

Research, development and innovation management in the energy sector

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Abstract. This study aimed to observe trends in the literature on research, development, and innovation management in the energy sector, using performance assessment systems. The paper presented a bibliometric analysis of 40 studies on the subject. These materials come from ScienceDirect, Scopus and the Institute of Electrical and Electronics Engineers (IEEE) databases from 2006 to 2016. The results showed an increasing trend in the number of publications on the theme, showing the scientific community's interest in the subject. In addition, it was verified that the predominant language used to write the publications was English, the country that most published articles in the area was Brazil and most of the articles were produced through collaboration between researchers. It was found that the journal with the greatest number of publications on the subject was the *Procedia – Social and Behavioral Sciences*, while the *Expert Systems with Applications* journal presented the article with the greatest number of citations. This analysis allowed us to identify important points of the research and its future directions, in addition to enabling a better understanding of the world trend of the subject approached.

Keywords: bibliometric analysis; research, development and innovation; management; performance assessment; triple helix; energy

1. Introduction

In society, knowledge has become an important aspect of production, besides capital and labor (Guerrero and Urbano 2012 O'shea *et al.* 2007). This means that the economic and social development of regions, states and countries is strongly tied to their ability to generate, disseminate and apply knowledge. In this way, universities assume a new position in relation to the productive sector, the government and society as institutions of creation, dissemination and

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with a great potential of applying knowledge (Etzkowitz and Klofsten 2005).

In view of this approach, there is the triple-helix model, which is based on the understanding that knowledge is developed dynamically (Etzkowitz and Leydesdorff 2000). They also argue that the generation of wealth can take place through the knowledge produced by institutional arrangements between knowledge organizers, such as universities, industries and government agencies (D'Avila *et al.* 2015). Besides that, for competitiveness in a globalized environment, research, development, and innovation (RD&I) of new products, processes and services become a key strategy to respond to a reality subject to constant change (Salguero *et al.* 2015).

Several studies have demonstrated that RD&I management practices have been adopted by a large part of the electric sector (Hecksher *et al.* 2012). Management systems have the function of maximizing the technical and financial sustainability of organizations (Lillo *et al.* 2015). This becomes important since the power sector faces the uncertainty of demand and needs to maintain an acceptable level of service coupled with a short waiting time in order to compete successfully in the market (Jiang and Seidmann 2014). In addition, energy services are crucial because they raise people's living standards, improve well-being and help eradicate poverty (Vera and Langlois 2007). In this context, performance assessment systems become significant to assist in the management of enterprises, given the importance of performance measurement concepts and techniques to support continuous improvement and efficiency management (Braz *et al.* 2011).

In this way, investment in research, development and innovation is one of the most important factors to increase technological progress and economic growth in developed and developing countries (Akcali and Sismanoglu 2015). The understanding of scientific production can promote new advances in science (Yi and Choi 2012). Bibliometrics stands out as one of the main technologies that make it possible to establish prognoses and trends in the production and dissemination of science and knowledge (Lazzarotti *et al.* 2011). The use of bibliometrics is very important to understand scientific knowledge, especially since it is the main raw material for the construction of this knowledge as an accelerator of innovation (Tanaka and Sakata 2016).

Within this context, the paper aims to evaluate the development of studies on RD&I management in the energy sector, based on performance assessment systems, through bibliometric techniques from 2006 to 2016. The results not only allow a better understanding of the global trend of RD&I management in energy, but may also influence future studies and publications on the topic (Araújo and Costa 2016).

2. Methods

This section describes all the steps of the method used in the analysis in order to base the study. This research is classified as descriptive, since it sought to investigate the evolution of publications through a bibliometric analysis (Facin *et al.* 2016) on research, development and innovation management in the energy sector, using performance evaluation systems.

The bibliometric study is a sophisticated and versatile technique that builds a large database of scientific articles (Stelzer *et al.* 2015). It is also a form of analysis of scientific publications that evaluates the development in the knowledge of a specific area (Albort-Morant and Ribeiro-Soriano 2016, Tsay 2008). It involves a series of techniques that quantify the process of written communication, and its results include intellectual structure, research topics, editorial organizations, authors, countries (Ma *et al.* 2014, Vogel and Güttel 2013). The purpose of bibliometric analysis is to increase the performance of researchers or to evaluate their trends by

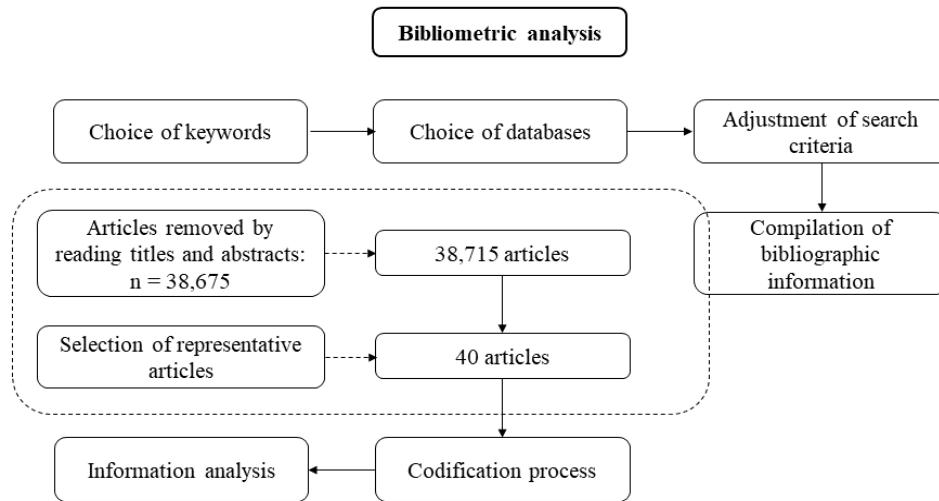


Fig. 1 Research methodology

identifying characteristics and patterns of publications (Araújo and Costa 2016).

Thus, for the study design, a research was adapted and eight steps were performed with the purpose of reaching the results (Albort-Morant and Ribeiro-Soriano 2016), as shown in Fig. 1. The steps consist of choosing the keywords of the search and the databases, adjusting the search criteria, compiling the bibliographic information obtained, reading the abstracts of the articles, selecting those that really fit the research theme, coding the selected material and finally analyzing the resulting information.

In view of the above, the following subsections present the development of each step mentioned in Fig. 1.

2.1 Choice of keywords

The first step in bibliometric analysis was to choose the keywords to be investigated in the search engines. Its purpose was to find materials that encompassed research, development and innovation management in the energy sector, with the aid of performance assessment systems. Thus, five keywords were defined for the search: “research, development and innovation”, given its importance to coordinate and direct the development of science, technology and innovation activities in industries oriented towards the realization of processes, products or improvements; “management model”, since it has as key role in exploring inventions, whether external, through new products and services, or internal, through improved processes or organizational forms; “performance assessment”, given its relevance to strategic management; “triple helix”, since the effective involvement of government, universities and companies is necessary for a successful innovation system to occur; and “energy”, representing the sector to be studied.

2.2 Choice of databases

The second stage of the research sought to identify the existing databases and select the ones that best fit the requirements of the study. Therefore, the study used the ScienceDirect, Scopus and

the Institute of Electrical and Electronics Engineer (IEEE) databases, since they are among the largest databases of quality scientific publications in the area.

Table 1 Systematic review of search conditions process

Keywords	“research, development and innovation”, “management model”, “performance assessment”, “triple helix”, “energy”
	((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) OR “management model” OR “performance assessment” OR “triple helix” OR “energy”)
	((((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “management model”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “performance assessment”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “triple helix”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “energy”) OR (“management model” AND “performance assessment”) OR (“management model” AND “triple helix”) OR (“management model” AND “energy”) OR (“performance assessment” AND “triple helix”) OR (“performance assessment” AND “energy”) OR (“triple helix” AND “energy”))
Search strings	((((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “management model” AND “performance assessment”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “management model” AND “triple helix”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “management model” AND “energy”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “performance assessment” AND “triple helix”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “performance assessment” AND “energy”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “triple helix” AND “energy”) OR (“management model” AND “performance assessment” AND “triple helix”) OR (“management model” AND “performance assessment” AND “energy”) OR (“management model” AND “triple helix” AND “energy”) OR (“performance assessment” AND “triple helix” AND “energy”))
	((((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “management model” AND “performance assessment” AND “triple helix”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “management model” AND “performance assessment” AND “energy”) OR ((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “management model” AND “triple helix” AND “energy”) OR (“management model” AND “performance assessment” AND “triple helix” AND “energy”))
	((“research, development and innovation” OR “research and development” OR “R&D” OR “RD&I”) AND “management model” AND “performance assessment” AND “triple helix” AND “energy”)
Databases	ScienceDirect, Scopus, IEEE

Table 1 Continued

Type of document	Article
Period of time	2006-2016

2.3 Adjustment of search criteria

The search for articles on the management of research, development, and innovation in the energy sector, based on performance evaluation systems, was conducted with the conditions presented in Table 1, in which the keywords, as well as combinations of them, were searched on the previously selected databases. The period between 2006 and 2016 was the delimiter, considering the criterion of the most relevant articles and the correlation of terms in all fields. With regards to the type of document, a decision was made to select only the articles published in a journal, since they are the main source of academic research (Pérez-Pérez *et al.* 2015).

2.4 Compilation of bibliographic information

From the search criteria adjusted in the previous step, the individual search of the keywords was performed. In the three databases cited previously, 4,895,604 articles were found, of which 3,064,364 were identified in Scopus, 1,565,991 in ScienceDirect and 265,249 in the IEEE database. However, considering the breadth of the searched terms, a new search was made, in which the terms were correlated in order to verify the publications that really approached the subject under study. In this search, 38,715 results were found, which will be analyzed in the next step according to the reading and identification of the association of the keywords in titles and abstracts.

2.5 Reading of abstracts

In this step, the 38,715 results compiled in the previous step were analyzed. This analysis proceeded by reading and verifying the existence of a link between the keywords searched in the titles and abstracts of the articles. This is due to the fact that title, abstract and keywords play a key role in research communication. That is, through the analysis of these criteria, it was possible to identify the themes of the studies, as well as their objectives, methodology and results, and to define if they are framed in the topic being researched.

2.6 Selection of representative articles

In this stage of the research, the abstracts, titles and keywords of the 38,715 articles were systematically analyzed, and exclusion criteria for articles were used to exclude studies that were not associated with the research. These criteria are, firstly, the analysis of articles that not contain the words searched in the title, abstract, or keywords and according to the articles that did not aim to study RD&I management and performance assessment in the energy sector. The application of these criteria resulted in 40 articles. The 40 articles were completely read in order to identify whether the studies were relevant to the purpose of the research.

2.7 Codification process

The encoding process consists in encoding research building on several variables such as:

authors, year of publication, countries with highest productivity, journals publishing articles, language, international cooperation, author's keywords and standards of journals and publications identified (Albort-Morant and Ribeiro-Soriano 2016, Araújo and Costa 2016, Zyoud and Fuchs-Hanusch 2017). To perform the analysis, the study coded articles extracted from the selected databases on December 2016.

Thus, each of the 40 articles in the sample was individually and manually recorded in Excel. The metadata of this sample, such as title, authors, year of publication, number of citations, keywords, country, language of publication, journal, impact factor and other data were stored. Therefore, all the analysis carried out in this study was related to the 40 articles selected, except for one criterion analyzed, in which there was a reduction of the verified articles due to lack of information, as in the case of the author's keywords (38 articles were analyzed and two articles without information).

To analyze the countries of publication, the types of collaboration were identified through the authors' addresses. Thus, the publication of a single country was given to articles whose authors were addressed in the same country, while the publication of international collaboration was attributed to articles whose authors resided in different countries.

The standards of the journals were identified through scientific indicators, such as impact factor, number of citations and number of articles produced. This data and information were extracted from the Journal Citation Reports (JCR®) statistical base of Thomson Reuters, the publisher. The impact factor of the journal is defined as the number of citations of all articles published in the last two years divided by the total number of articles published in those years. It is used to assess the relative importance of a journal, especially when compared to others in the same field (Chen *et al.* 2017, Ho 2007). The number of citations corresponds to an indirect indicator to determine the quality of an article and its particular utility (Durmusoglu 2016).

As a result of the encoding step, the research generated a table that presents the data of the variables raised for later analysis.

2.8 Information analysis

This step of the study aimed to analyze the data of the variables raised in the previous phases. This analysis aimed to organize and summarize the information in a way that would enable the provision of answers to the proposed research topic. In addition to that, it sought to identify original and relevant approaches that approximated the proposed research, as well as the quality standards of those publications.

3. Results and discussion

This study aimed to research and analyze the bibliometric variables associated with the management of research, development, and innovation in the energy sector, with the aid of performance assessment systems. The approach followed in this analysis used the ScienceDirect, Scopus and IEEE databases to collect systematic data. Using bibliometric techniques, it was possible to make a survey of the research trends of the subject under study.

The variables were evaluated in terms of the amounts of the published documents, while the quality of the research was evaluated using the impact factor and number of citations. In order to present a script related to the scientific activities carried out in the subject studied, the dimensions

and their results were considered and analyzed in detail in the following subsections.

3.1 Language of publication

Analyzing the distribution of the studies according to the language of publication, as shown in Fig. 2, it is possible to notice the absolute predominance of articles in English, represented by 34 articles, which correspond to 85% of the verified publications. Articles written in Portuguese represent 5% of the total, as well as publications in Spanish. On the other hand, publications in German and Latvian correspond to 2% of the total number of articles published. The prevalence of the English language derives from its advent as a global language, increasing the possibilities in several international sectors, mainly in the scientific field (Montgomery 2004, Zyoud and Fuchs-Hanusch 2017).

3.2 Output of publication

Fig. 3 shows the evolution of publications over the period established with the topic addressed in this research. This analysis sought to identify trends of growth or decrease in the development of research on the subject, classifying the articles of the sample according to the year

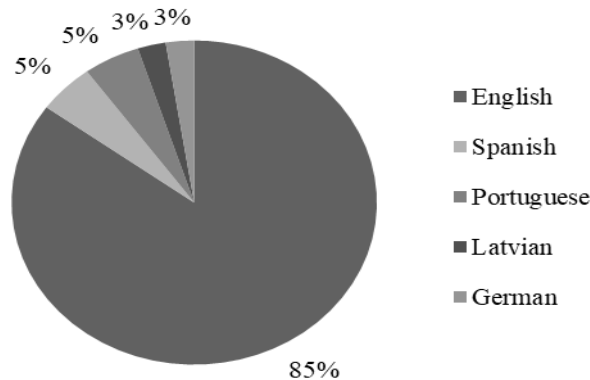


Fig. 2 Language of publication

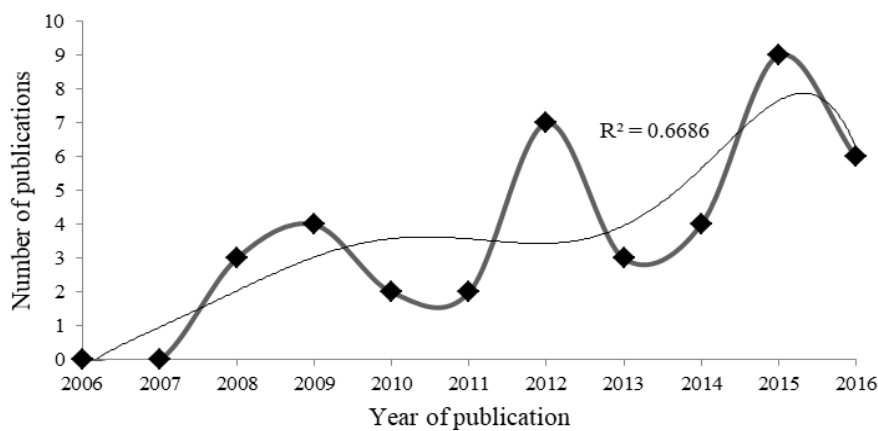


Fig. 3 Output of publication

of publication. It is possible to observe that in the initial years of the research, 2006 and 2007, there were no materials found with the subject in question. Meanwhile, the following years presented an oscillatory character, with an increase in the number of publications in the area. The evolution of the number of publications over the years was expressed through a polynomial model of degree 6 to verify the trend of growth in the period from 2006 to 2016, since it was the model that best fit the data, with coefficient of determination of 0.6686. This means that 66.86% of the dependent variable can be explained by the regressors present in the model.

The growing trend in the number of publications on the topic under study can be explained by the fact that research, development and innovation management in the energy sector plays an important role in the growth and development of countries (Inglesi-Lotz 2017). In this way, nations have increasingly developed research that integrates knowledge about market demand with knowledge about emerging technologies and technical feasibility in order to explore inventions through new products and services or through improved processes or organizational forms (Rohrbeck and Schwarz 2013, Vicente-Oliva, Martínez-Sánchez and Berges-Muro 2015). In addition, in the world scenario there is a growing trend of research and search for new sources of energy that meet the accelerated increase in the consumption of electric energy and minimize the impact caused by the energy crisis, leading to the development and progress of the countries (Rosa, Siluk and Michels 2016, Urooj and Ahmad 2017).

3.3 Publishing countries

With regards to the distribution of publications by country, the 40 articles selected were analyzed, since they presented information on author's addresses in the databases searched. Among the 40 articles published in the period from 2006 to 2016, six were published from international collaborations and 34 were independent publications.

Fig. 4 shows the global distribution of publications on RD&I management in the energy sector from 2006 to 2016, encompassing 15 countries in total. Brazil (9 articles) published the majority of articles among the 15 countries, followed by Spain (6 articles), Portugal (4 articles), Romania (4 articles), United States (2 articles) and Lithuania (2 articles). The other countries published only one article on the theme during the period studied.

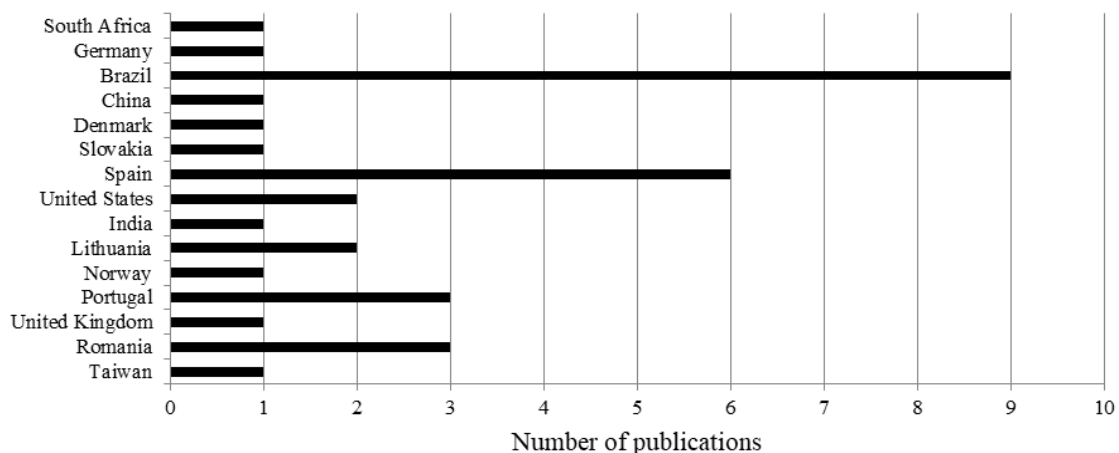


Fig. 4 Distribution of publications by country of origin

Brazil has a larger number of publications in the area during the period studied, since it has great energetic potential, counting on several rivers that favor the predominance of hydroelectric sources of generation (Aquila *et al.* 2017). In addition, the country has an extensive area with high levels of solar irradiation, allowing the implantation of systems of energy generation by photovoltaic cells (Pereira *et al.* 2012). Another factor that contributes to the development of studies on the subject in the country is related to the compulsion imposed by Brazilian regulation, which provides for a minimum and compulsory investment of 1% of net operating revenues of companies in research and development and energy efficiency programs (Brasil 2000). Thus, Brazil has taken several initiatives to promote the development of the energy sector, such as increasing investment in research, development and innovation in the area, seeking sustainable models that present lower cost and greater efficiency (Aquila *et al.* 2017).

3.4 International cooperation

As scientific knowledge develops rapidly, international cooperation studies play an important role in improving the level of scientific research and innovation capacity, given the limitations of the national research resources of each country around the world (Li *et al.* 2015). International cooperation is the best way to achieve common goals in the globalized world, opening up opportunities for developing countries (Silva 2007).

Out of the 40 materials analyzed, six were produced by international collaborations. Out of these, five were made by two countries, with Spain, United States and Sweden being the countries that most wrote articles with other countries, with each participating in two articles. In cooperation between three countries, there is only one article, produced in collaboration with Japan, China, and Austria.

International academic cooperation is extremely significant as it enables communication between countries to enhance research skills, improve understanding of studies, assist in the development of emerging countries, and broaden the search for innovative solutions (Chen *et al.* 2017). In addition, developing countries with backward technologies can gain advanced experiences in developing countries through international collaboration (Gao *et al.* 2016).

3.5 Authors

Through Fig. 5, it is possible to notice that most of the articles were written by three authors (13, 32.5%), followed by two authors (10, 25%), four authors (7, 17.5%), one, five and six authors (3, 7.5%) and finally by seven authors (1, 2.5%).

As can be observed, 92.5% of the articles were written by more than two authors, indicating that the vast majority of articles were made through collaboration between researchers.

The 40 articles analyzed were elaborated by 130 different authors, but they addressed topics within the same theme: management of research, development and innovation in the energy sector, with the aid of performance assessment systems. This is because the area is promising globally since RD&I management in the energy sector is of the utmost importance for the development of advanced technologies and assurance of sufficient energy availability to meet growing global demand (Araújo and Costa 2016). In addition, more and more researchers have been conducting studies on the energy sector with a view to raising the quality of life of the population, improving energy efficiency, establishing energy conservation plans and developing new technologies to renewable energy systems (Olatomiwa *et al.* 2016, Riesz and Elliston 2016, Tian *et al.* 2016).

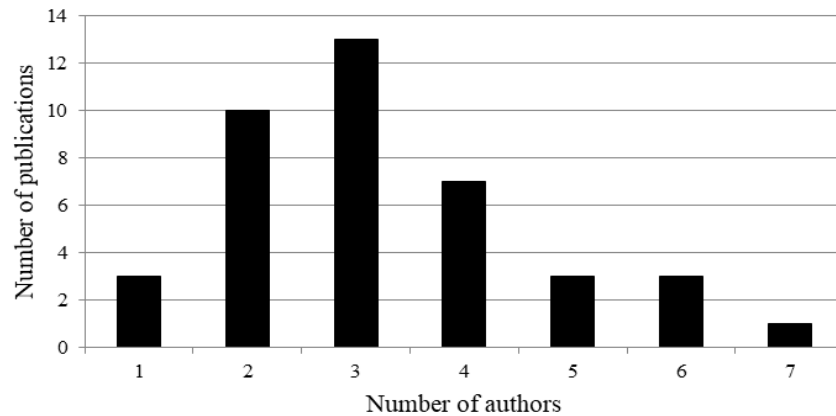


Fig. 5 Distribution of publications by number of authors

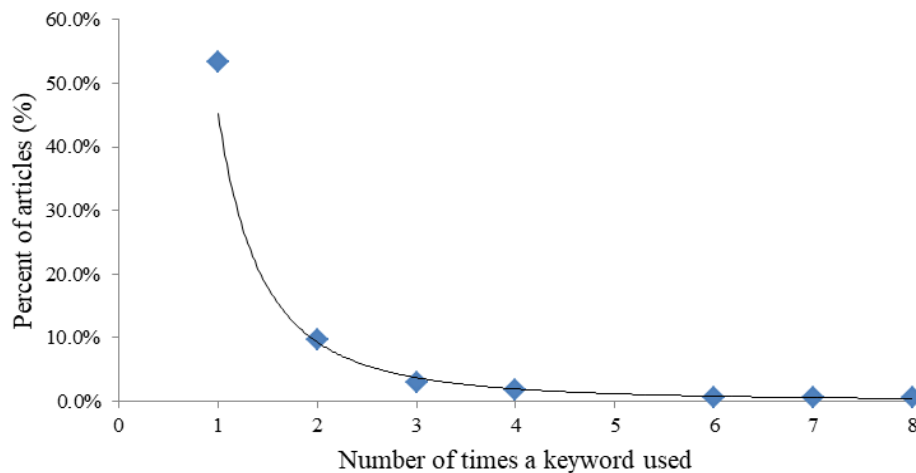


Fig. 6 Relationship between the percentage of total articles and the number of citations for a keyword

3.6 Distribution of author's keywords

For this variable, an analysis of the keywords listed by the authors for the articles found in the period from 2006 to 2016 was performed. Out of the 40 articles analyzed, two did not present author's keywords, so that 38 articles were verified in the analysis. For these 38 materials, 176 keywords related by the authors were identified, since each article must contain at least two keywords (Araújo and Costa 2016). The results obtained from the analysis indicated that 94 (53.4%) keywords were cited only once, 17 (9.7%) were cited twice, five (2.8%) were cited three times and three (1.7%) were cited four times. "Triple helix" was the most used keyword, with eight citations (0.6%), followed by "Balanced Scorecard" with seven citations, and "Innovation" with six citations. Based on the analysis of the author's keyword distribution, Fig. 6 shows a significant correlation with a power model to describe the relationship between the percentage of total articles and the number of times that a keyword was used (Chiu and Ho 2007). The dialog data graph showed the existence of a linear relationship with high coefficient of determination (0.9814) in the number of times, ranging from one to eight, that a keyword was cited.

3.7 Analysis of the most cited articles

Among the most popular bibliometric indicators used to evaluate the quality of the research is the number of citations that an article received (Oliva, Taulat and Romero 2006, Zyoud and Fuchs-Hanusch 2017). In this study, as presented in Table II, the 20 most cited articles related to RD&I management were analyzed based on performance evaluation systems in the energy sector. The most cited article was entitled “Designing a knowledge-based system for strategic planning: a balanced scorecard perspective” and was written by Huang (2009). The article reached 195 citations at the moment of the data analysis and aimed to propose an integrated framework for the Balanced Scorecard tool and a knowledge-based system using the hierarchical process analysis method, in addition to developing an intellectual Balanced Scorecard and a system based on knowledge for strategic planning.

An article titled “Intellectual capital dynamics in universities: A reporting model”, written by Sánchez, Elena and Castrillo (2009) took the second position among the most cited articles, with 115 citations at the time of data analysis. In this study, the authors analyzed the increasing attention given to universities and research organizations at the political level and the increasing implementation in these institutions of intellectual capital management, besides reporting mechanisms traditionally used by private companies.

In the third position, it is the article “Roles, resources and benefits of intermediate organizations supporting triple helix collaborative R&D: the case of Precarn”, written by Johnson (2008) and with 109 citations at the time of data analysis. In this study, the author sought to contribute to the literature dealing with research and development collaboration in the triple helix, exploring the roles and resources that intermediary organizations can use to facilitate the relationship between university, business, and government.

The article “Universities, technology and innovation centres and regional development: the case of the North-East of England” present 44 citations at the time of analysis and was written by Goddard, Robertson and Vallance (2012). In this research, the authors examined the role of technology and innovation centers in bridging the gap between the university research base and industry in order to stimulate economic development in a backward industrial region.

Table 2 Ranking of the 20 most cited articles

SCR*	Authors	Title	Journal name	Times cited
1 st	Huang (2009)	Designing a knowledge-based system for strategic planning: a balanced scorecard perspective	Expert Systems with Applications	195
2 nd	Sánchez, Elena, Castrillo (2009)	Intellectual capital dynamics in universities: A reporting model	Journal of Intellectual Capital	115
3 rd	Johnson (2008)	Roles, resources and benefits of intermediate organizations supporting triple helix collaborative R&D: the case of Precarn	Technovation	109
4 th	Goddard, Robertson, Vallance (2012)	Universities, technology and innovation centres and regional development: the case of the North-East of England	Cambridge Journal of Economics	44
5 th	Guimarães, Simões, Marques (2010)	Does performance evaluation help public managers? A Balanced Scorecard approach in urban waste services	Journal of Environmental Management	37

Table 2 Continued

SCR*	Authors	Title	Journal name	Times cited
6 th	Groene <i>et al.</i> (2009)	The balanced scorecard of acute settings: development process, definitions of 20 strategic objectives and implementation	International Journal for Quality in Health Care	33
7 th	Svensson, Klofsten, Etzkowitz (2012)	An entrepreneurial university strategy for renewing a declining industrial city: the Norrköping way	European Planning Studies	30
8 th	Villarreal, Calvo (2015)	From the Triple Helix model to the Global Open Innovation model: A case study based on international cooperation for innovation in Dominican Republic	Journal of Engineering and Technology Management	19
9 th	Schmidt (2008)	Research management and policy: incentives and obstacles to a better public-private interaction	International Journal of Public Sector Management	18
10 th	Klitkou, Godoe (2013)	The Norwegian PV manufacturing industry in a Triple Helix perspective	Energy Policy	15
11 th	Torres <i>et al.</i> (2011)	Knowledge management and communication in Brazilian agricultural research: an integrated procedural approach	International Journal of Information Management	14
12 th	Varrichio <i>et al.</i> (2012)	Collaborative networks and sustainable business: a case study in the Brazilian System of Innovation	Procedia - Social and Behavioral Sciences	14
13 th	Farinha, Ferreira, Gouveia (2016)	Networks of innovation and competitiveness: a triple helix case study	Journal of the Knowledge Economy	13
14 th	Fàbregas-Fernández <i>et al.</i> (2010)	Quality assurance in research: incorporating ISO 9001:2000 into a GMP quality management system in a pharmaceutical R+D+I center	Accreditation and Quality Assurance	11
15 th	Fundeanu, Badele (2014)	The impact of regional innovative clusters on competitiveness	Procedia - Social and Behavioral Sciences	8
16 th	Zhonghua, Wang (2012)	Research frontiers in public sector performance measurement	Physics Procedia	7
17 th	Piñero <i>et al.</i> (2012)	Vinculación y evaluación de políticas públicas de I+D+i para dinamizar la innovación en las PYMIS	Interciencia	6
18 th	Garcia <i>et al.</i> (2016)	Corporate sustainability management: a proposed multi-criteria model to support balanced decision-making	Journal of Cleaner Production	5
19 th	Roselund <i>et al.</i> (2015)	A cross-national environmental cluster collaboration: shifting between an analytical and management level of the triple helix	Science and Public Policy	3
20 th	Yan, Ma, Nakamori (2011)	Exploring the triple helix of academia-industry-government for supporting roadmapping in academia	International Journal of Management and Decision Making	2

*SCR: Standard Competition Ranking

Table 3 Standards of the most productive journals

Journal names	TP ^a	%(R) ^b	IF ^c	TC ^d	AC ^e
Procedia – Social and Behavioral Sciences	5	13 (1)	-	24	4.8
IEEE Latin America Transactions	2	5 (2)	0.436	0	0
Procedia Economics and Finance	2	5 (3)	-	2	1
Technological Forecasting and Social Change	1	3 (4)	2.678	2	2
Technovation	1	3 (5)	2.243	109	109
Energy Policy	1	3 (6)	3.045	15	15
Journal of Environmental Management	1	3 (7)	3.131	37	37
Journal of Cleaner Production	1	3 (8)	4.959	5	5
Expert Systems with Applications	1	3 (9)	2.981	195	195
International Journal of Information Management	1	3 (10)	2.692	14	14

^aTP: The total of publications of the journal during 2006-2016.

^b%(R): The percentage of the total publications of the journal and its rank in the data set established by this paper.

^cIF: The impact factor of the journal in 2015.

^dTC: Total citations of the publications of the journal established by this paper.

^eAC: Average citations of the publications of the journal established by this paper.

The analysis of citations is extremely important as a basic measure to evaluate the scientific impact of production and authors. Through it, it was possible to expand the scope of the research and find more related articles through the references, which may be more relevant in the researched scientific area.

3.8 Journal standards

In total, 40 articles were published in 34 journals, 32 of which published only one article each in the area of research, development and innovation management in the energy sector, based on performance evaluation systems.

Table 3 provides a profile of the ten journals that most published articles in the researched area, as well as the number of articles published, the percentage of publications in relation to the total analyzed, the impact factor, the total and the average citations of the set of articles selected in this research. These journals represent 40% of all publications, implying a diversified distribution of these materials and an interest in multiple perspectives.

Procedia – Social and Behavioral Sciences is the most published journal in the area of RD&I management in the energy sector, with five articles in total and an average of 4.8 citations per publication. IEEE Latin America Transactions occupies the second position in the ranking of publications, presenting two materials and impact factor of 0.436. Also with two published articles appears the Procedia Economics and Finance journal, with average of one citation per article and absence of impact factor. Each of the following journals in the ranking published only one article in the area of interest, and they all have an impact factor between 2.243 and 4.959, indicating that their publications should be referenced more frequently as sources of influence in the conceptual and methodological approaches of the researchers (Beatty, Feeley and Dodd 2012). This can be

seen from the total number of citations, which varied from two to 195 for this set of articles.

4. Conclusions

The focal point of interest in this study was to conduct a bibliometric analysis for the period from 2006 to 2016 in the field of research, development and innovation management in the energy sector, using performance assessment systems, considering the following dimensions: language, output and countries of publication, international cooperation, authors, distribution of the author's keywords, analysis of the most cited articles published and journals standards. Thus, from the use of the bibliometric tool, the results of a quantitative analysis were obtained, which allowed evaluating the trends, characteristics, and standards of the publications of the researched area.

The study presented an increasing trend in the number of publications on RD&I management in the energy sector in the last decade, demonstrating the worldwide interest in science and technology in the researched subject. Research, development and innovation are the driving force for competitive advantage and the key to economic and smart growth in a knowledge-based society (Paz-Marín, Campoy-Muñoz and Hervás-Martínez 2012). A key role in RD&I management is the creation of dynamic capabilities, which are related to the institution's ability to integrate, build, and reconfigure internal and external skills to work with volatile environments (Teirlinck and Spithoven 2013), such as the electric sector, which is constantly developing and searching for cleaner and more efficient technologies (Araújo and Costa 2016).

The results demonstrate that English is the predominant language in published articles, since it can be considered the universal language and offers authors much more opportunities for publication when compared to other languages. In addition, the study analyzed the productivity per country, noting that the country with the largest number of publications in the area of RD&I management in the energy sector is Brazil, considering its great energy potential and the development of new, renewable, lower cost and more efficient technologies. Spain, United Kingdom, and Sweden were the countries that produced the most with international cooperation, encouraging the development of high-level scientific research through the transfer of knowledge and technology between countries.

The vast majority of the articles were produced through collaboration between researchers, that is, the materials were written by more than two authors, implying qualified and diversified productions. *Procedia – Social and Behavioral Sciences* is the journal that most published articles in the field of research, with five materials, while *Expert Systems with Applications* published the most cited article, presenting 195 citations.

The results of this bibliometric study have several important implications for the evaluation of scientific information on RD&I management in the energy sector, based on performance evaluation systems. This analysis revealed a set of data, in which the researchers can gain insights about the contributions of the countries, journals, and authors that approached the subject in question. In addition, it documented the scientific achievements and identified important points of the research and its future directions. The indicators raised can provide a basis for future assessments and analyses of the results of research in the field studied, as well as identify changes in future research trends compared to existing ones. Therefore, it is expected that this study will assist researchers and academics in future work through the advancement of research in this area.

4.1 Research limitations

Bibliometric analyses have the potential to provide insights into scientific research activities and may present evidence-based descriptions, comparisons, and visualizations of search results (Zyoud and Fuchs-Hanusch 2017). Although bibliometric methods have expanded in all areas of research evaluation, their application is limited to the literature published in indexed journals and do not include unpublished studies, research published in non-indexed journals, unpublished reports, dissertations, and theses (Rosas *et al.* 2011).

This study considered only the documents classified as articles, leading to the omission of some relevant contributions that may have been published in other types of documents. In addition, the research was conducted in the databases ScienceDirect, Scopus and IEEE, which can lead to the exclusion of relevant materials from other databases. Thus, it is possible that some valuable works in the field under study were omitted, since limitations are inevitable.

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