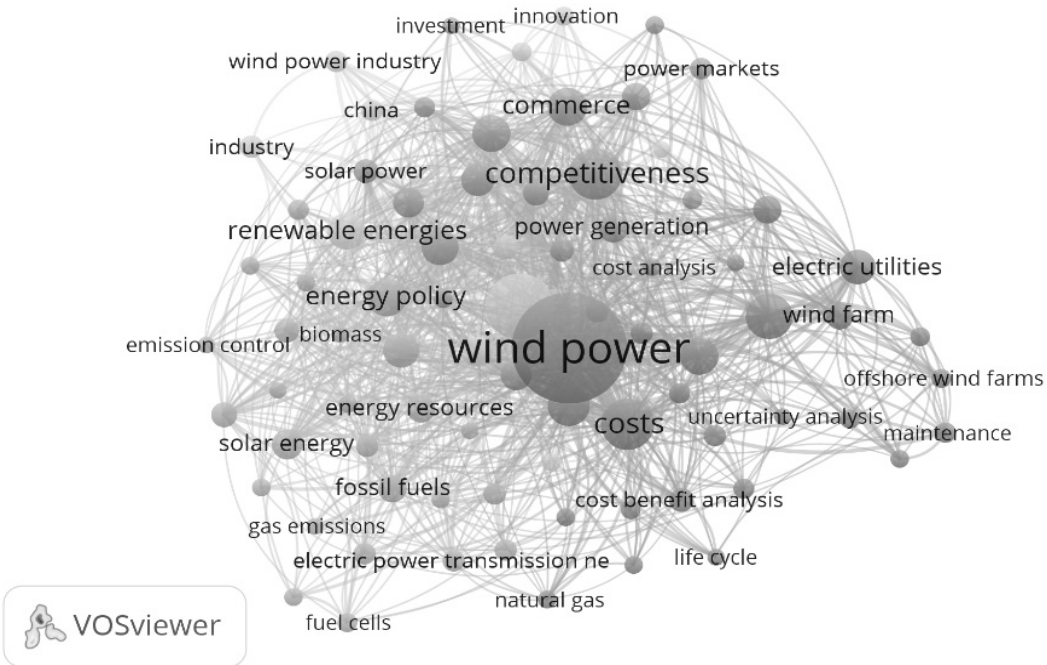
The 314 articles that constituted the analytical body of this research provided 1,576 keywords. On average, there were approximately five keywords for each publication. They represent the basic units of a given field of study, thereby providing an overview of the investigated field of knowledge, as well as future research trends (AZEVEDO; SANTOS; ANTÓN, 2019).

Using the co-occurrence analysis of keywords, modeling in the Vosviewer a minimum occurrence limit of 10 keywords, Figure 8 could be generated, which represents a co-occurrence network of keywords. Each word corresponds to a node in the network and its co-occurrence constitutes the borders among the nodes. The mapped keywords come from an analysis that included representative indicators of connection

among them, such as density, degree, centralization and inclusion. Density is defined as the ratio between the number of actually formed relationships and the total number of possible relationships; centralization refers to the degree to which relationships are concentrated in some individuals; while inclusion means the number of nodes connected to each other on the network. The centrality analysis was held to find important nodes in the network and to find out which keyword is located in the center of the network, thereby having the ability to influence a greater number of keywords (KIM; JANG; LEE, 2018).

The application of this approach identified four main groups of keywords. The smaller subnet, yellow in color, is a cluster that is primarily concerned with competitive issues at the macro level, such as the renewable energy market, analysis of the wind industry in the countries, especially China, innovation and technological performance. It is a cluster that is strongly connected with the blue cluster, given the overlapping links between them. The blue group focuses on research in the area of electricity generation from clean sources. The green cluster mainly discusses issues related to environmental preservation, sustainable development and mitigation of climate changes through the control of GHG emissions in the atmosphere, replacing fossil sources with cleaner sources such as hydrogen, produced through the use of clean and renewable energies such as wind power. The red cluster, the most significant in terms of number of keywords (25 in total), is primarily interested in competitive aspects related to operational costs, economic and financial feasibility analyzes, market competition and research on hybrid structures generation, such as synergies between wind and solar and wind energy and waves.

Figure 8 – Keyword co-occurrence network



Source: Authors, 2020

The most important keywords identified in the pertinent literature were wind power, costs, competition, competitiveness, wind turbines, economic analyzes, renewable energies, profitability, electricity generation and solar energy. Accordingly, the analysis of keywords reveals the main terms and concerns related to wind power and competitiveness, thereby providing subsidies to identify and relate these terms with focal points associated with the main aspects of competitiveness theory. This analysis is presented in the following section.

3.4.1 Analysis of focal points

From the bibliometric analysis, especially after the evaluation of the keywords, a qualitative research was carried out in all 314 articles of the studied time series (from 1977 to February 2020). Of the 314 articles selected in this research, 10 could not be allocated to any focal point. This happened, mainly, with the Business Articles (4 publications) and six Conference Reviews, which did not fit in any of the nine highlighted aspects. Accordingly, they were not included in the analysis of focal points. In order to demonstrate it, the five most cited articles were selected for each focal point, as shown in Chart 1, which, in addition to the citations, shows the title of the article, the authors and the source of the publication. The qualitative research served to classify the publications in nine items, already presented in the Introduction and deepened in this section, related to aspects of competitiveness, which are:

Economic Analysis: Publications with a bias in the analysis of the feasibility of wind parks and concerns with initial investments in projects. Regional studies for the implementation of wind parks were also considered;

Competition: In this regard, articles that discussed competitive relationships among different sources, under different aspects, were selected, such as, for example, prices;

Technology: This item considered articles that explored new technologies for wind power generation, encompassing new equipment, processes, management information systems, artificial intelligence, hydrogen production and energy storage processes;

Operational Costs: In this regard, publications related to processes to reduce costs and optimize equipment used for power generation were classified;

Regulation/Government: Analysis of regulatory processes and energy management and transition of countries and regions were selected for this topic. It also covered public policies to encourage renewable energies and tax breaks for the sector;

Environmental Impacts: The articles classified in this section analyzed, as a priority, the impacts of the use of renewable energy sources, especially wind power, considering aspects such as GHG mitigation and savings on other resources that could be used for electricity generation such as, for example, water;

Competitiveness: Some publications analyzed wind power by considering several factors related to the theory of Competitive Analysis, using classic models of competitiveness such as, for example, Porter's Diamond. Accordingly, articles with these characteristics were grouped in this section;

Market: It covered publications that prioritized variables related to market behavior, such as: analysis of energy demand, production capacity and economic welfare relationships;

Hybrid Generation: It classified articles that analyzed synergy relationships between wind and solar energy and wind and wave energy.

Chart 1 - Most cited Articles, Journals and Authors related to the selected Focal Points

FOCAL POINT	Paper	Author (s)	Source	Year	TC
Competition	Wind as an alternative source of energy in Jordan	Habali, S.M., Amr, M., Saleh, I., Ta'Ani, R.	Energy Conversion and Management	2001	28
	Successful renewable energy development in a competitive electricity market: A Texas case study	Zarnikau, J.	Energy Policy	2011	45
	The competitiveness of wind power compared to existing methods of electricity generation in Iran	Moslem Mousavi, S., Bagheri Ghanbarabadi, M., Bagheri Moghadam, N.	Energy Policy	2012	14
	Investigating the energy autonomy of very small non-interconnected islands. A case study: Agathonisi, Greece	Kaldellis, J.K., Gkikaki, A., Kaldelli, E., Kapsali, M.	Energy for Sustainable Development	2012	22
	Evaluation and comparison of the levelized cost of tidal, wave, and offshore wind energy	Astariz, S., Vazquez, A., Iglesias, G.	Journal of Renewable and Sustainable Energy	2015	43
Competitiveness	Performance of wind power industry development in China: A Diamond Model study	Zhao, Z.Y., Hu, J., Zuo, J.	Renewable Energy	2009	65
	Wind power and market power in competitive markets	Twomey, P., Neuhoff, K.	Energy Policy	2010	57
	An integrated performance evaluation model for the photovoltaic industry	Lee, A.H.I., Lin, C.Y., Kang, H.-Y., Lee, W.H.	Energies	2012	27
	Factors and competitiveness analysis in rare earth mining, new methodology: case study from Brazil	Silva, G.A., Petter, C.O., Albuquerque, N.R.	Heliyon	2018	5
	Competitiveness and competitive advantages of enterprises in the energy sector	Kapitonov, I.A., Zhukovskaya, I.V., Khusaenov, R.R., Monakhov, V.A.	International Journal of Energy Economics and Policy	2018	12

Economic Analysis	Economic analysis of wind-powered desalination	García-Rodríguez, L., Romero-Ternero, V., Gómez-Camacho, C.	Desalination	2001	51
	Establishing the role that wind generation may have in future generation portfolios	Doherty, R., Outhred, H., O'Malley, M.	IEEE Transactions on Power Systems	2006	102
	Syngas production via high-temperature steam/CO2 co-electrolysis: An economic assessment	Fu, Q., Mabilat, C., Zahid, M., Brisse, A., Gautier, L.	Energy and Environmental Science	2010	179
	Comparison of the financial attractiveness among prospective offshore wind parks in selected European countries	Prässler, T., Schaechtele, J.	Energy Policy	2012	45
	Energy system investment model incorporating heat pumps with thermal storage in buildings and buffer tanks	Hedegaard, K., Balyk, O.	Energy	2013	49
Environmental Impacts	Energy policy and climate change	Jean-Baptiste, P., Ducroux, R.	Energy Policy	2003	56
	Renewable energy and the need for local energy markets	Hvelplund, F.	Energy	2006	77
	Life cycle environmental and economic analyses of a hydrogen station with wind energy	Lee, J.-Y., An, S., Cha, K., Hur, T.	International Journal of Hydrogen Energy	2010	45
	Alternatives No More: Wind and Solar Power Are Mainstays of a Clean, Reliable, Affordable Grid	Milligan, M., Frew, B., Kirby, B., (...), O'Malley, M., Tsuchida, B.	IEEE Power and Energy Magazine	2015	29
	The European low-carbon mix for 2030: The role of renewable energy sources in an environmentally and socially efficient approach	Dellano-Paz, F., Calvo-Silvosa, A., Iglesias Antelo, S., Soares, I.	Renewable and Sustainable Energy Reviews	2015	45
	Plant-level dynamic optimization of Cryogenic Carbon Capture with conventional and renewable power sources	Safdarnejad, S.M., Hedengren, J.D., Baxter, L.L.	Applied Energy	2015	47
Hybrid Generation	Regulating the output characteristics of tidal current power stations to facilitate better base load matching over the lunar cycle	Clarke, J.A., Connor, G., Grant, A.D., Johnstone, C.M.	Renewable Energy	2006	46
	The optimal share of variable renewables: How the variability of wind and solar power affects their welfare-optimal deployment	Hirth, L.	Energy Journal	2015	62
	Co-located wind-wave farm synergies (Operation & Maintenance): A case study	Astariz, S., Perez-Collazo, C., Abanades, J., Iglesias, G.	Energy Conversion and Management	2015	49
	China's supply of critical raw materials: Risks for Europe's solar and wind industries?	Rabe, W., Kostka, G., Smith Stegen, K.	Energy Policy	2017	20
	Optimization and assessment of floating and floating-tracking PV systems integrated in on- and off-grid hybrid energy systems	Campana, P.E., Wästhage, L., Nookuea, W., Tan, Y., Yan, J.	Solar Energy	2019	16
Market	Trading wind generation from short-term probabilistic forecasts of wind power	Pinson, P., Chevallier, C., Kariniotakis, G.N.	IEEE Transactions on Power Systems	2007	376
	Technical, economical and regulatory aspects of virtual power plants	Werner, T.G., Remberg, R.	3rd International Conference on Deregulation and Restructuring and Power Technologies	2008	19
	Wind power price trends in the United States: Struggling to remain competitive in the face of strong growth	Bolinger, M., Wiser, R.	Energy Policy	2009	61
	From laggard to leader: Explaining offshore wind developments in the UK	Kern, F., Smith, A., Shaw, C., Raven, R., Verhees, B.	Energy Policy	2014	48
	China's wind industry: Leading in deployment, lagging in innovation	Lam, L.T., Branstetter, L., Azevedo, I.M.L.	Energy Policy	2017	23

Operational Costs	Realistic costs of wind-hydrogen vehicle fuel production	Linnemann, J., Steinberger-Wilckens, R.	International Journal of Hydrogen Energy	2007	43
	Structural health monitoring for a wind turbine system: A review of damage detection methods	Ciang, C.C., Lee, J.-R., Bang, H.-J.	Measurement Science and Technology	2008	541
	Assessing the costs of photovoltaic and wind power in six developing countries	Schmidt, T.S., Born, R., Schneider, M.	Nature Climate Change	2012	41
	Cost reductions for offshore wind power: Exploring the balance between scaling, learning and R&D	Van der Zwaan, B., Rivera-Tinoco, R., Lensink, S., van den Oosterkamp, P.	Renewable Energy	2012	34
	Incorporating life cycle external cost in optimization of the electricity generation mix	Rentizelas, A., Georgakellos, D.	Energy Policy	2014	30
Regulation / Government	Renewable electricity in Sweden: An analysis of policy and regulations	Wang, Y.	Energy Policy	2006	54
	Comparing the feed-in tariff incentives for renewable electricity in Ontario and Germany	Mabee, W.E., Mannion, J., Carpenter, T.	Energy Policy	2012	71
	Global wind power development: Economics and policies	Timilsina, G.R., Cornelis van Kooten, G., Narbel, P.A.	Energy Policy	2013	57
	A critical review of factors affecting the wind power generation industry in China	Zhao, Z.-Y., Yan, H., Zuo, J., Tian, Y.-X., Zillante, G.	Renewable and Sustainable Energy Reviews	2013	66
	Is Germany's energy transition a case of successful green industrial policy? Contrasting wind and solar PV	Pegels, A., Lütkenhorst, W.	Energy Policy	2014	63
Technology	Wind energy and the hydrogen economy-review of the technology	Sherif, S.A., Barbir, F., Veziroglu, T.N.	Solar Energy	2005	277
	Valuation framework for large scale electricity storage in a case with wind curtailment	Loisel, R., Mercier, A., Gatzen, C., Elms, N., Petric, H.	Energy Policy	2010	50
	Status and problems of wind turbine structural health monitoring techniques in China	Liu, W., Tang, B., Jiang, Y.	Renewable Energy	2010	93
	Wind power integration using individual heat pumps - Analysis of different heat storage options	Hedegaard, K., Mathiesen, B.V., Lund, H., Heiselberg, P.	Energy	2012	147
	Automotive hydrogen fuelling stations: An international review	Alazemi, J., Andrews, J.	Renewable and Sustainable Energy Reviews	2015	87

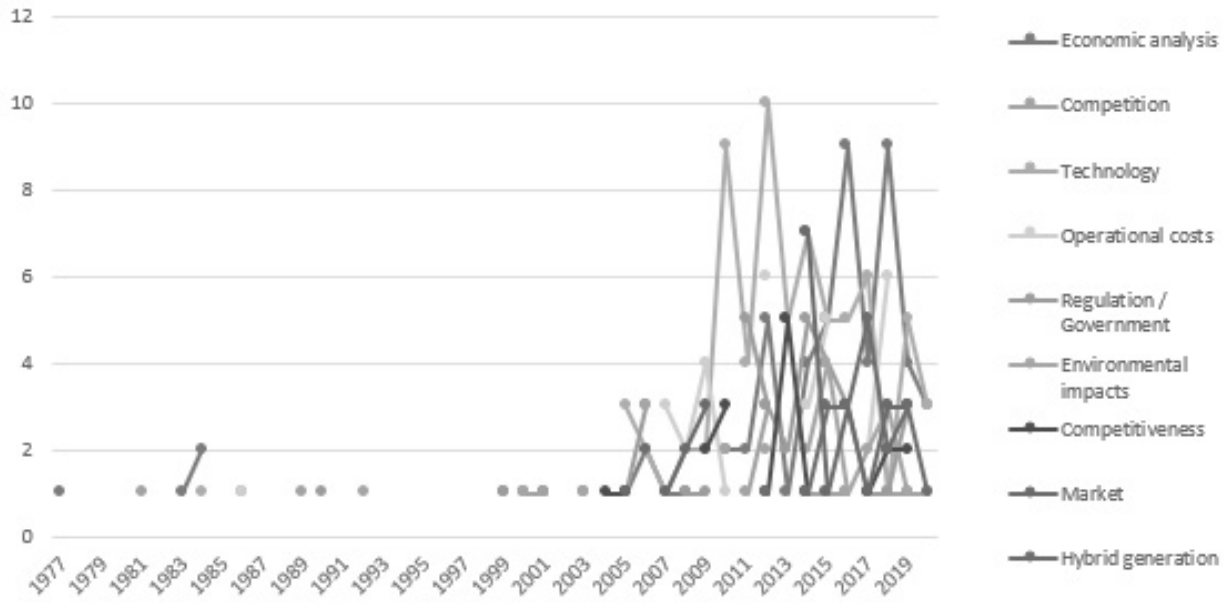
Source: Scopus, 2020

The evolution in the amount of publications took place from the year 2006. Before that, as already mentioned at the beginning of the results and discussion section, the scientific production on the topic of interest was small, totaling an approximate average of one publication per year. The majority of the articles published were on the issue of Technology. Analyzing the entire period, 74 surveys were released, representing 24% of the total articles. They dealt with different topics by associating competitiveness to technology, from development of patents (ALAM et al., 2020; LAM; BRANSTETTER; AZEVEDO, 2017; ODAM; DE VRIES, 2020) to the development of new processes and products, especially new turbines (HÜBLER et al., 2020; WANG et al., 2018a; ZHANG et al., 2019). The average number of publications, from 2006, was four articles per year. Another prominent topic in the publications analyzed competitive

aspects related to the analysis of economic and financial feasibility. Considering the entire historical series, it corresponded to 59 articles, that is, 19% of the entire production. Highlight for the year 2016, where, of the 25 publications on wind power and competitiveness, nine were related to economic analysis (32%).

The competitive relationships related to wind power still produced 35 works on operational costs (11%), highlighting especially maintenance and conservation processes of equipment, especially wind turbines, 35 works also on Regulation and Government, showing that the evaluation of public policies is a recurring theme of research concern. Associated with the analysis of public policies, there are market and consumption relationships, which presented 25 papers in the period of analysis, that is, 7.5%. The concern with environmental impacts was the theme of 23 studies (8%), with emphasis on research aimed at CO_2 mitigation processes, from the replacement of fossil fuels with wind energy. The annual evolution of the themes, as well as the amount of articles, can be seen by means of Figure 9.

Figure 9 – Classification and evolution of publications by topics related to Competitiveness



Source: Authors, 2020

4 FINAL CONSIDERATIONS

The bibliometric analysis showed that the topics Wind Power and Competitiveness analyzed together are relevant, particularly from 2006 onwards, being concerned primarily with externalities related to new energy and electricity production technologies and specific points associated with

the economic and financial evaluation of wind-related projects, as they require a substantial range of investments to come into operation.

The study also made it possible to demonstrate the development of research from a quantitative perspective, showing the performance of publications and the main countries interested in the theme. The highlight was China, which, over the past five years, has surpassed the United States and has consolidated itself as one of the exponents of academic production on the topic of interest, with a total of 44 publications, or 14% of all surveys, compared to 41 documents from the United States (13%), despite having less collaborative relationships with other countries like the latter. In this section, it is important to highlight the role of the European continent. Of the 10 countries most concerned about the relationship between competition and wind power, six are European nations.

The research also highlighted the performance of the main means of disseminating academic works, having been formed, almost exclusively, by scientific journals. The most used and most cited Journal was the Energy Policy, showing 29 publications, with a total of 928 citations. The research lines of the main journals focused on the analysis of public policies on the wind sector, especially tax exemption policies, economic evaluation of investment projects and adoption of less costly materials and processes, insertion of new technologies, especially processes and systems of energy storage and generation from clean sources, environmental impacts and generation of energy and electricity by hybrid means, mainly wind-solar.

The relevance of the main researchers was also analyzed, highlighting their publications on the topic of interest and the number of citations. It was found that, while there are collaborative groups that work with very specific competitive aspects and that researchers work in isolation, there are also some clusters that defend similar positions and, apparently, do not exchange information about their surveys. By disclosing this last fact, it could cause, for example, research enrichment, through the socialization of knowledge, technology transfer agreements and exchange among researchers from different countries.

Lastly, a co-occurrence analysis of keywords was carried out, which revealed the main current concerns of researchers when dealing with competitiveness in the field of wind power generation and enables the articles to be classified in line with aspects directly related to competitiveness.

It is hoped that this study will assist researchers and facilitate their future research directions, whether in the specific theme discussed here, wind power and competitiveness, or in adjacent themes, with the purpose of providing that they may be benefited with new ideas and relevant information for

decision-making processes, academic or marketing, by identifying the most relevant journals, authors and research groups.

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