



## **Sustainability Under Research in Green Energy : A Bibliometric study**

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**Abstract :** The reduction of the amount of pollution and toxicity by the manufacture of products has been a topic widely investigated by many international organizations, looking for an answer that help humanity to minimize the environmental impact. The main objective of this paper is to study the literature of Green engineering from 2007 to 2017 using bibliometric techniques for obtaining an overview of the production behavior of publications in this topic. The information was discharged and analyzed using tools such as Web of Science (WOS) and HistCite to get important results of the international contribution developing significant advances in this area. According to the results obtained, USA has been the most important country researching in this subject, providing 36.8% of the total publications. From the 257 publications, 60.9% were journal articles, where the Abstracts of papers of the American Chemical Society was the most relevant journal with 14 papers. Between 2014 and 2017 an important increase in the published production was presented, being 2016 the year with the most papers published with 15.6% of total investigations. In recent years, green engineering has been consider in many process on industries as a key tool to help the control of the greenhouse emissions, reducing the environmental impact providing some steps to achieve goals proposed for 2050 according to the ISO 50001 standard. Introducción.

Keywords : Green energy, sustainability, bibliometric study.

### **1. Introduction**

Over the last 20 years the concept of sustainability and sustainable development has been explored, due to the environmental implications of industrial development, the first concept of sustainability appeared in 1713, at that time sustainability was considered as the fact of cutting as much wood as trees are growing back, since 2007, for the first time in history, there are more habitants in urban areas than in rural areas. By 2030, it is expected that at least 60% of the population will live in cities, so society will face critical urban problems<sup>1-3</sup>.

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Considering that fossil fuels have a limited life span and have a negative effect on the environment, within the means of transport, private cars produce 31% of the CO<sub>2</sub> that is then emitted into the atmosphere. Therefore, research has been carried out into the production of cars that use alternative fuels as a base, this research has led to the conclusion that the definitive solution to this problem is the use of a car that combines the advantages of hydrogen and fuel cells, The industrial sector is one of the largest consumers of fossil fuels, the industrial transformation processes contribute to the increase in CO<sub>2</sub> levels in the atmosphere, therefore in industries such as cement, the use of green concrete is promoted, in this sector the production of CO<sub>2</sub> pollutant gas is reduced by up to 80% compared to other types of cement<sup>4-7</sup>. In addition to this, the benefits of building houses underground have been investigated, and it was observed that the greater the volume of construction in contact with the ground, the less the heating of the house, leading to a more comfortable indoor environment and lower energy consumption<sup>8</sup>.

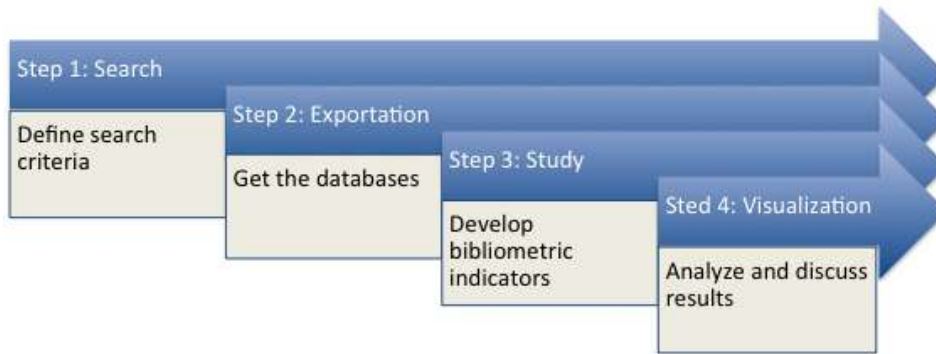
Green engineering does not only produce benefits in the environmental field, but also in the economic field, as evidenced in a Malaysian construction in which the annual energy consumption was evaluated and it was found that the energy saving was 71%.1% compared to the most commonly used industrial methods, from the point of view of the life cycle I save around 5756 kW h/m<sup>2</sup>, which corresponds to \$2,796,456, which provides empirical evidence of the gains brought by the use of an alternative method associated with energy consumption in green buildings, so research has been carried out to raise awareness of the benefits that the use of this type of engineering can bring in industry<sup>9-11</sup>. Given the importance of the life cycle in the field of sustainability, it is important to evaluate the quality of this measure from a life cycle perspective. Therefore, a quantitative comparison was presented from a case study with the help of a software specially designed for this case [12], it is important not only to optimise consumption in households, but also in industry, so it is essential to develop new ways of reducing and optimising consumption in industrial processes<sup>13-15</sup>.

The development of green engineering is such that ways are being proposed to bring the knowledge and applicability of green engineering to schools in order to awaken the interest of young people in this type of subject and the advantages it has with respect to the other possibilities offered<sup>16</sup>. This area has policies that regulate research, so there are a number of patents, the European Union is turning towards sustainability so it is expected that by 2020 60% of the budget is related to sustainable development, China is a clear example of what can be obtained with green engineering<sup>17,18</sup>.

The main contribution of this article is to analyze and quantify the degree of research that green engineering has, with the use of Histcite and its tools for scientific analysis, to find out which countries have turned to questioning what can be achieved and its scope within sustainable development.

## 2. Materials and Methods

This article was made with the purpose of analyzing the tendencies in the researches carried out having as main subject the ecological engineering or green engineering, making a ranking with the 5 countries that have made more researches in this field, where the importance and the impact that each country has was analyzed, using the database of Web of Science (WoS) using "Green Engineering" as a search parameter, the search was filtered for a period of time that goes from the year 2007 to the year 2017. Using the Software Histcite, a computer tool that allows the categorization and quantification of the metadata obtained from the WoS page, in this way and with quantitative parameters, the contribution of each country in the topic treated was analyzed. The analysis also took into account the journals that carry out more publications and the level of impact that they have using TLCS (Total local citation score) and TGCS (Total global citation score) as a measure to determine the quality of the publications made in these journals. The four steps applied to developed the bibliometric study is shown in Figure 1 as follow.



**Figure 1: Bibliometric study steps**

### 3. Results and Discussion

A total of 257 publications were found under the theme of green engineering. Table 1 shows the ranking occupied by each country, where Recs represents the number of total publications, the percent column is the percentage it represents in the database obtained, the total local citation score (TLCS) represents the number of total citations it has received within the subject matter investigated, while Total global citation score (TGCS) represents the number of citations received within the WoS database.

**Table 1: Ranking of the 5 countries with the most publications**

#	Country	Recs	Percent	TLCS	TGCS
1	USA	96	37.4	9	1964
2	China	38	14.8	4	537
3	UK	22	8.6	4	799
4	Canada	14	5.4	7	98
5	Germany	12	4.7	1	229

Table 1 shows that the country with the highest number of publications is China, with a difference of 58 publications, there is a contrast that lies in the low number of citations received in the search, in addition to this is the country with the highest number of citations received in its publications, due to the quality of the publications made and the importance of the community responsible for conducting research.

Figure 2 shows the degree of relevance of the top five countries in this topic, which shows that the largest weight within these countries is taken by the USA with 52.75% and China 20.88%, the contribution of the USA is such that the total publications made by the other countries in the top, which is 47.25% is not higher than the made for them. It makes sense that China and the United States are among the countries with the greatest participation in the issue, due to the agreement signed by the leaders of both countries, made with the firm intention of gradually reducing the pollution produced by them, the Chinese Minister estimates that by 2020, at least 20% of energy produced in this country will be generated through alternative clean energies, despite the few publications made by Canada, it can be considered a country that makes a great contribution to green engineering, since in this country will begin to produce within a few years the so-called green aluminum, a type of aluminum whose reduction will reduce the emission of greenhouse gases into the atmosphere.

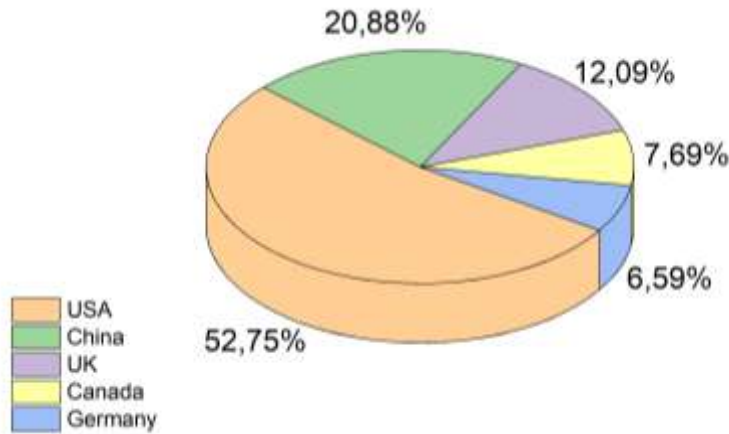


Figure 2: Pie chart with the 5 first countries

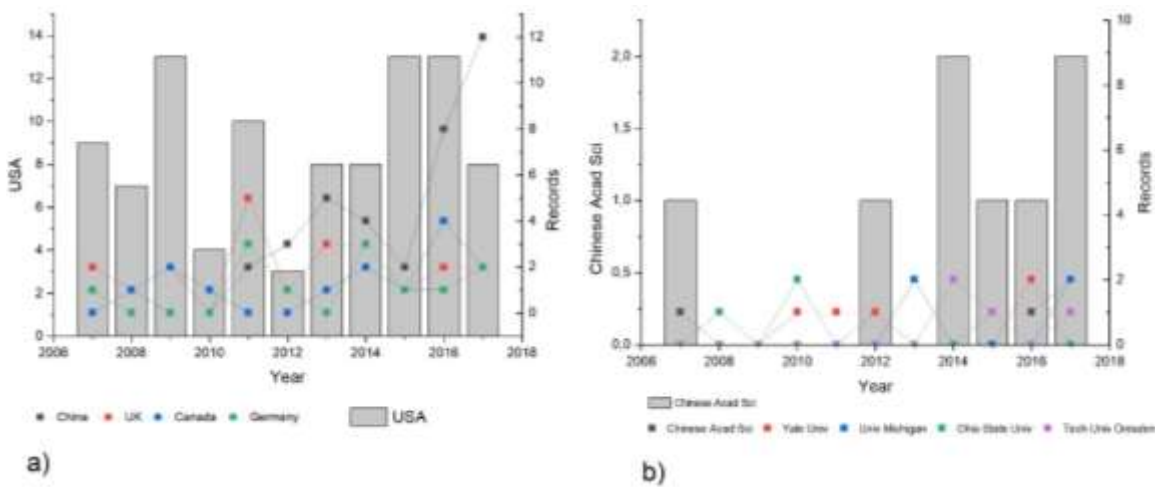


Figure 3: Publication evolution, a) comparative chart between the USA and other countries, b) publication by institutions

Figure 3a represents the number of publications made by the country with the most publications, which is represented by a column-type graph, with respect to the rest of the countries this allows us to measure the importance that each country had in each year, where it is evident that only China in two periods had more articles published than its counterpart in the USA, which occurred in 2012 and 2017, the behavior of the graph shows an irregular frequency of publications, in which a clear or predictable pattern of behavior cannot be observed.

The abrupt increase in 2009 is due to the recovery and reinvestment law implemented by former US President Barack Obama, although he did not have the response that was expected in the following periods, for 2017 there was a decrease in this aspect due to the new President Donald Trump and his environmental policy, in Figure 3b it is observed that the majority of institutions belong to the USA, but the one that has the greatest number of publications belongs to the country of China.

From the results showed in Figure 4a and Figure 4b, it is concluded that the publications in this topic are in article format, this type of publications is more than three times more than the second category, in the category others is Book review, Correction, letter and Review: Book Chapter, in addition it is observed that the predominant language to make the publications is English, reason why at the moment of making a research on the subject, to know the language must be one of the minimum requirements to obtain information.

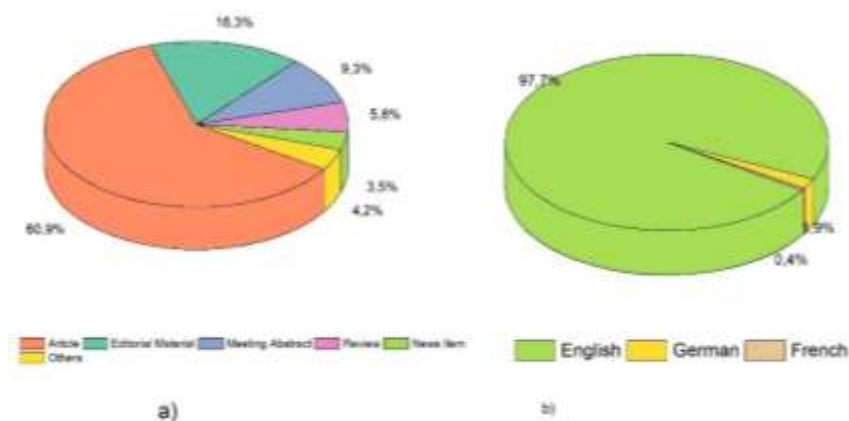


Figure 4: bibliometric indicator, a) Document type. b) Language of publications

Table 1: Journals with most publications

#	Journal	Recs	Perc ent	TL CS	TG CS	TLCS/ Recs	TGCS/ Recs
1	ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY	17	5.8	0	0	0	0
2	ACS SUSTAINABLE CHEMISTRY & ENGINEERING	9	3.5	4	44	0,44	4,89
3	GREEN CHEMISTRY	6	2.3	2	399	0,33	66,5
4	GREEN PROCESSING AND SYNTHESIS	6	2.3	0	3	0	0,5
5	JOURNAL OF CLEANER PRODUCTION	5	1.9	0	46	0	9,2

Table 4 shows that the majority of publications for this topic are made by 'ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY', but that despite having the largest number of publications, it is one of those with the lowest citation scores with respect to the rest of the magazines in the top, the first place in terms of the number of citations received within the search is ACS sustainable chemistry & engineering, while the journal with the highest number of citations within the entire WoS database is Green Chemistry, with a citation rate per article of 66.5, due to the quality of the publications presented by this journal being a reference to take into account when it is required to investigate the subject of green engineering.

The results by countries presented above are due to the fact that the governmental policies of China, the USA and Germany have been based on the use of renewable energies, sustainability and preservation of the environment, but a topic of greater interest is sustainable development from the green energies. At the moment of observing the bibliometric indicators elaborated from the results of research in this area, it is possible to identify a great need to deepen in the investigations elaborated in green energies, besides identifying the important actors in this subject, which come from the countries that have decided to invest efforts in this area, countries that in the last decade have stood out for having the greatest growth both in the use of this energy source, and publishing the results of research in this area, and thus progress in the use of new energy resources.

In this sense, when evaluating the work of research groups in the field of green energy, in addition to the USA, countries of the European economic community, such as Germany and the UK, have played a fundamental role in science and technology. Technology in the development of these energy sources, which in the 90s were presented to the world based on patents and scientific articles that provided the most up-to-date information on this subject, but to date they are already a widely used reality in these countries.

#### 4. Conclusions

The data obtained from the database gives us the result that China is the country that makes the most publications, but its impact on both the subject matter consulted and general publications is low in comparison with the USA, which, although it is the second country in terms of publications received the most citations, so it

can be concluded that the quality of publications is much higher than that of the Asian country. The world powers are always committed to the search for knowledge and technological advances that will allow the quality of life of their inhabitants to be improved, the environment has suffered throughout history from industrial progress, and for this reason the countries have agreed on measures to reduce the negative effect of this and find alternative ways to continue the progress that has been made, but which are not so harmful to the environment.

Bearing in mind the above and the fact that China and the USA are the largest emitters of CO<sub>2</sub> with 28.21% and 15.99% respectively, it is to be expected that they will be the most interested in reducing the environmental pollution they generate, as the countries with the greatest economic power worldwide have the capacity to carry out research not only in this area, but also in different areas.

Given the spread of the article-type format, it is normal that this is the type of document that is preferred for publishing each new finding made on the subject, but analyzing the journals and the number of publications it is suggested that although Abstracts of Papers of the American Chemical is the journal with the most publications, it could be considered the one with the lowest quality publications, Given the low number of citations received by its articles and/or research publications, while Green Chemistry could be considered the best publication for its publications, given that despite having a low number of publications, in total it is the journal with the highest number of citations in the entire WoS database, so if you are interested in the subject, you should take this journal into account.

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