International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.11 No.09, pp 176-182, 2018

Research Evolution on Concentrated Solar Power From 2007 To 2018: A Bibliometric Focus

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Abstract: This article presents an analysis of the state of research on the trends of new technologies in concentrated solar power based on the information obtained for the period 2007-2018. The results obtained from the bibliometric techniques used made it possible to identify the behavior of production at an international level. Of the 486 publications, 81.5% correspond to articles in journals showing the strong influence that the scientific community has on this subject with the development of new technologies in the energy generation sector. In this period, the United States is the country with the highest production, occupying 28.2% of the volume of published articles. The results of this research provide researchers with an overview of how the development of this alternative production and supply of energy as a substitute for fossil fuels is progressing, with the aim of reducing the pollution generated by traditional processes.
Keywords : Concentrated solar power, bibliometric analysis, energy technology.

1. Introduction

Concentrated solar power (CSP) is a promising renewable energy technology that involves methods to concentrate the sun's energy onto receiver systems that generate steam, activate turbines and consequently generate electrical power[1-3]. Electricity consumption is growing rapidly in many countries; its global use increased by 54% between 1990 and 2005. Nowadays, electricity is the second major energy commodity in countries with a share of 22%, after oil products with a 47% [4], for that use of renewable energies is essential, producing the looking for one feasible way to produce electricity from renewable energy how is CSP plants[5]. By 2050, with appropriate support, CSP could provide 11.3% of global electricity, with 9.6% form solar power and 1.7% from backup fuels[6].

DOI= http://dx.doi.org/10.20902/IJCTR.2018.110923

The operation of a CSP plant consists in concentrating the sunlight using mirrors onto a system containing heat transfer fluid (HTF), which is the conducted to a power-block for generation of electricity[7-9]. Optionally, HTF can be transferred to an auxiliary storage system, often referred to as a thermal energy storage (TES) system is greatly used to collect energy for later need[10-12]. A TES system is critically needs for CSP to smooth out the short-term transients and to extend the daytime operation to nighttime[13,14]. Also, TES has many advantages such as lower capital costs and high round-trip efficiency, compared to mechanical or chemical energy storage technologies[15].

The most common CSP technologies are parabolic dish systems (PDS), parabolic trough collector (PTC), solar power tower (SPT) and linear Fresnel reflector (LFR). Among these, the parabolic trough collectors are currently the most utilized technology with 95% of the CSP installations. Although the CSP technologies date back to 1970s, most of the commercial plants have been developed in the last decade[16,17]. Spain is currently the largest producer of CSP electricity, with 50 CSP plants and total capacity of 2.304 GWe. USA has 19 CSP plants in operation with a total installed capacity of 1.60 GWe up to July 2015[18]. Other countries having good solar resources like United Arab Emirates, Australia, China, Italy, Mexico and South Africa also have CSP Programs and commercial or demonstration projects at different stages of construction operation[19,20].

A typical CSP plant consist in mirrors to redirect the direct normal irradiance (DNI) to an absorber, a system of heat transfer to conduct the captured heat to a power cycle, a system of thermal energy storage to maintain the energy supply throughout a 24h day and optionally a back-up system to aid the control of electricity generation[21,22].

Based on the aforementioned studies of this technology, a bibliometric review is necessary to obtain a global approach to the subject matter. As a result, the main contribution of this article is to quantify the growth in the literature on the development of concentrated solar power technology, allowing for the analysis of qualitative results on the impact of this information on society in the period 2007 to 2018 by means of bibliometric techniques (23) that allow us to examine the characteristics of the published production.

2. Materials and Methods

The information for the analysis in this research was obtained from the Web of Science database that contains information from the Sciences Citations Index and Social Sciences Citations Index developed by Thomson Scientific. Concentrated solar power has been used as keywords for the search in the period 2007 to 2018, obtaining 486 publications containing titles, abstracts, publication dates, document types and references cited. 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 article used indicators that evaluate the quality and impact of journals and countries in this research. The impact factor of the journals for 2016 was obtained from the publishers where they are subscribed. The h-index was obtained from WOS, where indicators such as the Global Citation Score were used to analyze data performance.

3. Results and Discussion

The 486 documents on this subject in the period established were categorized by type of document, with 81.5% contributed by scientific journals, 10.9% by reviews and 3.9% by articles from published papers. Figure 1 shows the number of total articles published for the most representative country in this area, showing the production of the United States by year and a trend of growth in the research of this technology between 2010 and 2014 showing the latter as the most productive. On the other hand, the international community had the largest production in 2017, showing the positive impact that the development of this technology has on exponent countries and extending the solution to other parts of the world.

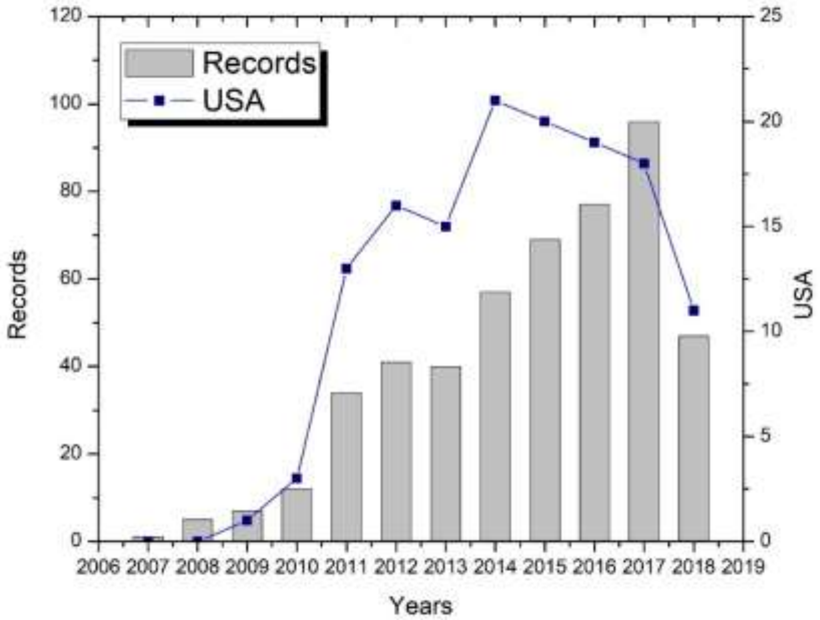

Figure 1.Annual number of published papers between 2007 and 2018.

The top 5 countries in concentrated solar power research were ranked by the number of articles published, representing 71.8% of total production. Among the countries with the largest production volumes is the United States, which leads the publications, followed by Spain, which has one of the largest and most advanced plants in Europe. Then there is the People's Republic of China and 2 countries of Western Europe such as Germany and Italy. Figure 2 shows the volume of publication by country presented annually.

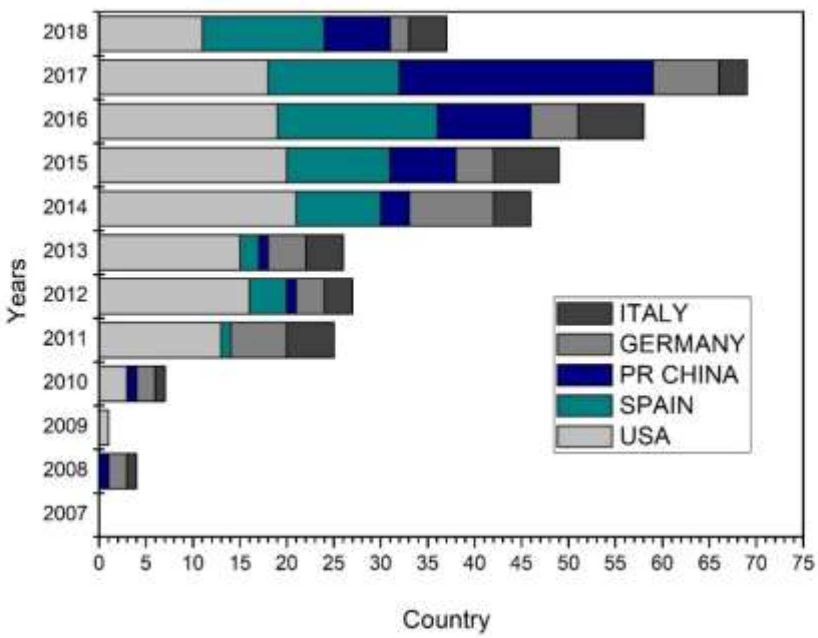

Figure 2. Top 5 most productive countries (2007-2018) with the number of publications

Table 1. Top 10 most productive Journals and the impact factor.

Journal name	TP	Percent	R	IF (2016)
Solar Energy	53	10,9	1	4.018
Renewable & Sustainable Energy Reviews	39	8	2	8.050
Applied Energy	35	7,2	3	7.182
Energy	29	6	4	4.520
Renewable Energy	28	5,8	5	4.357
Energy Policy	24	4,9	6	4.140
Applied Thermal Engineering	21	4,3	7	3.444
Journal of Solar Energy Engineering-Transactions of the ASME	21	4,3	8	1.944
Solar Energy Materials and Solar Cells	21	4,3	9	4.784
Energy Conversion and Management	14	2,9	10	5.589

To analyze the quality of the information, Table 1 presents the journals with the highest research output in the last decade. It is possible to observe that the journal solar energy has 53 publications representing 10.9% of the total number of publications, which places it in first place, but it is not the journal that presents the greatest impact in terms of information quality to the scientific community, where the journals renewable & sustainable energy reviews and applied energy with 8,050 and 7,128 Impact Factor respectively are located, which allows us to conclude that the two journals present significant advances for the good development of this technology in the countries.

Figure 3 shows the number of articles published by the 5 most influential journals in this field over the period. As can be seen, Solar Energy presents its largest production of articles between 2014, 2015 and 2017, responding with these figures to the main axes that are products of its research. In second place is the Renewable & Sustainable Energy Reviews journal with 39 publications supporting 8% of the publications at the international level. The Applied Energy, Energy and Renewable Energy journals represent significant research in this area, complementing 40% of the total volume of publications at the international level of the top 5 journals that have more contributions.

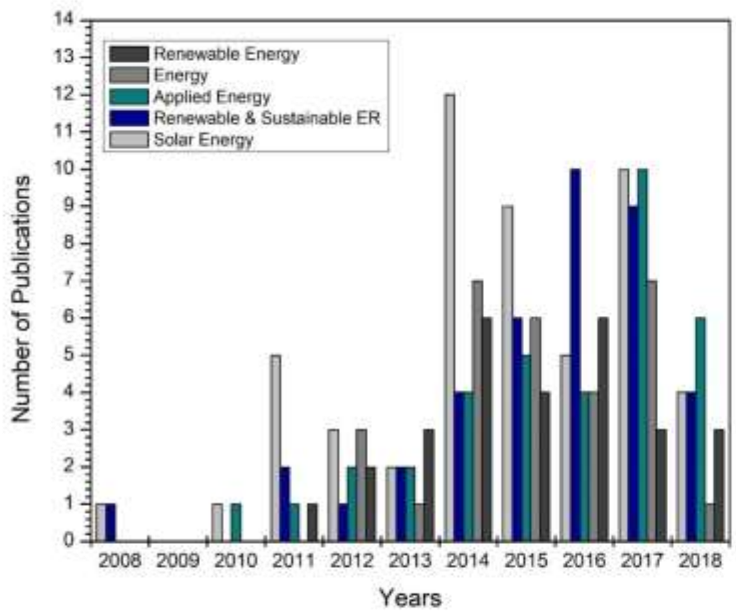

Figure 3.Number of publications by top 5 most productive journals.

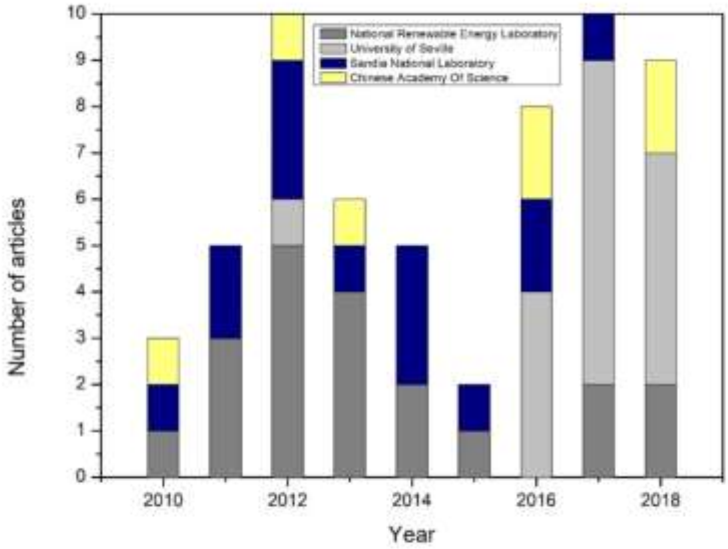

Figure 4. Top 4 research organizations and the performance of publication between 2010 and 2018.

Based on the analysis of the participation in the production by countries, 4 research organizations stand out as shown in Figure 4, which are the most productive in this area of research, of which one is from Spain, one from China and two from the United States, which gives evidence of the global impact by countries in the search for the solution of energy availability without affecting the global climate conditions. Figure 4 shows the production of these research groups, showing that their production is more recent than the dynamics that had begun with the technological development of this field in 1970, presenting results from 2010 to the present. It is analyzed in the graph that the National Renewable Energy Laboratory presents continuous advances of its production since it entered into this thematic in development, publishing an average of 2.5 articles per year.

Table 2 shows which organizations have the greatest influence on the development of this research at the international level, presenting the number of times that the information that has been circulated by these entities has been referenced in research. Placing the National Renewable energy in first place with 437 citations worldwide and second place to the Sandia National Laboratory with 354 referenced citations, responding to the greater influence of its research, the latter entity since it has better H-index (23.6), allowing us to show that its information has made better contributions to the contribution to development.

Table 2.Top 5 Research organizations and the H-index.

Research Organization	**Total Production**	**R Percent**	**Total Global citations**	**H-Index**
National Renewable energy Laboratory	20	1 (4,1)	437	21.85
University of Seville	17	2 (3,5)	110	6.47
Sandia National Laboratory	15	3 (3,1)	354	23.6
Chinese Academy Of Science	12	4 (2,5)	8	1.5

Table 3 shows the 5 most important articles, which present high impact information presenting significant advances for the development and good use of the conceptual availability of this technology. Therefore, we present the article thermal energy storage technologies and systems for concentrating solar power plants which presents in detail the main components and ranges of work in the storage of captured and stored energy. This article has generated great impact and has given way to new research looking for the best results, so it has been referenced 48 times by the scientific community.

Table 3. Top 5 most cited articles in concentrated solar power.

Tilte	Author	Journal	Year	LCS
Thermal energy storage technologies and systems for concentrating solar power plants	Kuravi S, Trahan J, Goswami DY, Rahman MM, Stefanakos EK	PROGRESS IN ENERGY AND COMBUSTION SCIENCE.	2013	48
Concentrated solar power plants: Review and design methodology	Zhang HL, Baeyens J, Degreve J, Caceres G	RENEWABLE & SUSTAINABLE ENERGY REVIEWS.	2013	34
The potential role of concentrated solar power (CSP) in Africa and Europe-A dynamic assessment of technology development, cost development and life cycle inventories until 2050	Viebahn P, Lechon Y, Trieb F	ENERGY POLICY	2011	25
Innovation in concentrated solar power	Barlev D, Vidu R, Stroeve P	SOLAR ENERGY MATERIALS AND SOLAR CELLS.	2011	24
Review on concentrating solar power plants and new developments in high temperature thermal energy storage technologies	Liu M, Tay NHS, Bell S, Belusko M, Jacob R, et al.	RENEWABLE & SUSTAINABLE ENERGY REVIEWS.	2016	23

4. Conclusions

Finally, it is concluded that the research in concentrated solar power is significantly increasing due to the search for new technologies to reduce the harmful effects that affect the climatic conditions and maximizing the trend in increasing environmental practices for the solution of the growing energy demand. There is a strong commitment by the international community to make this technology beneficial to the economic sector in the coming years and to meet the expectations of energy storage and optimization for better distribution without resorting to fossil fuels.

In this study it was possible to analyze that the largest production of articles on this subject was obtained between 2014 and 2017, representing 61.5% of the total production. Of the 486 papers, the United States has the largest production by country with 137 impact studies for the scientific community, with two of the most productive research organizations, the National Renewable Energy Laboratory and the Sandia National Laboratory, standing out. It is also worth mentioning the emerging participation of Spain with contributions from the University of Seville to complement the information channels in the search for the total and efficient development of this technology. The analyses provided in this paper allow us to know the current position of the scientific community on this issue and to identify a direction for new contributions in the development of the technologies needed to maximize the benefits.

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