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Bibliometric Analysis of the Thermal Storage Systems Research in the Last Ten Years

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Abstract: In this research we analyze the state of the art of the technological developments that are being presented by the scientific community to mitigate the strong environmental changes with renewable energies. The results obtained by the bibliometric techniques in the period 2007-2018 show that in the 1900 published articles the People's Republic of China presents the highest volume of 32.3% of the total publications, showing a strong influence on the development of energy storage technologies and the availability of materials. The results presented in this article allow us to evaluate the development of researchers in this alternative of energy storage as a replacement to the distribution that is done with traditional methods.
Keywords : Thermal energy storage, bibliometric analysis, energy technology.

1. Introduction

Thermal energy storage (TES) has been shown to improve the efficiency of solar absorption cooling systems by capturing excess insolation during peak to reserve energy for the low insolation periods[1]. To alleviate the associated environmental problems, reduction of the use of fossil fuel by developing more cost effective renewable energy technologies becomes more and more contingent[2]. Renewable energy is a key factor to solve energy problem, one of the most attractive is to use heat storage technology, which will improve efficiency of the concentrated solar power plants[3,4]. TES has the potential to achieve high delivery capability and enable high penetration of other renewable energy sources for power generation as wind and photovoltaics PV[5,6]. Energy storage presents the most attractive option for preventing large amounts of curtailment and increasing penetration of renewable resources[7,8].

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A TES has many advantages also of various energy storage technologies, such as lower capital costs and high round-trip efficiency, compared to mechanical or chemical energy storage technologies. A TES system incorporated in California in a solar project, has reported efficiency greater than 97% in a round-trip[9-11].

A TES system may directly save hot heat transfer fluid (HTF) for pump it out at the same temperature for energy discharge, offering the highest energetic and exergetic efficiencies. The cost of HTF is high, most TES systems use a cheap thermal storage medium that needs heat transfer between the storage medium and HTF, for that configuration the design needs a containment system that hold the storage medium and facilities the heat exchange between the storage medium and HTF for energy charge and discharge. HTFs in commercial CSP plants use air, Water or steam, oils and inorganic molten salt[12-13]. Water is the most commonly used thermal storage medium in solar cooling applications, the small operating temperature range of solar systems limits its energy density[14]. Solar collectors need to have good optical performance for absorbing all the possible heat, whilst the thermal storage subsystems require high thermal storage density as small volume and low construction cost and excellent heat transfer rate for absorb and release heat at the required speed[15-18].

Based on bibliometric studies[19-20] in this field, a global approach was obtained for the development of the scientific community. As a result, the main contribution of this research work is to analyze the growing progress of information on the development of energy storage technology and its main contributions to complement technologies developed for greater efficiency in energy acquisition and distribution, allowing the analysis of the qualitative and quantitative results of scientific contributions to society in the period 2007 to 2018.

2. Materials and Methods

The information for analysis in this research was obtained from the Web of Science database that contains the information developed by Thomson Scientific. The thermal storage system has been used as keywords for the search in the period 2007 to 2018, obtaining 1900 publications that contained the basic information to carry out the trend analysis in the research. The data was stored in txt format, to be analyzed in the HistCite platform quantitatively and to be able to analyze the trends of the indicators obtained. This paper used indicators that assess the quality and impact of institutions, using indicators such as the Total Local Citations Score and Total Global Citation Score to analyse the impact of institutions and authors.

3. Results nd Discussion

The production of the research from 2007 to 2018 is shown in Figure 1 according to the information collected. During this period, the research trend on the subject has increased, with an important peak between 2015 and 2017.

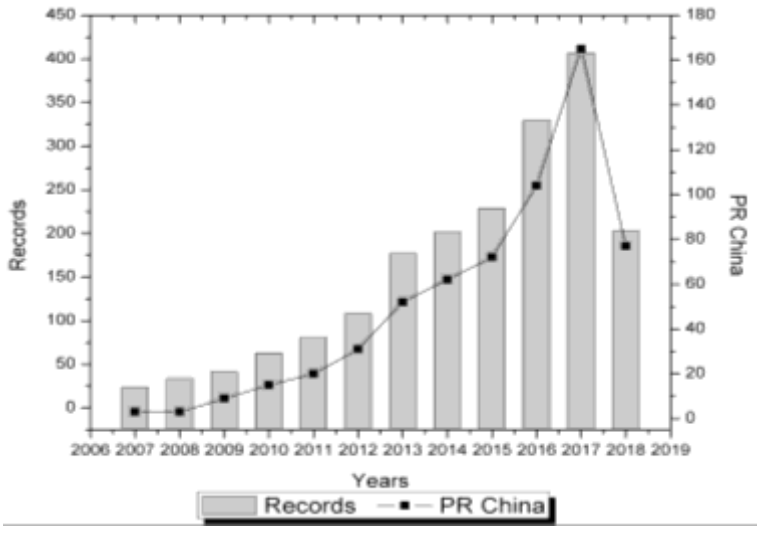

Figure 1. Annual production of the research.

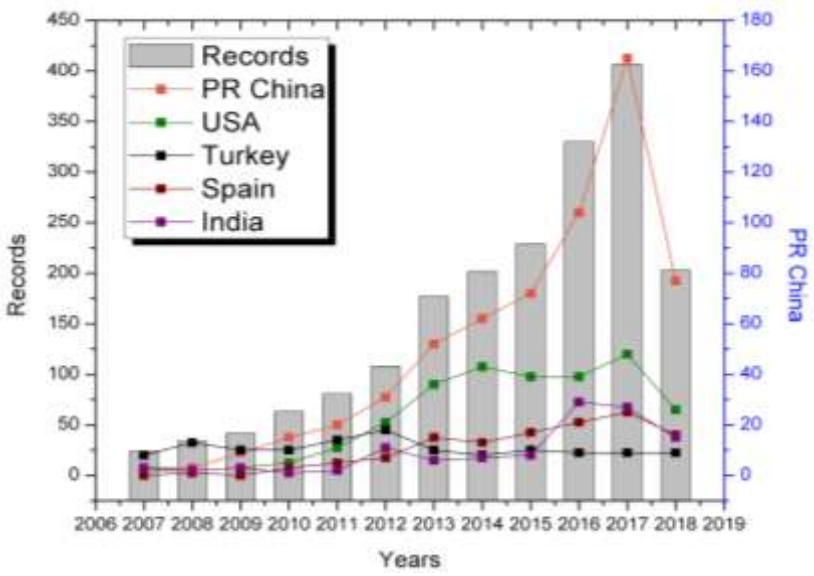

Figure 2. Total publications by country from 2007 to 2018

During this research period, 75 countries have contributed to the research, where countries with high research resources such as China, USA lead the production with 613 and 275 publications respectively, while Turkey, Spain and India follow these two countries with 126, 123 and 114.

The distribution of research results and citations by Institution can help to better visualize the research activities and capacities of institutions around the world. Table 1 shows that the institution with the most publications is the Chinese Academy of Science with 79 publications, followed by Gaiosmanpasa University with 68 publications and La Lleida University with 53 publications, these three institutions located in Asia and Europe, show that research on thermal energy storage has been in force during the research period.

The institution-based distribution of citations is done with the TLCS bibliometric indicator, where gaiosmanpasa University has 1228 citations, which makes it the most cited. Lleida University, Nanjing University, Shanghai JT University and Devi Ahilya University have 83, 424, 403 and 386 citations respectively. Although the Chinese Academy of Science is the institution with the highest number of publications, it does not imply that all its articles generate a great impact on research, taking the case of Devi Ahilya University which has only two publications, but 386 citations, which have generated a great impact.

Table 1. Classification of the top five countries of published papers and TLCS.

Institution	**Records**	**Institution**	**TLCS**
Chinese Academy of Science	79	Gaiosmanpasa University	1228
Gaiosmanpasa University	68	Lleida University	683
Lleida University	53	Nanjing University	424
Shanghai JT University	45	Shanghai JT University	403
Nanjing University	38	Devi Ahilya Univ	386

With respect to journals, 1900 publications were published in 331 journals in thermal energy storage research during this period. All journals were ranked in descending order by analyzing each journal's publications by year and their publication trend. The magazine with the most publications is Applied Energy, with 205, which presents a peak of publications during the years 2015 and 2017. Applied Thermal Engineering magazine, with 165 publications, has had the largest growth, due to its high number of publications during the years 2014 and 2017. The Solar Energy Materials & Solar Cells and Energy magazines have experienced considerable growth during this investigation period.

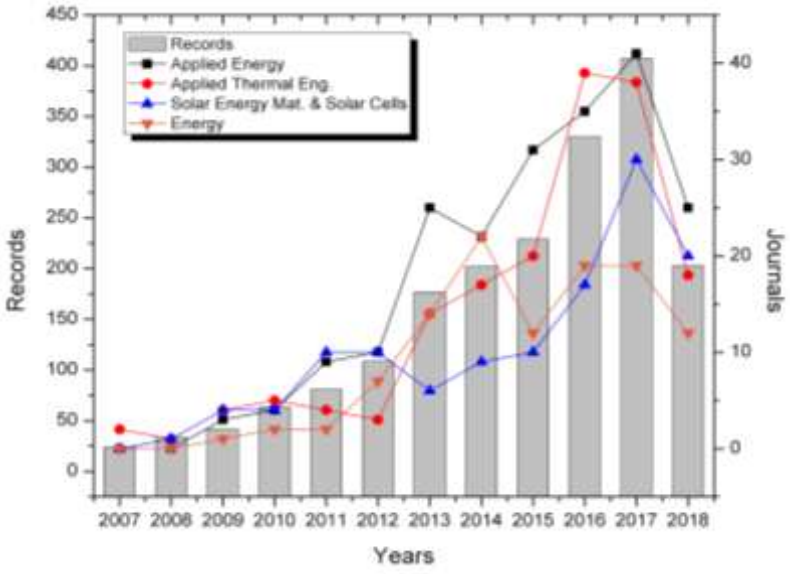

Figure 3. Classification of the top five journals of publication.

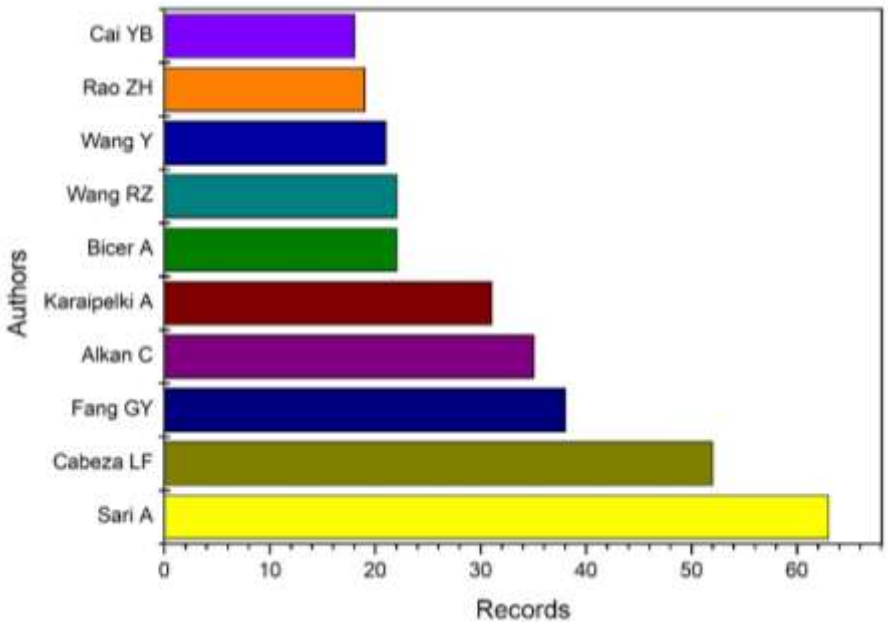

Figure 4. Top 10 of the autor with more publications.

In figure 4 we can see the 10 most influential authors in this field, showing the record of their production where Sari A has a volume of publications of 3.3% of the total number of published articles showing their great influence in the scientific community with high impact contributions due to the number of local and global citations with 1230 and 3430 respectively as can be seen in table 2.

In Table 2 is exposed the total global citations score, indicator that show the impact that have the autor in the scientific community with his apport.

Table 2. Top 10 of the autor with more publications and the total local citations and total global citations.

Author	Recs	TLCS	TGCS
Sari A	63	1230	3430
Cabeza LF	52	664	2511
Fang GY	38	424	1166
Alkan C	35	542	1473
Karaipekli A	31	877	2599
Bicer A	22	293	673
Wang RZ	22	143	549
Wang Y	21	84	281
Rao ZH	19	34	124
Cai YB	18	137	389

HistCite was used to generate a chronological display of citations for thermal energy storage research articles. As shown in Figure 5 the first 30 articles with high TLCS were taken to generate the graph. However, the minimum value of TLCS is 46 and the maximum is 346. The relative size of the nodes in the figure shows the quoted number of documents, while the arrows point to the quoted documents.

From the figure it can be seen that in 2009 and 2010 the most cited articles were found and that article 69, written by Atul Sharma et al, was the most cited, having a great impact on research into the development of thermal energy storage. In the article by Atul Sharma et al[21], the authors conduct an analysis of thermal energy research using phase change materials, studying their applications in different contexts and their availability for them. Many of the articles cited have the same direction of research, such as articles 107, 110 and 120, which perform analysis with PCM for the research topic and cite article 69. It should be noted that most of the articles that cite article 69, including the 3 mentioned above, are from the Renewable & Sustainable Energy Reviews magazine, being of great impact to the research of thermal energy storage.

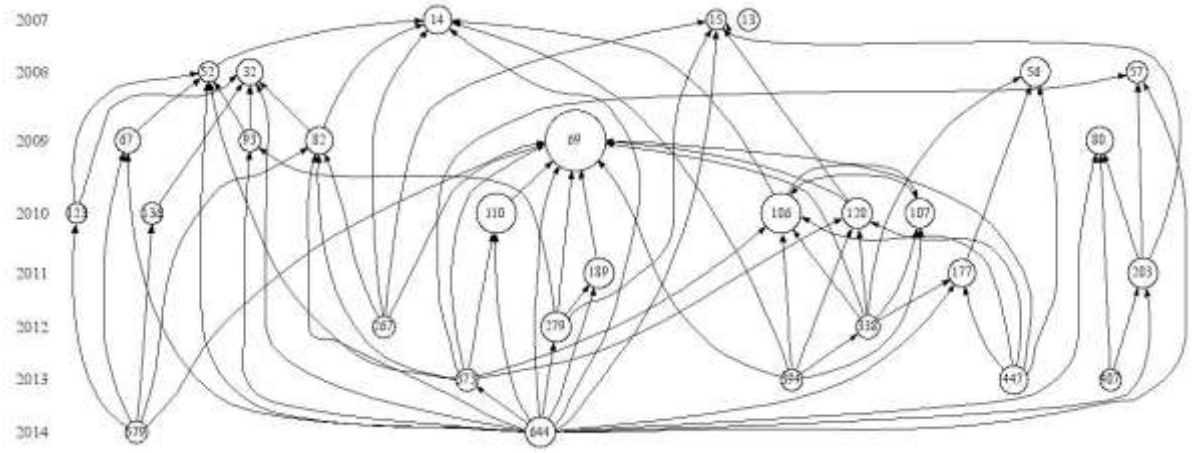

Figure 5. Top 30 most cited articles between 2007 and 2014.

4. Conclusions

Finally, it can be concluded that the scientific development in energy storage technology is growing significantly, seeking to increase the efficiency of new energy acquisition technologies such as concentrated solar power plants. There is a strong contribution from the scientific community in search of optimizing and harnessing all the energy through subsystems that reduce operating costs and materials to use and mitigate the use of traditional technologies.

In this research work it was possible to evaluate the characteristics of the information, obtaining as a result that the greatest technological advances were obtained between 2016 and 2017 representing 38.8% of the total production. China is the country with the greatest contribution to the development of production since it presents 613 articles from the 1900 articles that were published in this period of time, supporting the main participation of the Chinese Academy of Science with 79 publications. The sample of information from the

journals corresponds to Applied Energy in its maximum participation with 205 articles, constituting 10.8% of the publications and presenting its maximum contribution level in 2017. The analyses presented in this research allow us to show the current position in the technological development, identifying a direction to obtain new contributions in the storage characteristics, optimizing the working capacity and increasing the benefits.

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