energies

Article

Analysis of Research Topics and Scientific Collaborations in Energy Saving Using Bibliometric Techniques and Community Detection

Carmen de la Cruz-Lovera [1,*], Alberto-Jesus Perea-Moreno [1], José Luis de la Cruz-Fernández [1], Francisco G. Montoya [2], Alfredo Alcayde [2] and Francisco Manzano-Agugliaro [2]

1 Departamento de Física Aplicada, Universidad de Córdoba, ceiA3, Campus de Rabanales, 14071 Córdoba, Spain; g12pemoa@uco.es (A.-J.P.-M.); fa1crfej@uco.es (J.L.d.l.C.-F.)

2 Department of Engineering, University of Almeria, ceiA3, 04120 Almeria, Spain; pagilm@ual.es (F.G.M.); aalcayde@ual.es (A.A.); fmanzano@ual.es (F.M.-A.)

* Correspondence: zr52crloc@uco.es; Tel.: +34-957-218-553

Received: 15 April 2019; Accepted: 24 May 2019; Published: 27 May 2019

Abstract: Concern about everything related to energy is increasingly latent in the world and therefore the use of energy saving concepts has been increasing over the past several years. The interest in the subject has allowed a conceptual evolution in the scientific community regarding the understanding of the adequate use of energy. The objective of this work is to determine the contribution made by international institutions to the specialized publications in the area of energy-saving from 1939 to 2018, using Scopus Database API Interface. The methodology followed in this research was to perform a bibliometric analysis of the whole scientific production indexed in Scopus. The world's scientific production has been analysed in the following domains: First the trend over time, types of publications and countries, second, the main subjects and keywords, third, main institutions and their main topics, and fourth, the main journals and proceedings that publish on this topic. Then, these data are presented using community detection algorithms and graph visualization software. With these techniques, it is possible to determine the main areas of research activity as well as to identify the structures of the collaboration network in the field of renewable energy. The results of the work show that the literature in this field have substantially increased during the last 10 years.

Keywords: energy-saving; energy conservation; energy utilization; energy efficiency; scientific collaboration

1. Introduction

The energy problem has become a global issue in a world where science and technology are undergoing a great evolution in a short period of time [1]. Consequently, the development of renewable energy and the use of energy saving concept has been increasing in last years, becoming a research focus around the world [2]. The growing interest in the subject has allowed a conceptual evolution in the scientific community regarding the understanding of the adequate use of energy.

While there is a close relation between the terms "energy saving" and "energy efficiency", there are certain distinctions that need to be clarified. The energetic saving entails a change in the habits of consumption. Sometimes it is enough to eliminate habits that waste energy. On the other hand, energy efficiency is the fact of minimizing the amount of energy needed to satisfy the demand without affecting its quality [3]; it supposes the substitution one machine to another that, with the same benefits, consumes less electricity. Therefore, this does not mean changes in consumption habits. The behaviour of the user remains the same, but less energy is consumed due to the consumption of energy to carry out the same service, which is lower. In Alcott, an extensive review of the literature on the subject of "sufficiency" can be found [4]. To achieve greater energy sustainability as much as possible, renewable energy and energy saving have been combined [5]. In this way, we will achieve a twofold purpose thanks to a combined strategy of energy saving and energy efficiency, without reducing the quality of life. In fact, it will be maintained, and even increased. These concepts are also making significant advances in the residential construction sectors [6]. Energy saving is not only linked to monetary savings [7], it also contributes to reducing greenhouse gas emissions [8], sustainable development and achieving a sustainable energy supply. However, the reduction of energy demand is not as easy to carry out as is thought and the actions that are imposed are in many cases insufficient to achieve real transformation [9].

Thus, it is necessary to emphasize that, sometimes, many improvements of the energetic efficiency do not reduce the consumption of energy in the amount predicted by the simple engineering models [10]. This is called a rebound effect, since the fact that energy services improve means that they are cheaper and, in turn, that the consumption of these services increases [11]. The Paris Agreement on climate change is an agreement within the framework of the United Nations Framework Convention [12] and energy consumption was the main point to deal with and the creation of an agreement worldwide. To achieve the objectives of this agreement, an outstanding change in the energy sector is necessary, the origin of at least two thirds of greenhouse gas emissions.

The transformation of the electricity sector, with renewable energy, has focused attention on a new debate on the design of the electricity market and electrical safety [13]. However traditional concerns about energy security have not disappeared. In addition, there are also pending issues related to energy access and affordability, global warming and CO_2 emissions. Therefore, the massive social concerns can be understood and lead to an increasing demand for ways to improve social and individual energy efficiency.

There remains an urgent demand for ways to improve the energy efficiency of society and people and a need to move increasingly to alternative, low-carbon or non-carbon energy systems. [14]. If we want to achieve sustainable development, energy efficiency becomes a key factor. It is a reality that only a few countries are engaged in research into renewable energy, representing between 70% and 80% of scientific production [15]. In general, countries are in the process of achieving, and in some cases exceeding, many of the objectives set in their commitments under the Paris Agreement. This is enough to reduce the expected increase in global CO_2 emissions related to energy, but it is not enough to limit the global warming to less than 2 °C. The increase in energy consumption, especially in HVAC systems (heating, ventilation and air conditioning), and CO_2 emissions have contributed to more energy policies focusing on the development of energy saving and efficiency strategies as an absolute priority [16]. An example of this is the European Energy Performance of Buildings Directive.

The major advanced economies: USA, the European Union, and Japan appear to be clearly on track to achieve their climate commitments, although it will be vital that these countries introduce other additional improvements in energy efficiency. A clear example of it would be the cement production industry, one of the most polluting. However, several mitigation measures are gaining importance in the recent years, and this industry is increasingly turning towards cleaner production. This is because new alternatives are used as raw materials and fuels. In existing industries, mathematical statistical models, simulation processes, optimization of procedures are everyday methods [17]. Natural gas and oil are going to continue to be the essence of the global energy system for years to come, as governments have indicated in terms of climate. Faced with this situation, the fossil fuel industry should consider the risks of a more direct transition. The interdependence between energy and water will become more pronounced in the upcoming years. In this sense, the management of the relationship between energy and water is crucial for the successful fulfilment of a series of development and climate objectives. It is evident that, to promote energy saving, it should be tried to create efficient energy systems and banish old ones. In fact, there is great potential for energy savings in the renovation of the housing stock in many cities, as is the case in Denmark, where 75% of the buildings were built before the eighties, when the first important demands were introduced for the energy performance of the building [18].

In this way, without altering the development of the technique, significant energy savings will be achieved. Nor should we ignore the human factor; the education and global awareness of citizens is important to achieve energy savings.

Recent studies show how construction technologies have been developed to improve comfort and energy savings in both conventional buildings using concrete or heavy structures, and also in timber buildings. An example of these technologies is the thermal insulation added to the facades and the improvement of the performance of the glazing or a district heating designed in a residential area. Nevertheless, although these technological advances can be implemented in concrete and wood buildings, the studies carried out highlight how timber construction is associated with thermal comfort and is perceived as innovative [19].

This is paradoxical because, after having expanded the use of gravel and concrete, the wood construction was increasingly neglected for a period of time. However, in recent years the Kyoto Protocol has pushed to limit CO_2 emissions in all productions. The use of sustainable materials is definitely being stimulated worldwide, as they can store carbon dioxide. The advantages of using sustainable materials have been confirmed by various scientific studies [20].

Buildings using sustainable materials are called green buildings. They reduce and optimize their energy and water consumption as much as possible and integrate into their environment, whether natural or urban, causing the least possible environmental impact. Smaller buildings tend to achieve these objectives satisfactorily. However, in larger green buildings it is much more difficult to meet the requirements of comfort, lighting, noise, use of space, or more hours of operation. It is feared that these innovative buildings will run the risk of repeating past mistakes, especially if they are too difficult to manage [21].

In this process of constructing eco-friendly buildings, it is fundamentally important to know the user's perception of indoor environmental quality and satisfaction in green buildings. Numerous studies show that employees perceive green spaces better than conventional buildings, but those surveyed are not able to differentiate between both types of buildings. However, there is an unequivocal correlation between ecological attitudes among employees of green buildings, showing them to be more satisfied and more prone to sustainable attitudes [22].

In order to achieve appropriate low-carbon rehabilitation interventions, users play a very important role. A sound learning process must be ensured for occupants, designers and building managers. The behavioural habits of citizens are themselves an essential component in reducing consumption patterns [23].

2. Materials and Methods

The aim of this work is to analyse all the world scientific publications of renewable energy indexed in the Scopus database in order to study the most important areas of investigation in energy saving, as well as to highlight the existing worldwide relationships between researchers and institutions. It is decided to select Elsevier's Scopus for this study as it is the largest database in the world. Thanks to the API interface, it is very easy to automate the search for literature related to the topic by selecting it by authors or by institutions. The two main scientific databases, Scopus and Web of Science pose the question of the comparability and consistency of the results of the different data sets [24]. With respect to journals reported in the two main scientific databases Scopus and Web of Science, a comparative study reveals that the volume of journals on the Web of Science is inferior to the number of journals in Scopus [25], and the relationships obtained in the results with both databanks for the items and the citation numbers by country, and for their rankings, are very robust (R2 $\approx$ 0.99) [26]. This methodology was successfully used in several scientific fields, so only Scopus data has been used in this research [27].

2.1. Automated Data Collection Applying Scripts

The flowchart shown in Figure 1 explains how automatic data extraction would be carried out from Scopus. The process that is carried out by Research Network Bot (ResNetBot) [28] could be separated into the following stages: (1) Obtaining information on documents containing 'energy savings' as keywords or included in the title. We must notice that analyse the keywords in scientific articles is one of the most common research topic in different fields of engineering science. This information is represented graphically, where the size of the nodes is proportional to the h index and the lines between two nodes indicate that they are cited. (2) Obtaining information from authors of the works mentioned in step (1), which includes for each author the Scopus author identification number, affiliations, publications and dates, number of citations and h-index. (3) Processed to obtain the collaborative network of authors who have published articles that contain 'energy savings' as keywords or are included in the title. The information stored refers to the number of collaborations between co-authors and their affiliations, country and city. With all this information a graph will be created where the size of the nodes will indicate the scientific production according to the country and will be proportional to the H index and the distance between them will represent the collaboration with one another.

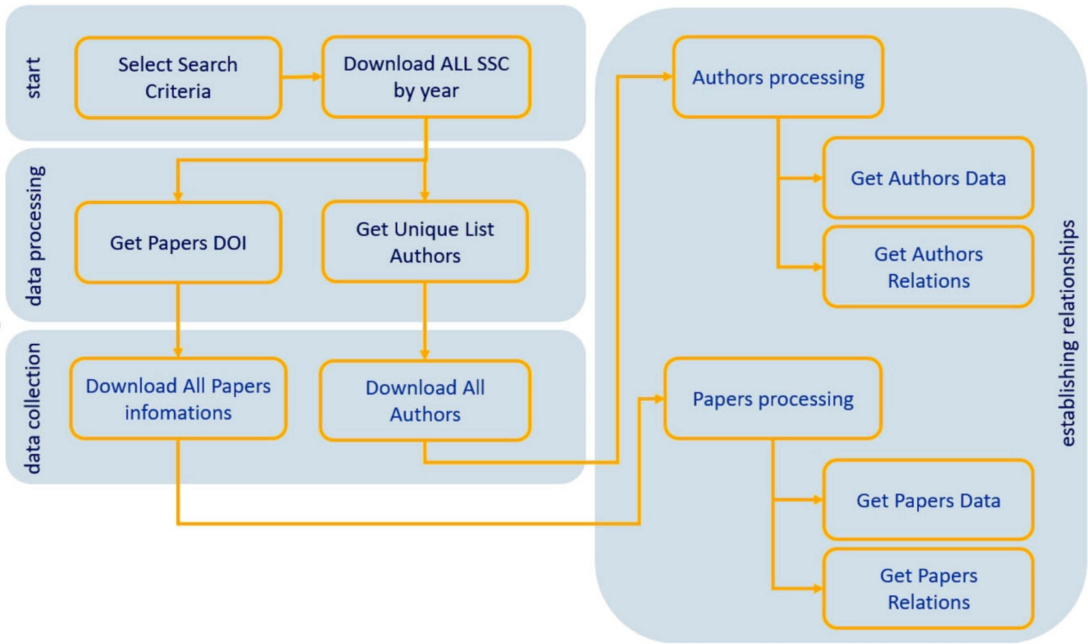

Figure 1. Flow diagram showing how the software obtains information from the Scopus database (ResNetBot).

2.2. Data Evaluation and Polishing of Texts

ResNetBot obtained data that was classified by domains and stored as a compendium of text files in JSON format., http://www.json.org. The Scopus API gives the option of requesting information through all type of details, so we programmed the bot to request all the information available in the files and choose the most convenient data for our work. As a result of the vast volume of data, some irregularities were observed during the work of checking the information. This, however, is a frequent and common problem in these large databases [29]. Phrases with a very similar meaning may sometimes appear written with slight changes. For this reason, it is very important to carry out a debugging process that allows us to obtain the appropriate information. The same expression may not be exactly the same written depending on whether we use capital letters in the first word, the second word, or both. We see an example of this, "Energy saving", "energy Saving", and "Energy Saving".

Therefore, some of the improvement criteria are applied from OpenRefine (http://openrefine.org), which contains some formulae such as clash of keys and neighbourhood algorithms to combine all expressions that correspond to the same idea but are not written in the same way. In order to classify data information and identify singular values, data sheets are finally used; this program has already been successfully carried out in former studies [30] and could be performed on key-words and author names.

Diagnostics and Data Viewing

The data collected by ResNetBot and further processed with OpenRefine was archived in a separate databank. Once this process has been completed, the latter information will be analysed using visualisation tools and statistics based on diagrams.

A graph is a set of vertices(elements) joined by edges. Graphically, the vertices are points and the edges are lines that join them, representing a relationship between two vertices. The visualization of graphs is a great help to determine the interrelation between the different parts. On the other hand, this representation makes it possible to incorporate specific values of the elements and their links. Over the last few years, powerful graphic representation programs have been created that enable the exhaustive analysis of the particularities of the graphics through the use of various functions, such as the reorganization of the vertices and the design of the vertices represented with different colours and sizes depending on their properties. One of the best known when using open source instruments is Gephi [31], which encompasses several statistical tools.

3. Results

3.1. Energy Saving Publication Relationship

In Figure 2, the documents obtained in the search described above have been represented all together. The graph represents the relationship between the documents, with each node representing a file. Of the total of 20,095 papers, in the outer halo formed by 12,402 individual papers are represented those that do not cite any other Energy Saving paper, this is 61.7%. Then there is another intermediate halo of 1919 papers that are linked to at least one other paper, but do not connect with the central core, which represent 9.6%. Finally, there is the central nucleus formed by 5774 nodes that are linked together, and that account for 28.7% of the total, is what could be defined as works that scientifically deepen in that field, because they are based on the previous ones to make some type of contribution.

In our research, there are a total of 70,951 keywords. As there is a large number of papers that are not part of the central core, we proceed to a refining of the 5774 core papers. 23,083 unique keywords were obtained, which after the refining process, 10,119 different keywords remain. After this process, the analysis of the documents that are related to each other is done, and they are represented according to the communities detected with the modularity algorithm of Gephi. Once this process is finished, Figure 3 is obtained. Of the 29 communities detected, the 15 main ones, with a percentage higher than 2%, have been represented in colour to distinguish them.

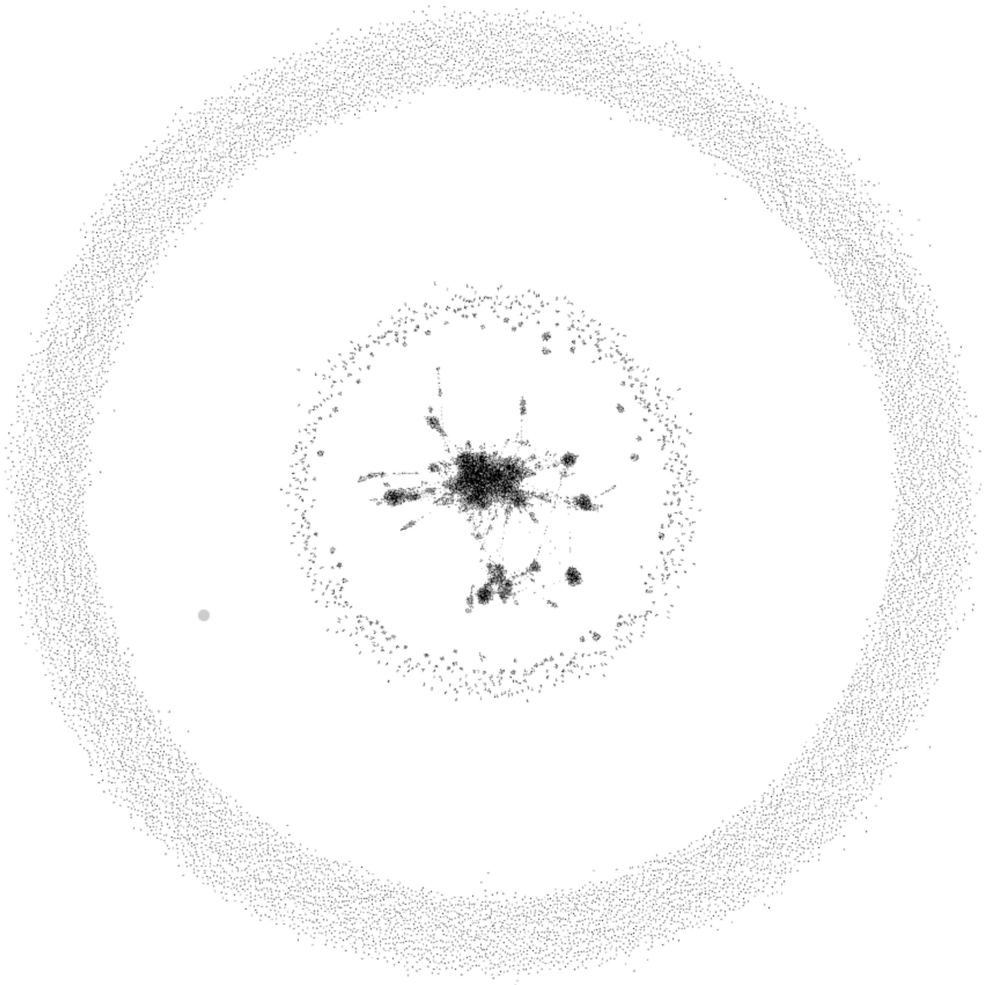

Figure 2. Display of the whole energy saving publication relationship indexed by Scopus.

This process has been necessary to reduce the excess of information that would impede the global vision we pursue.

Figure 4 shows the main 15 communities which have been named to facilitate the analysis. This table shows the main keywords of each community detected.

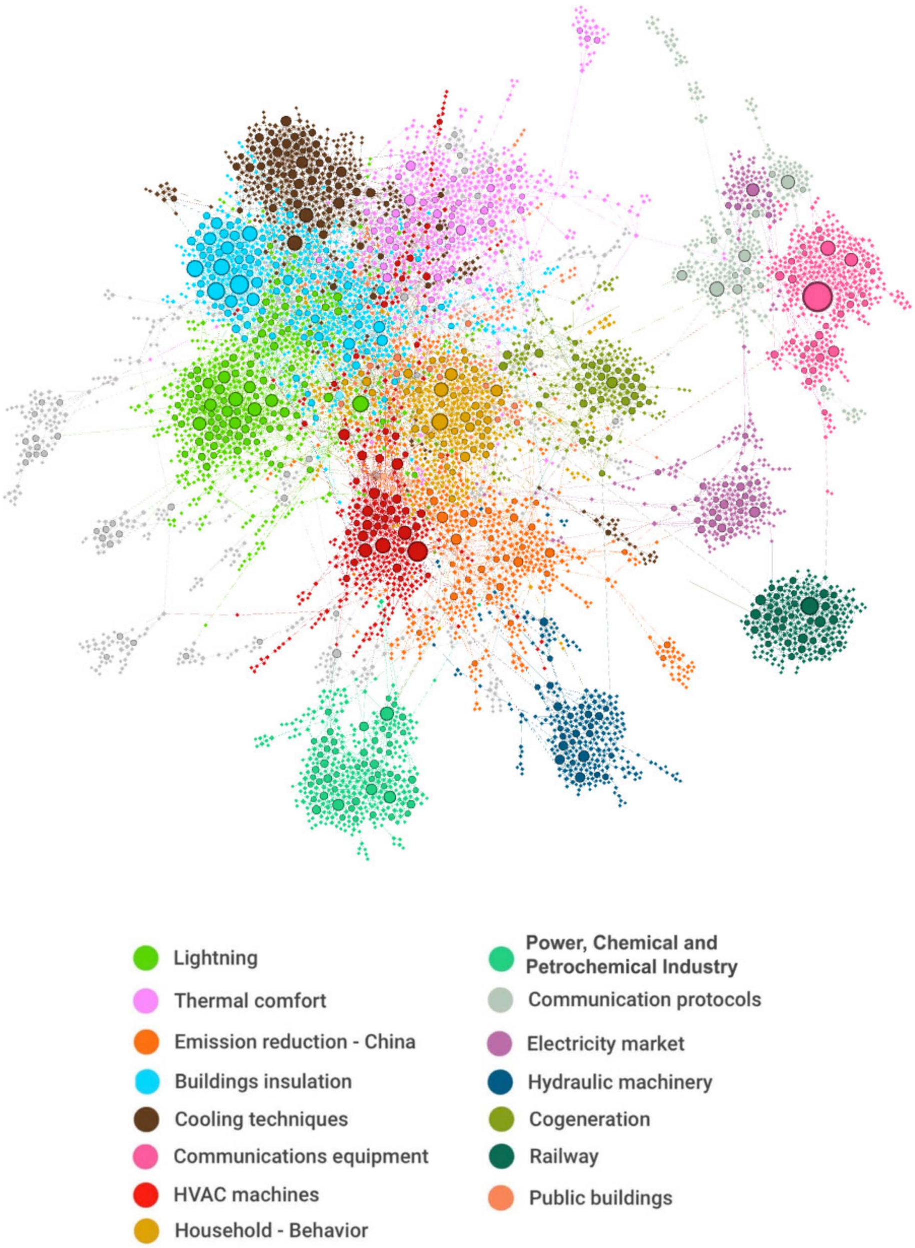

Figure 3. Display of the whole energy saving publication relationship indexed by Scopus.

Fifteen communities are detected within the large network of publications related to the term energy saving. In Figure 5, it can be seen that the area with the highest number of publications is lightning and thermal comfort, followed by emission reduction and building insulation. The high energy consumption that occurs in homes and businesses, together with the growing concern about the impact that energy consumption has on the environment, could show how important the search for facilities and systems that enable energy savings in these field is becoming. On the contrary, the railway and public buildings communities are in the last place of the ranking, with a percentage lower than 4%.

Lightning	Thermal comfort	Emission reduction	Buildings insulation	Cooling techniques
(9.44 %)	(9.18 %)	(8.76%)	(8.61%)	(6.94 %)
Daylighting Energy efficiency Lighting control Daylight Lighting Lighting systems Energy consumption Energy conservation Lighting system Thermal comfort Energy saving potential Energy audit Building automation LED Optimization Energy saving system	Thermal comfort Energy efficiency Air conditioning HVAC Indoor air quality Evaporative cooling Building energy saving Natural ventilation Data center Liquid desiccant Ventilation Optimization Fuzzy logic Office buildings Free cooling Air conditioner	China Energy saving potential Energy intensity Energy saving and emission reduction Emission reduction Energy consumption Energy saving device Data envelopment analysis Economic growth CFD Waste heat recovery Energy-saving technology Sustainable development Iron and steel industry Energy conservation	Optimum insulation thickness Buildings Energy consumption Residential buildings Building envelope Thermal comfort Insulation Thermal insulation Energy Life cycle cost District heating Payback period Retrofit Energy saving measures Insulation thickness	Phase change material Cool roof Energy efficiency Thermal comfort Green roof Buildings Building energy saving Passive cooling Thermal energy storage Building envelope Urban heat island Solar reflectance PCM Non-linear complex heat transfer Finite element modelling Sustainability

Communications equipment	HVAC machines	Household - Behavior	Power, Chemical and Petrochemical Industry	Communication protocols
(6.29%)	(6.25%)	(6.01%)	(5.95%)	(5.02)
Heterogeneous networks LTE Cellular networks Green communications Sleep mode Green networks Green networking Small cell Energy consumption Base station Optimization Green Internet Traffic Engineering Energy-saving management LTE-Advanced	Emission reduction Variable speed drive Energy consumption Thermal comfort Energy management Efficiency Air conditioning Energy Optimization HVAC system Compressed air systems Energy conservation Energy audit Induction motors Machine tool	Energy consumption Energy saving behaviour Behavior Household Residential buildings Residential sector Climate change White certificates Energy conservation Energy saving potential Energy audit Willingness to pay Occupant behavior Energy Persuasive technology	Distillation Heat integration Dividing wall column Reactive distillation Heat pump Process simulation HIDiC Self-heat recuperation Extractive distillation Economics Process design Heat exchanger network Simulation Optimization Exergy analysis	IEEE 802.16e Cloud computing Energy efficiency Sleep mode Smartphone Energy consumption WiFi WiMAX Cellular networks Power control LTE Mobile TV offloading Mobile cloud computing Virtualization

Electricity market	Hydraulic machinery	Cogeneration	Railway	Public buildings
(4.75%)	(4.47%)	(4%)	(3.46 %)	(2.63%)
Energy saving and emission reduction Electricity market Energy-saving generation dispatching Energy-saving and emission-reducing Energy-saving dispatch Smart grid Sleep mode Distribution network Passive optical networks QoS Energy efficiency EPON Unit commitment Genetic algorithm Power system	Hydraulic excavator Excavator Accumulator Energy efficiency Hybrid system Energy recovery Hydraulic system Hybrid power Hydraulic transformer Load sensing Control strategy Power matching Hydraulic accumulator Construction machinery Mechanical engineering	Cogeneration Primary energy saving Trigeneration Energy efficiency Optimization Economic analysis Operational planning Emission reduction Combined heat and power CHP Energy saving rate Solar energy Supermarket Carbon dioxide emissions Fuel cells	Optimization Regenerative braking Genetic algorithm Supercapacitor Energy storage Energy-saving operation Electric railway Regenerative brake Energy storage system Speed profile Simulation Efficiency metro Dynamic programming Traction power supply	Energy consumption Energy efficiency Activity recognition School buildings HVAC Occupancy Energy management Ventilation Energy audit Wireless sensor networks Office buildings Thermostat Smart Home Ambient intelligence IoT Context-awareness Schools

Figure 4. Communities detected for Energy Saving.

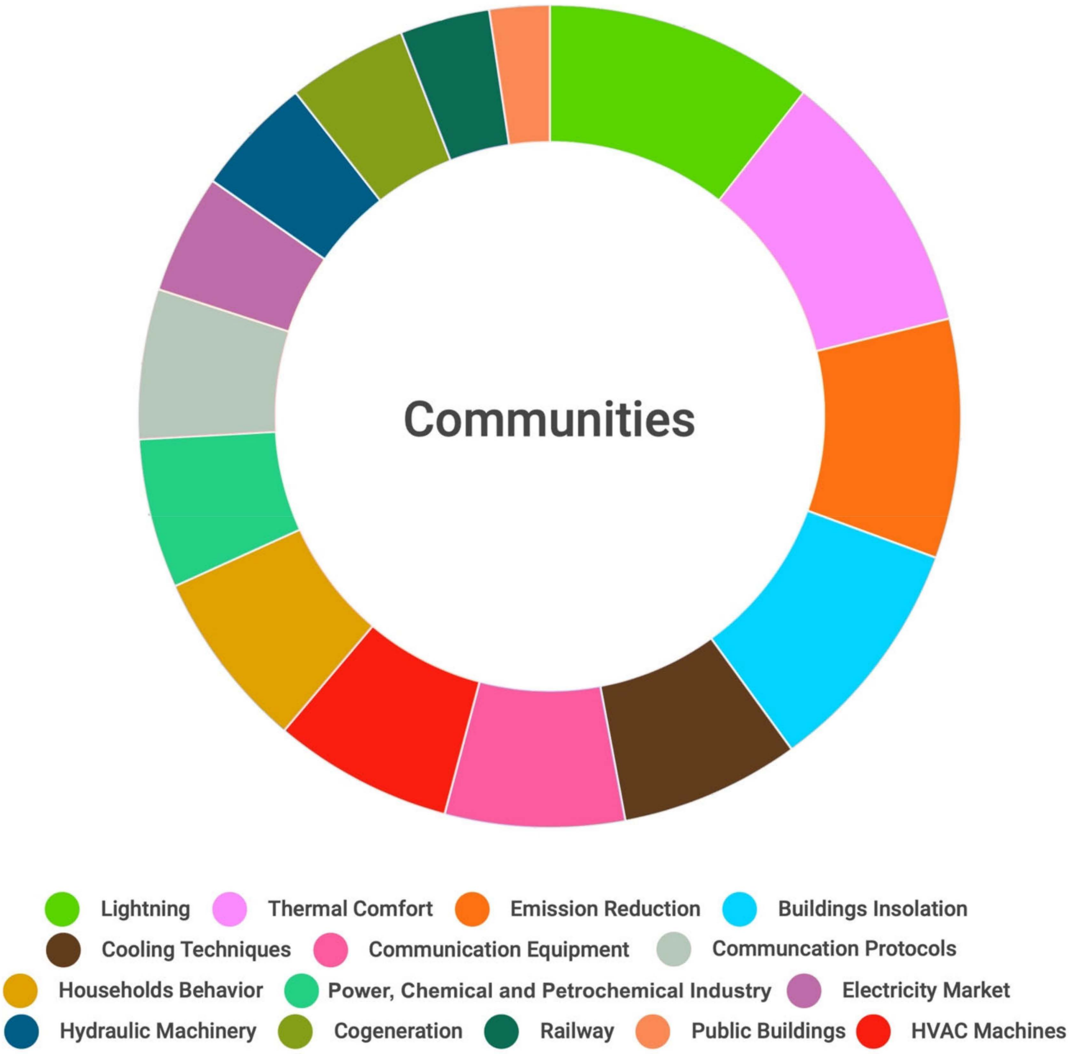

Figure 5. Communities are detected within the large network of publications related to the term energy saving.

3.2. Authors, Affiliations and Countries in Energy Saving

Regarding the authors and their relationship among them, it has been seen that in total there are 43,860 researchers. In Figure 6, the authors have been represented by colours according to the country of origin. This figure shows that the researchers that contribute most to the development of scientific production, come from academic and scientific institutions from China, which has the highest number of authors with more than half of the total number, followed by Italy (9.5%), the USA (8.9%), and Japan with 6.8%. Afterwards, with less percentage are Malaysia (4.77%) and Spain (2.2%), and finally a block of countries with a percentage below 2%. Null means that the Scopus register does not contain information on the country of the author.

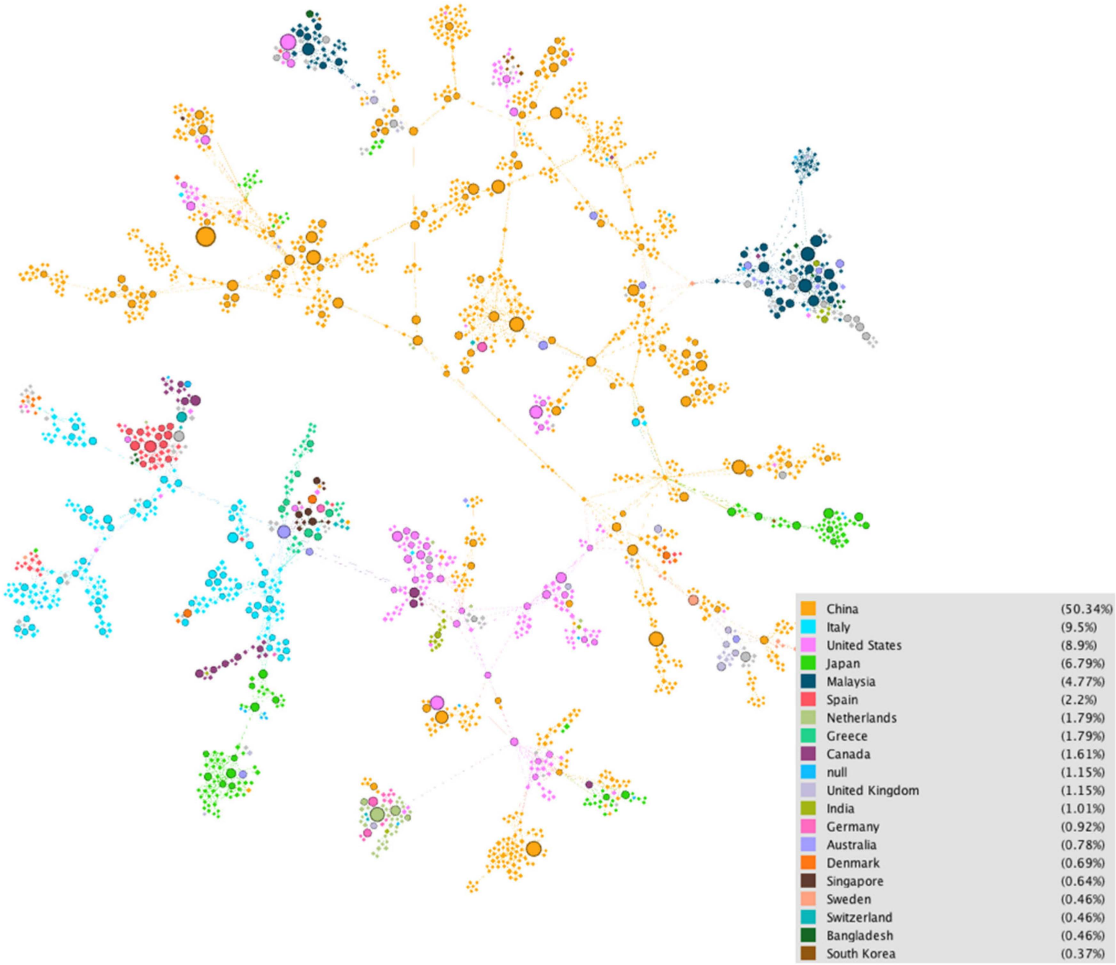

Figure 6. Collaborations between scholars from various countries. The size of the nodes is proportional to the H index.

From Figure 6 it can be drawn as conclusions that among Chinese researchers there is a tendency to collaborate among themselves, but also at the international level with American authors, Malaysians, and to a lesser extent, Japanese authors.

Whereas at European level, the relationship between its authors is with those authors belonging mainly to the European environment. These appear isolated, as can be observed in the lower left part of the graph, where it is extracted that the Italian researchers, the most productive, are mainly connected with the Spanish or with Greek authors among others, but also Japanese and Canadian.

Several layers are observed, being the most external (as explained above) that of the authors who have written about energy saving, but who do not collaborate with anyone in energy saving. Here are 2763 authors, which means a large minority. Then there are intermediate layers, where groups of collaborations are going from less to greater intensity. In this intermediate layer there are 41,097 authors, and it is observed that it is the most numerous. As a result of this international collaboration, many papers have been published.

The method is focused not only on the analysis of the scientific collaborations between institutions of each country, but also to determine which of these institutions are more involved in energy saving.

Researchers associated with Chinese institutions is shown in Figure 7, highlighting the number of people involved in energy savings in the following order: Tsinghua University (2.27%), North China Electric Power University (1.98%), and Tianjin University (1.91%).

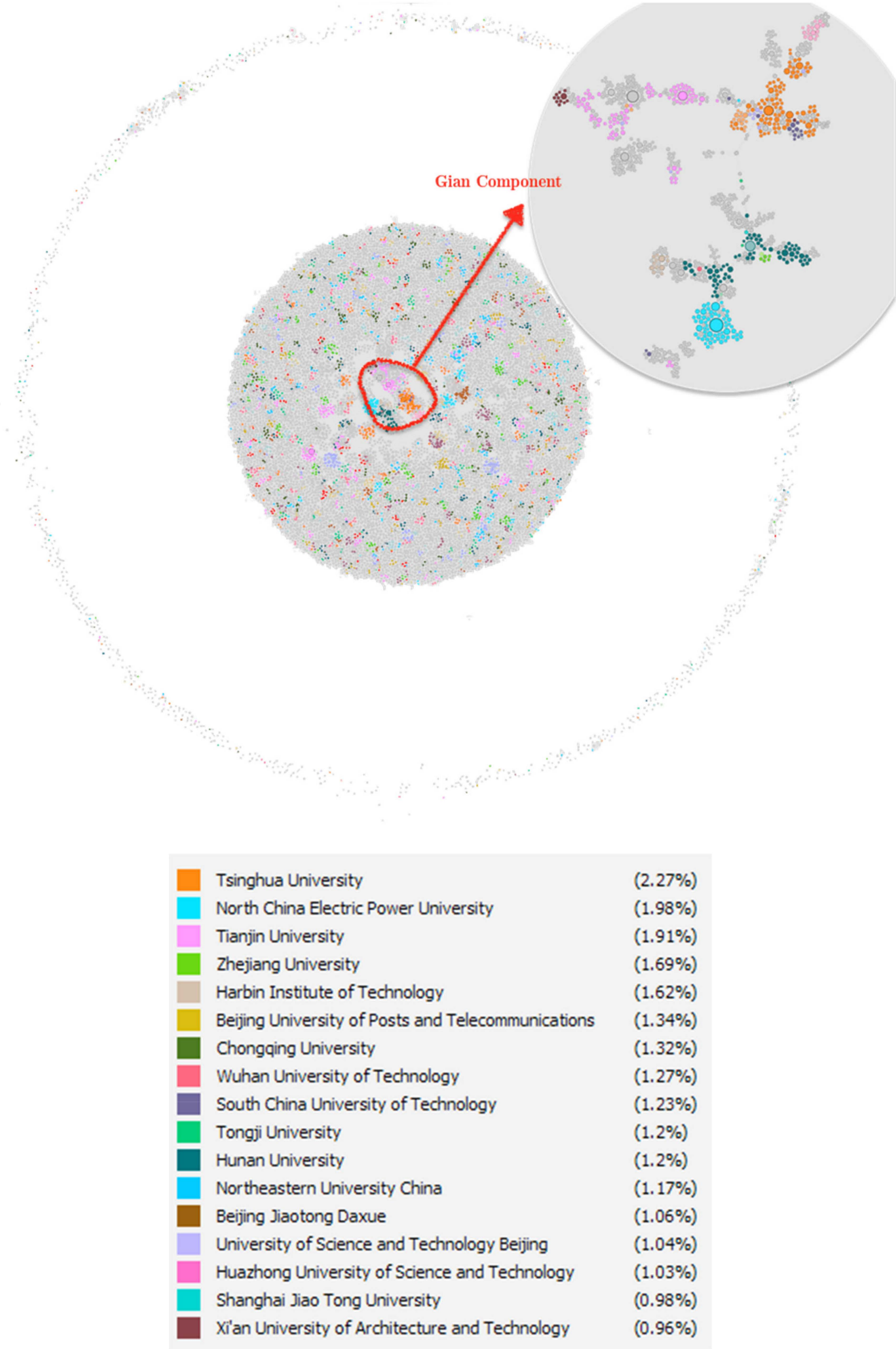

Figure 7. Connection of authors belonging to Chinese institutions.

In Figure 8 and Table 1 we can see the evolution of the publications developed by the most productive institutions worldwide in the last 10 years (2009–2018). On the bottom of the figure, the production of Ministry of Education of China can be seen, which is the most important institution registered. It does not surprise that, as a fact, it would englobe a lot of researching in the most populated country in the world. This institution represents the 1.64% of the total research (718 publications). Above it, the Tsinghua University represents the 1.59% (699 publications). This institution is one of the biggest universities in Asia with more than 40,000 students, 32,000 of which belong to masters or doctorate degree. After them, we have more institutions and as we can guess, all of them belong to China. It was a highlight surprise to notice all the research developed in this country and the high difference between China and other countries, at least in this search.

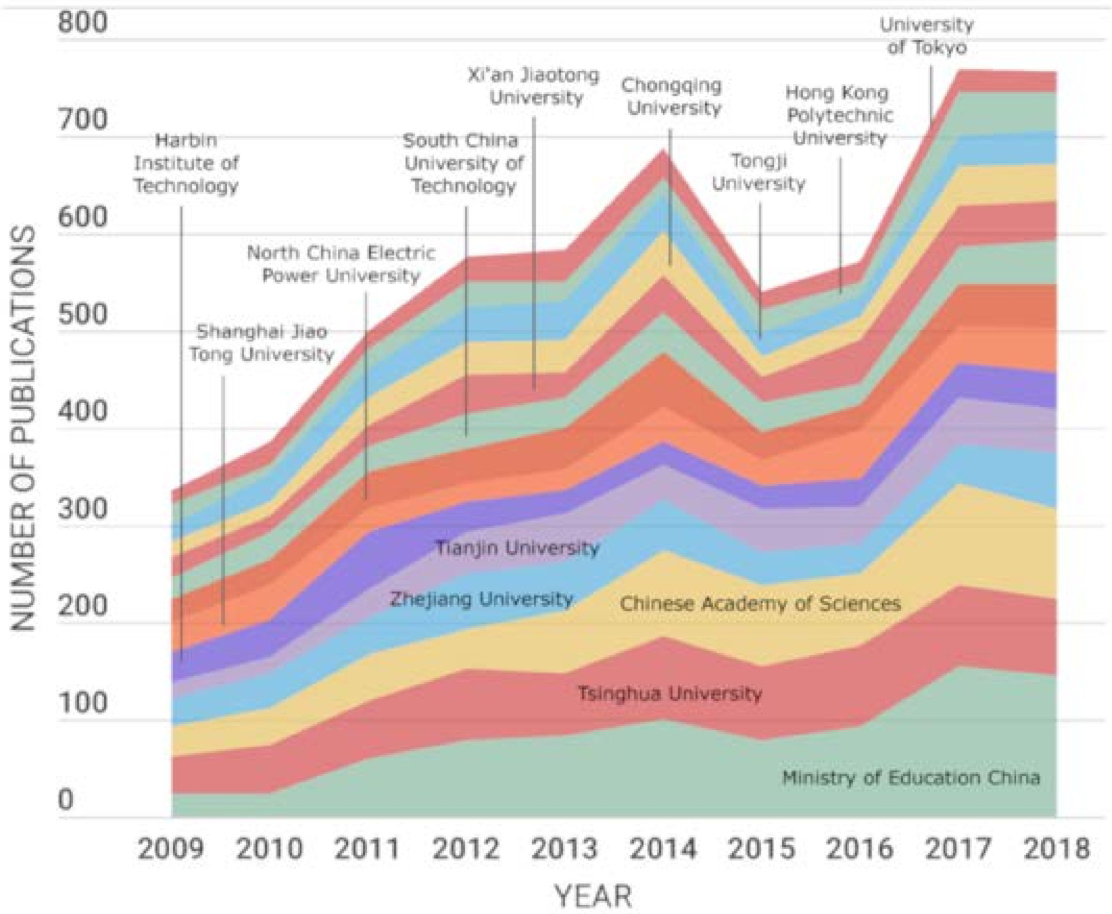

Figure 8. Ten most productive institutions during the period 2009–2018.

Table 1. Number of publications of the ten most productive institutions and universities between 2009–2018.

Institution	Total	%	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Ministry of Education China	847	1.93	24	25	60	78	83	101	78	93	154	146
Tsinghua University	703	1.60	38	48	60	74	64	85	77	83	85	78
Chinese Academy of Sciences	685	1.56	30	40	46	41	64	88	82	73	103	92
Zhejiang University	443	1.01	29	35	38	56	50	53	34	31	42	59
Tianjin University	383	0.87	18	17	30	43	52	34	45	39	48	45
Harbin Institute of Technology	352	0.80	29	38	59	32	23	25	25	28	34	36
Shanghai Jiao Tong University	344	0.78	33	34	23	18	22	36	26	50	38	46
North China Electric Power University	376	0.86	22	28	38	36	41	57	29	26	44	45
South China University of Technology	337	0.77	22	27	26	36	32	40	31	23	38	45
Xi'an Jiaotong University	331	0.75	21	17	22	41	25	39	26	44	43	42
Chongqing University	303	0.69	18	16	28	33	34	45	22	25	39	37
Tongji University	308	0.70	16	27	32	35	40	37	23	21	32	36
Hong Kong Polytechnic University	260	0.59	21	11	20	27	20	17	23	14	46	39
University of Tokyo	235	0.54	14	22	18	27	33	30	20	22	23	20

3.3. *Typology of Literature, Languages of Publications and Distribution of Output in Subject Categories*

Table 2 shows the different types of publications during period 2009–2018. We can see how more than half of the total of publications of the search are articles (50.7%). Following them, the conference papers, with 43.1% of the total. After that, the quantity decreases to different types of documents as Reviews (2.3%), Book Chapter (1.6%), or Conference Revision (1.05%).

Table 2. Distribution of the searching documents according to the type of publications between 2009–2018.

Type	Publications	%
Article	18,510	50.67
Conference Paper	15,792	43.13
Reviews	848	2.32
Book Chapters	582	1.59
Conference Reviews	384	1.05
Article in Press	188	0.52
Short Survey	75	0.21
Note	70	0.19
Book	49	0.13
Editorial	32	0.09
Other	21	0.1

The vast majority of articles are published in international journals. Because of that reason, more than 87% of the work have been published in English (31,992), approximately 10% have been published in Chinese (3642) and only 3% includes other languages as Japanese, German, Russian, Polish, or Korean. In Table 3, shows the publications organized by language. Figure 9 shows the classification of publication results by subject, according Scopus.

Table 3. Most used languages in documents.

Language	Publications	Percentage (%)
English	31,992	87.31
Chinese	3642	9.94
Japanese	395	1.08
German	203	0.55
Russian	150	0.41
Polish	71	0.19
Korean	56	0.15
Spanish	54	0.15
French	48	0.13
Ukranian	29	0.08

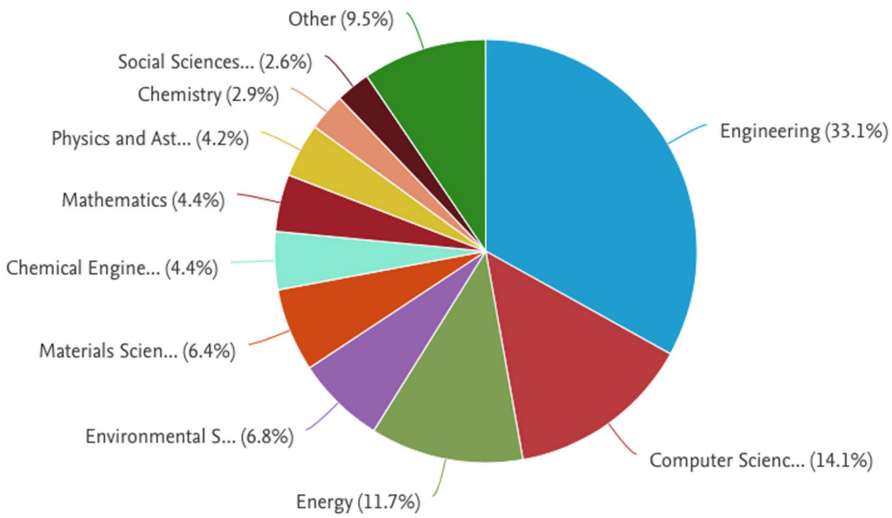

Figure 9. Classification of publication results by subject, according Scopus.

3.4. Literature Distribution by Area and Entity

Figure 10 shows the distribution of publications by country. On the map, red is associated with a high number of publications. Green indicates that there are less publications or grey means that there are no publications or a very limited number of them. It is easily observed how China is the country with more publications (18,309), followed by United States (3716), Japan, and Italy. Also highlight Germany, United Kingdom or Taiwan. This information leads us to the idea of how important the energy saving in the industrialised countries has become, as the richer states have also become involved in this issue by using harsh policies to achieve the proposed objectives. Figure 11 shows the 15 countries that have contributed the most in the last decade.

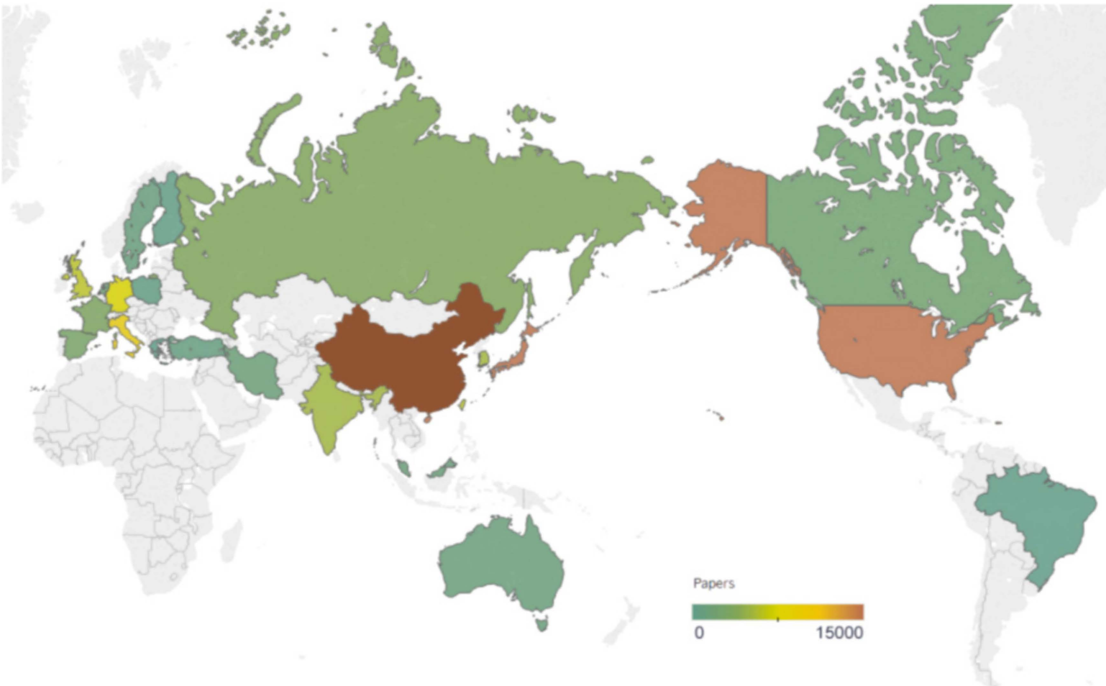

Figure 10. World Map with the 25 countries with a higher number of publications.

It should be taken into account the number of inhabitants of each country in order to properly analyse the results. It is not a big surprise to find out that China is the country with more publications as the population in China is the highest in the world (1,386,000,000 in 2017). This is followed by United States, also with a high population: 327,200,000 at 2018 and Japan with 126,800,000 in 2017. However, it is interesting to find countries such as Italy (60,590,000 in 2017) or Germany (82,790,000) with a lower population but still with a significant number of publications.

In Figure 12, the five keywords that appeared the most in our search are shown. 4/5 of these are related to energy, being the usual investigation and research of this field to create and find new ways of energy optimization and its use in new technologies. We can see how the term "Energy Conservation" started to be used in the beginning of the century and it has increased remarkably from 2013. In the second place, there is the term "Energy utilization" followed by "Energy Efficiency". After them "Energy saving" was very often used from 2008–2010, but it decreased as the researchers tend to focus their work in the conservation of the energy more than the saving of it.

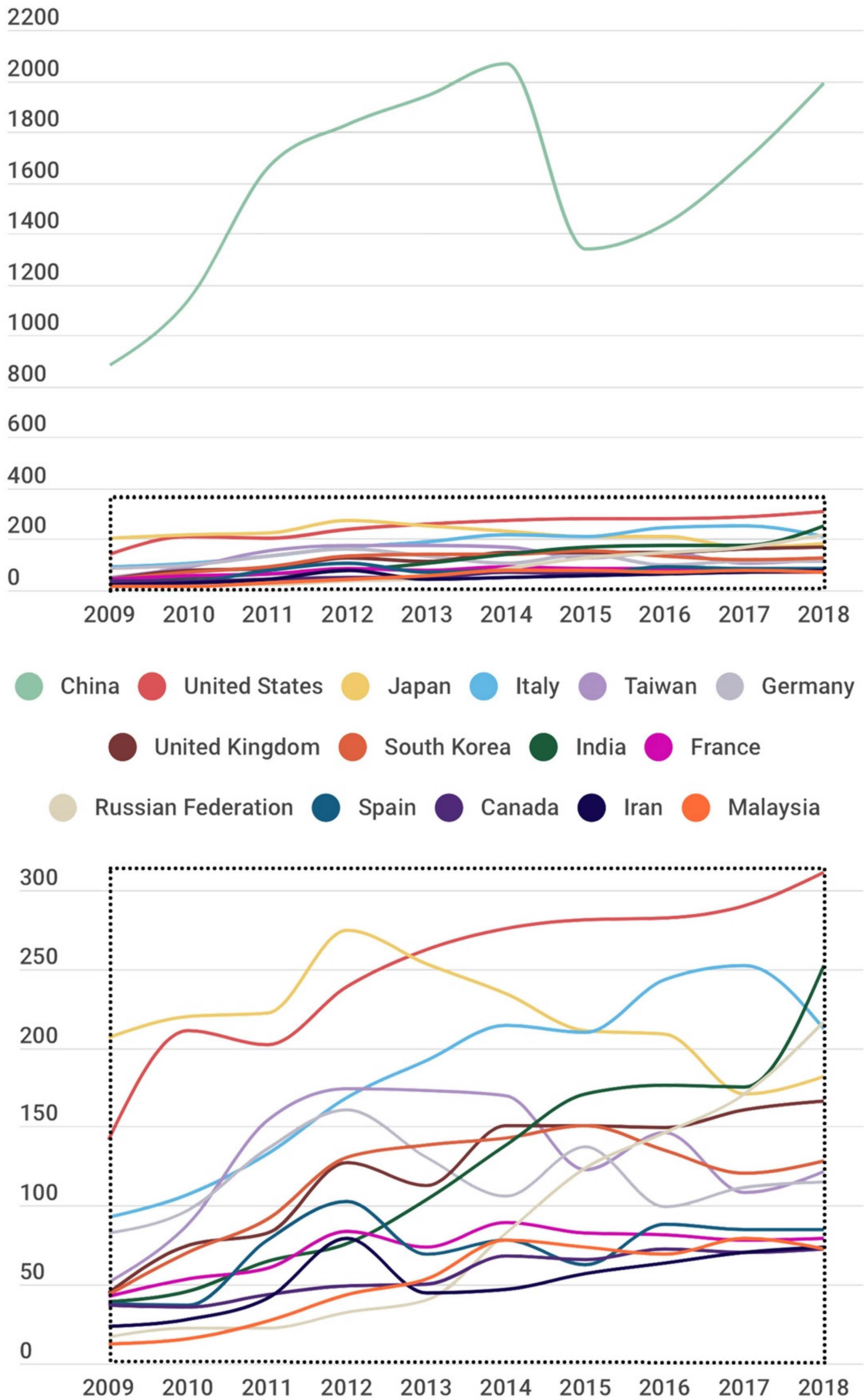

Figure 11. 15 countries that have contributed the most in the last decade.

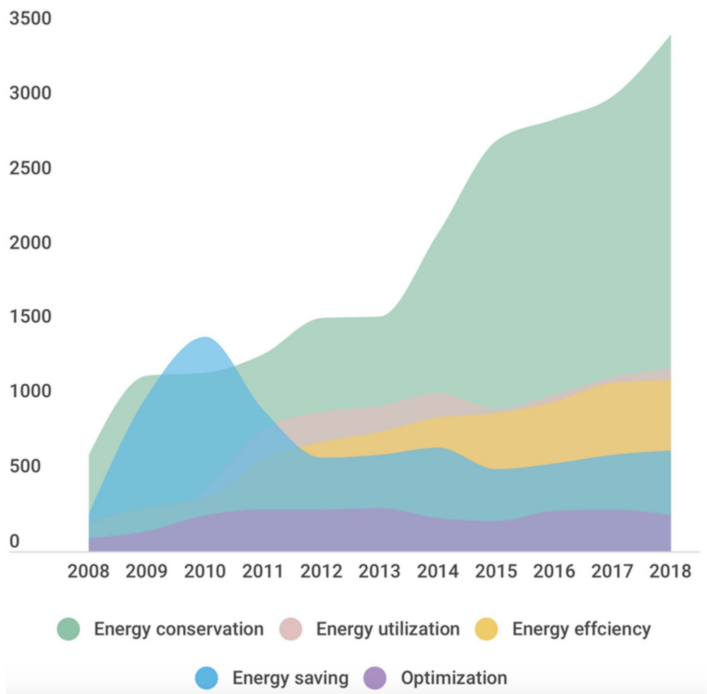

Figure 12. 5 most important Keywords and how often they were used during the last decade.

In Figure 13 and Table 4, the ranking of the six most important journals are shown. We have analysed not only the Scimago Journal Rank by Elsevier, but also the CiteScore. The metric of the latter calculates the citations of all papers submitted in the past few years preceding a title. It also includes Source Normalized Impact per Paper, SCImago Journal Rank, quotation and documents counting, and quotation rates. In the figure we have included also the H-Index as it has become very popular in the last decade and the reader can figure it out by the size of the circle according to each of the journals. We can see how "Renew. Sust. Energ. Rev." is the journal with higher not only SJR (3.04), but also CiteScore (10.54).

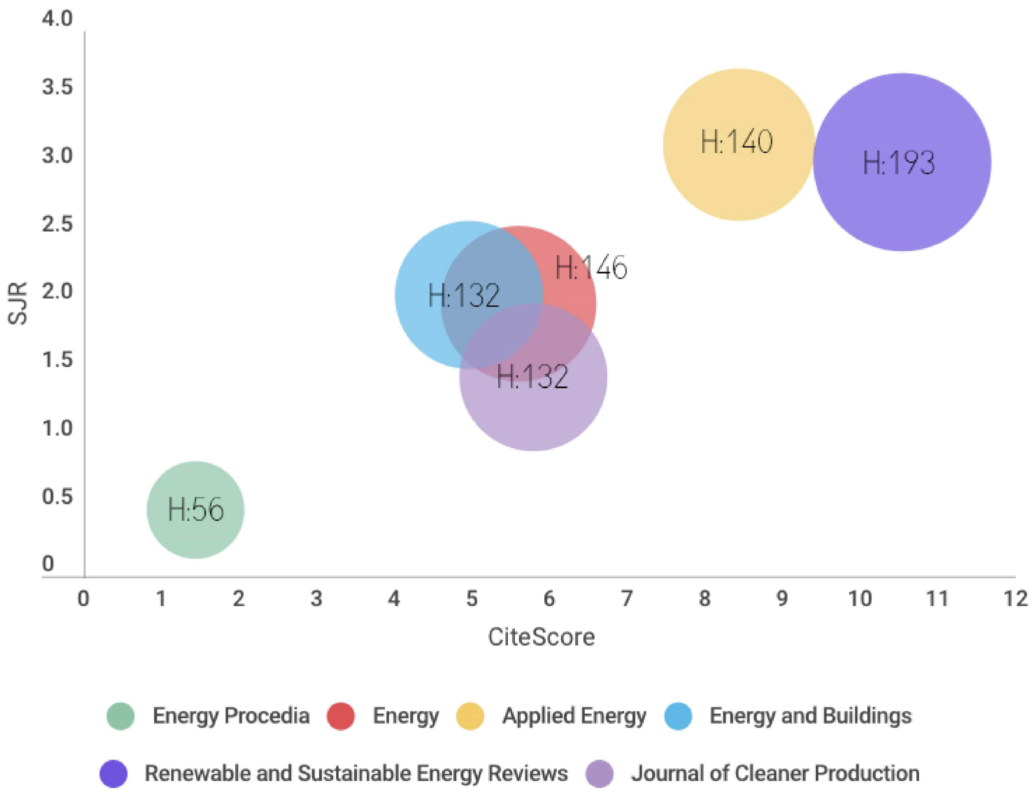

Figure 13. Classification of the first 6 journals. CiteScore is the Scopus ranking and SJR (Scimago Journal Rank) by Elsevier. The size of the circles indicates the H-index.

Table 4. Most important journals through the research.

Journals	Country	Quartile	JCR	H Index	Cite Score	SJR	SNIP
Energy Procedia	U. Kingdom	Q2	#N/A	56	1.44	0.49	0.799
Energy	U. Kingdom	Q1	4.968	146	5.6	1.999	1.923
Appl. Energy	U. Kingdom	Q1	7.900	140	8.44	3.162	2.765
Energ. Buildings	Netherlands	Q1	4.457	132	4.96	2.06	2.120
Renew. Sust. Energ. Rev.	United States	Q1	9.184	193	10.54	3.04	3.594
Journal of Cleaner Production	United States	Q1	5.651	132	5.79	1.467	2.194

The 21st century is the century of sustainability. This is why the building sector is investing a lot of resources in increasing energy efficiency, concerning both the materials and technologies used to make buildings and building techniques more energy efficient. In other words, it is not only a question of constructing more energy-efficient buildings, such as passivehause buildings and internship rehabilitation, but also of how to construct them, applying more efficient construction techniques, energy savings that must also be extended to the manufacture of construction materials and their transport to the construction site.

In Figure 14 we can see the most important authors related with the search through 2009 to 2018. The most important author is Kansha, who against all odds, is not from China, he is from Japan and has published a total of 57 papers related to the search, representing the 0.16% of the total of publications. He has a total of 1103 citations through all his work and a h-Index of 21. After him, Yang has a total of 47 works (0.13%) related to energy saving. All his work has a total of 8829 citations, getting a 45 H-Index. Other authors such as Li go after with 45 works (0.12%) and the Japanese Tsutsumi with 44 (0.12%).

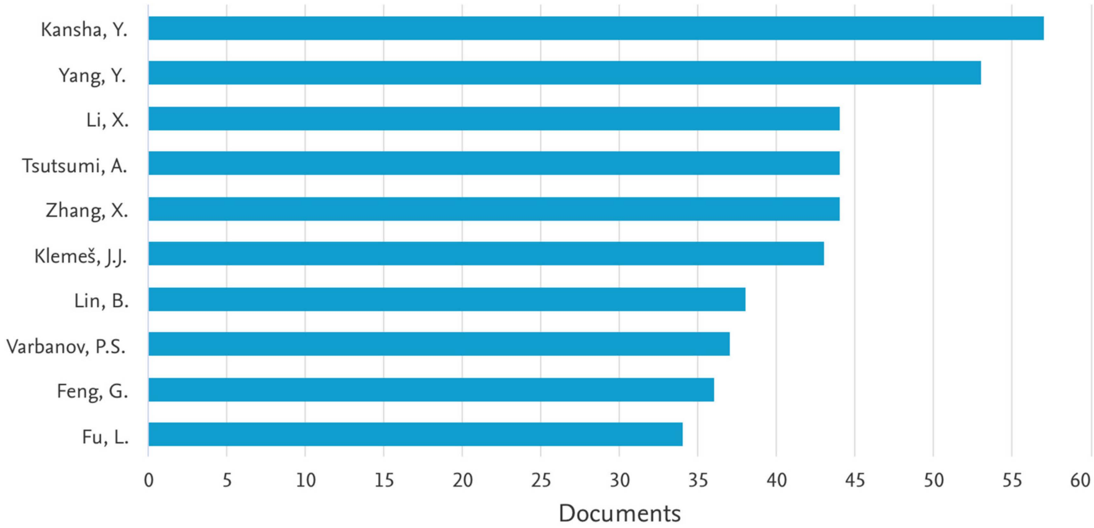

Figure 14. Authors who have published related with the search through the last 10 years.

4. Discussion

The scientific publications in relation to energy saving have had an exponential growth since the year 2000, from that date until now more than 90% of scientific production is condensed. This indicates that the last 20 years are those that have generated the interest of the States through their researchers and programs to support this research. For example, the research related to energy saving in communication and computation [32]. The works published in the topic of energy saving, are mainly in the form of scientific articles (50.7%), but there is an important number in the form of conference papers (43.1%), which indicates that today it is a novel field of research, in which this topic is addressed in many scientific meetings. It is observed that the books are a percentage below 1%, which means that it is not yet a very well established issue.

Regarding the language of publication, as expected, is dominated by English in more than 87.1%. However, when compared to other scientific fields, it is usual to be above 90%, which suggests that journals in particular countries address this issue in a significant way. As example the Dianli Xitong Zidonghua/Automation of Electric Power Systems, or Zhongguo Dianji Gongcheng Xuebao/Proceedings of the Chinese Society of Electrical Engineering. Such is the case of China, which contributes almost 10% of all publications in its own language. To a lower extent, German (e.g., the journal eb—Elektrische Bahnen) and Japanese (e.g., the journal IEEJ Transactions on Power and Energy from The Institute of Electrical Engineers of Japan), both around 2%, stand out. In any case, it is clear that China, as one of the world largest consumers of energy, has a great concern for energy saving [33], as was to be expected. This is also evident if it is observed that the main institutions that publish on this subject are also from China, Table 2. If the analysis focuses on the scientific fields where these works are assigned, Figure 9, it is remarkable that the first is not energy, but that the first place is occupied by engineering with 33.1%, showing that developments in this field are the largest part of the contributions, especially those related to energy conservation [34]. On the other hand, it is surprising that Computer Science plays such an important role in this field; this is justified by optimisation-related works [35]. Finally, it should be noted that one of the largest group is "others" with 9.2%. This should indicate the great diversity of scientific fields from which this subject is approached, being important the contribution to the energy saving that is studied from the greater number of points of view [36], which is what will allow to contribute to the global energy saving including geographical areas with serious energy shortages [37].

From the point of view of the networking of the works among themselves, this work shows a vast number of works published on the subject of energy saving, but the most important fact is that about 62% do not cite other work related to this subject. This implies great individualism, and scarce scientific connection in this field, which should make researchers reconsider, because it is important that research is based on previous studies to progress. However, it may also imply that they are researchers from other fields of knowledge who are becoming aware of or are including these items in their work, which is very encouraging. Within the works that are related to each other and are the core of scientific research in energy saving through the identification of communities have been detected the top 15. In the central positions, we find the scientific fields that might be said are most popular, see Figure 4: Lighting, thermal comfort, building insulation, cooling techniques, HVAC techniques, household-behaviour, or public buildings. Lighting has undergone a revolution since the emergence of solid-state light sources. The efficiency of solid-state technology provides, in a multitude of applications, energy savings, and environmental benefits [38]. Above all energy saving based on lighting has been studied for residential issues [39], public buildings, schools [40], or shopping malls [41]. Another one of the great challenges of energy saving is thermal comfort. Thermal comfort implies a good indoor climate that is important for the success of a building [42], not only by making its occupants feel comfortable, but also by deciding their energy consumption and thus influencing its sustainability [43]. On the other hand, persons have a natural trend to adapting to the conditions changing in their surroundings. This is especially the case with the scientific communities found around the central core of energy saving: building insulation, cooling techniques or HVAC techniques. Therefore, saving energy from households is one of the priorities of most countries, such us China, Italy, USA, or Japan. Those that occupy external positions are considered less integrated with the others, still have great possibilities of integration with the core and are generally the smallest. This is the way to find it: Distillation, communication protocols, electricity market, communication equipment, or railway. Related to these scientific communities it should be mentioned that distillation is still the most popular separation technology of chemical plants, and it uses around half of the operational costs, which shows the major concern of the researchers in applying here the energy saving. The energy savings in the communication protocols has been developed mainly using mobile telephony, where the terminals have a limited battery capacity. The third scientific community found is that related to the electricity market, being this one of variable tariffs, makes energy savings in certain time slots is of special interest. Regarding communication equipment, given the rising digital level of the developed countries, there is a growing concern about the data centres, especially in two respects, cooling and IT load. The amount of world energy consumption has gone from 0.5% in 2000 to 1% in 2005. With respect to the railway, the electric railway system is considered the most environmentally friendly means of locomotion. This is due to two important points: Firstly, the low resistance to running and secondly, the regeneration of energy during braking.

5. Conclusions

This study presents a wide range of data on the international contribution to scientific knowledge in the field of energy savings during the period from 1939 to 2018. The newness of this work is the application of community detection algorithms which identify scientific communities in the world that develop their work in fields related to energy saving. They also detect the collaboration preferences of their authors at an international level or even at an institutional level as in the case of China. It should be noted that many of the published papers have been the result of this international collaboration.

This methodology makes it possible to understand two complex systems: the network of publications based on quotations and the network of scientific collaborations based on the nationality of the co-authors.

Research Network Bot was used to search for publications indexed by Scopus containing ’energy savings’, in the title or keywords. The information obtained was used for the analysis and graphical representation of these networks of scientific collaboration of researchers working in this field.

49,539 documents have been found, from which 55.5% are articles and 38.5% are conference papers. In this period there has been an exponential increase in publications, highlighting the categories of Engineering, Energy, and Computer science.

In light of the data obtained, Chinese institutions have provided an important contribution to the field. It is noted that, logically, the compound terms related with energy are the most used keywords, being energy conservation, energy utilization, energy efficiency, energy saving, and fifthly, optimization, proved as the most popular terms. Different aspects of the publications are analysed, such as language, type of publication, scope, top contributors' countries, institutions, journals, authors, as well as the frequency of appearance of keywords. Geographically, the giants China and United States, followed by Japan and Italy are highlighted as the top contributors' countries. The most active categories within the field of Energy are Lighting with 9.44%, Thermal Comfort (9.18%), Emission reduction and Buildings Insulation, both of then representing more than 8.5%. These 4 fields represent areas where energy saving plays a very important role as buildings, responsible for more than 40% of the energy consumption. In order to reduce this, there should be a release of a kind of regulation or policy to control systems for the installation of lighting.

Therefore, the communities that are in the lead, refer to the state of comfort, but also to the latent concern for the waste emitted into the atmosphere and how these can directly affect our planet in the future. Policies actually adopted in developed countries are insufficient to ensure a significant reduction of the energy consumption. It forecasts that the current global demand for energy in buildings will double by 2050. Thus, it is necessary to implement, at the global level, effective saving policies [44]. The challenge is always to reduce the energy consumption without forgetting the comfort of the user and the requirements of the building. The results of the work show that during the last 10 years have substantially increased the number of publications in this field, which indicates that research in terms of energy saving is assumed as an important and relevant issue in the international scientific scene.

During the last decade China, the most productive country in "energy saving" has become the main leader in the growth of energy efficiency. Its GDP grew a total of 7.8% per year and the energy intensity fell a total of 18.2%. This outstanding result is related with how energy efficiency policies have become the center of the political landscape through these year [45]. Energy efficiency was first included in the five-year plans, in the mid-2000s. It was a first sign of China's acceleration towards greener policies. In addition, energy efficiency has played a role in number of key Chinese economic policies: The market liberalisation and privatisations of the 1990s, the quest for energy security, economic development, or the fight against climate change.

This shows that there is a correlation between the number of publications in this country and the application of energy policies, but we do not have data to extend this assertion to the rest of the countries of the world. The study of the implementation of energy policies in each country, the energy savings achieved and the relationship with its scientific production on the subject, both quantitatively and qualitatively, would be the subject of future work.

Author Contributions: J.L.d.l.C.-F. and C.d.l.C.-L. performed the literature review and article writing. A.A. and A.-J.P.-M. analysed the data using community detection methods and article writing. F.M.-A. and F.G.M.: Research idea, article writing, and formatting; they jointly contributed to the structure and aims of the manuscript, paper drafting, editing, and review. All authors have read and approved the final manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Wang, S.J. Discuss on building energy saving and energy saving materials. *Adv. Mater. Res.* **2012**, *512–515*, 2736–2739. [CrossRef]
2. Wang, J.; Li, L. Sustainable energy development scenario forecasting and energy saving policy analysis of China. *Renew. Sustain. Energy Rev.* **2016**, *58*, 718–724. [CrossRef]
3. De la Cruz-Lovera, C.; Perea-Moreno, A.-J.; de la Cruz-Fernández, J.-L.; Alvarez-Bermejo, J.A.; Manzano-Agugliaro, F. Worldwide Research on Energy Efficiency and Sustainability in Public Buildings. *Sustainability* **2017**, *9*, 1294. [CrossRef]

4. Alcott, B. The sufficiency strategy: Would rich-world frugality lower environmental impact? *Ecol. Econ.* **2008**, *64*, 770–786. [CrossRef]
5. Montoya, F.G.; Peña-García, A.; Juaidi, A.; Manzano-Agugliaro, F. Indoor lighting techniques: An overview of evolution and new trends for energy saving. *Energy Build.* **2017**, *140*, 50–60. [CrossRef]
6. Papadopoulou, E.V. Energy efficiency and energy saving. In *Energy Management in Buildings Using Photovoltaics*; Springer: London, UK, 2012; pp. 11–20.
7. Perea Moreno, A.J.; Hernandez-Escobedo, Q.; Jesus Aguilera-Urena, M. Water supply security and clean energy: A project proposal for irrigators in the river torrox. *Tecnol. Cienc. Agua* **2017**, *8*, 151–158.
8. AlFaris, F.; Juaidi, A.; Manzano-Agugliaro, F. Intelligent homes' technologies to optimize the energy performance for the net zero energy home. *Energy Build.* **2017**, *153*, 262–274. [CrossRef]
9. Sorrell, S. Reducing energy demand: A review of issues, challenges and approaches. *Renew. Sustain. Energy Rev.* **2015**, *47*, 74–82. [CrossRef]
10. Behar, O.; Khellaf, A.; Mohammedi, K. A novel parabolic trough solar collector model—Validation with experimental data and comparison to engineering equation solver (EES). *Energy Convers. Manag.* **2015**, *106*, 268–281. [CrossRef]
11. Sorrell, S.; Dimitropoulos, J.; Sommerville, M. Empirical estimates of the direct rebound effect: A review. *Energy Policy* **2009**, *37*, 1356–1371. [CrossRef]
12. Yun, G.; Xiang, G.; Zhang, X. The 2 °C global temperature target and the evolution of the long-term goal of addressing climate change—From the United Nations framework convention on climate change to the Paris agreement. *Engineering* **2017**, *3*, 272–278.
13. Cucchiella, F.; D'Adamo, I.; Gastaldi, M. A profitability assessment of small-scale photovoltaic systems in an electricity market without subsidies. *Energy Convers. Manag.* **2016**, *129*, 62–74. [CrossRef]
14. Dovì, V.G.; Friedler, F.; Huisingh, D.; Klemeš, J.J. Cleaner energy for sustainable future. *J. Clean. Prod.* **2009**, *17*, 889–895. [CrossRef]
15. Alcayde, A.; Montoya, F.G.; Baños, R.; Perea-Moreno, A.-J.; Manzano-Agugliaro, F. Analysis of Research Topics and Scientific Collaborations in Renewable Energy Using Community Detection. *Sustainability* **2018**, *10*, 4510. [CrossRef]
16. Pérez-Lombard, L.; Ortiz, J.; Pout, C. A review on buildings energy consumption information. *Energy Build.* **2008**, *40*, 394–398. [CrossRef]
17. Mikulcic, H.; Klemeš, J.J.; Vujanović, M.; Urbaniec, K.; Duić, N. Reducing greenhouse gasses emissions by fostering the deployment of alternative raw materials and energy sources in the cleaner cement manufacturing process. *J. Clean. Prod.* **2016**, *136*, 119–132. [CrossRef]
18. Tommerup, H.; Svendsen, S. Energy savings in danish residential building stock. *Energy Build.* **2006**, *38*, 618–626. [CrossRef]
19. Caniato, M.; Bettarello, F.; Ferluga, A.; Marsich, L.; Schmid, C.; Fausti, P. Thermal and acoustic performance expectations on timber buildings. *Build. Acoust.* **2017**, *24*, 219–237. [CrossRef]
20. Asdrubali, F.; D'Alessandro, F.; Schiavoni, S. A review of unconventional sustainable building insulation materials. *Sustain. Mater. Technol.* **2015**, *4*, 1–17. [CrossRef]
21. Leaman, A.; Bordass, B. Are users more tolerant of "green" buildings? *Build. Res. Inf.* **2007**, *35*, 662–673. [CrossRef]
22. Sant'Anna, D.O.; Santos, P.H.D.; Vianna, N.S.; Romero, M.A. Indoor environmental quality perception and users' satisfaction of conventional and green buildings in Brazil. *Sustain. Cities Soc.* **2018**, *43*, 95–110. [CrossRef]
23. Gupta, R.; Chandiwala, S. Understanding occupants: Feedback techniques for large-scale low-carbon domestic refurbishments. *Build. Res. Inf.* **2010**, *38*, 530–548. [CrossRef]
24. Perea-Moreno, M.-A.; Samerón-Manzano, E.; Perea-Moreno, A.-J. Biomass as Renewable Energy: Worldwide Research Trends. *Sustainability* **2019**, *11*, 863. [CrossRef]
25. Mongeon, P.; Paul-Hus, A. The journal coverage of web of science and scopus: A comparative analysis. *Scientometrics* **2016**, *106*, 213–228. [CrossRef]
26. Archambault, E.; Campbell, D.; Gingras, Y.; Lariviere, V. Comparing bibliometric statistics obtained from the web of science and scopus. *J. Am. Soc. Inf. Sci. Technol.* **2009**, *60*, 1320–1326. [CrossRef]
27. Aznar-Sánchez, J.A.; Belmonte-Ureña, L.J.; Velasco-Muñoz, J.F.; Manzano-Agugliaro, F. Economic analysis of sustainable water use: A review of worldwide research. *J. Clean. Prod.* **2018**, *198*, 1120–1132. [CrossRef]

28. Montoya, F.G.; Alcayde, A.; Baños, R.; Manzano-Agugliaro, F. A fast method for identifying worldwide scientific collaborations using the Scopus database. *Telemat. Inform.* **2018**, *35*, 168–185. [CrossRef]
29. Valderrama-Zurián, J.-C.; Aguilar-Moya, R.; Melero-Fuentes, D.; Aleixandre-Benavent, R. A systematic analysis of duplicate records in Scopus. *J. Informetr.* **2015**, *9*, 570–576. [CrossRef]
30. Montoya, F.G.; Montoya, M.G.; Gómez, J.; Manzano-Agugliaro, F.; Alameda-Hernández, E. The research on energy in spain: A scientometric approach. *Renew. Sustain. Energy Rev.* **2014**, *29*, 173–183. [CrossRef]
31. Bastian, M.; Heymann, S.; Jacomy, M. Gephi: An open source software for exploring and manipulating networks. *ICWSM* **2009**, *8*, 361–362.
32. Intanagonwiwat, C.; Govindan, R.; Estrin, D. Directed diffusion: A scalable and robust communication paradigm for sensor networks. In Proceedings of the 6th Annual International Conference on Mobile Computing and Networking, Boston, MA, USA, 6–11 August 2000; ACM: New York, NY, USA, 2000; pp. 56–67.
33. Wang, G.; Wang, Y.; Zhao, T. Analysis of interactions among the barriers to energy saving in China. *Energy Policy* **2008**, *36*, 1879–1889. [CrossRef]
34. De la Cruz-Lovera, C.; Manzano-Agugliaro, F.; Salmerón-Manzano, E.; de la Cruz-Fernández, J.-L.; Perea-Moreno, A.-J. Date Seeds (*Phoenix dactylifera L.*) Valorization for Boilers in the Mediterranean Climate. *Sustainability* **2019**, *11*, 711. [CrossRef]
35. Banos, R.; Manzano-Agugliaro, F.; Montoya, F.; Gil, C.; Alcayde, A.; Gómez, J. Optimization methods applied to renewable and sustainable energy: A review. *Renew. Sustain. Energy Rev.* **2011**, *15*, 1753–1766. [CrossRef]
36. Schultz, P.W.; Nolan, J.M.; Cialdini, R.B.; Goldstein, N.J.; Griskevicius, V. The constructive, destructive, and recon-structive power of social norms. *Psychol. Sci.* **2007**, *18*, 429–434. [CrossRef]
37. Juaidi, A.; Montoya, F.G.; Ibrik, I.H.; Manzano-Agugliaro, F. An overview of renewable energy potential in Palestine. *Renew. Sustain. Energy Rev.* **2016**, *65*, 943–960. [CrossRef]
38. Schubert, E.F.; Kim, J.K. Solid-state light sources getting smart. *Science* **2005**, *308*, 1274–1278. [CrossRef]
39. AlFaris, F.; Juaidi, A.; Manzano-Agugliaro, F. Energy retrofit strategies for housing sector in the arid climate. *Energy Build.* **2016**, *131*, 158–171. [CrossRef]
40. AlFaris, F.; Juaidi, A.; Manzano-Agugliaro, F. Improvement of efficiency through an energy management program as a sustainable practice in schools. *J. Clean. Prod.* **2016**, *135*, 794–805. [CrossRef]
41. Juaidi, F.; AlFaris Montoya, F.G.; Manzano-Agugliaro, F. Energy benchmarking for shopping centers in gulf coast region. *Energy Policy* **2016**, *91*, 247–255. [CrossRef]
42. Manzano-Agugliaro, F.; Montoya, F.G.; Sabio-Ortega, A.; García-Cruz, A. Review of bioclimatic architecture strategies for achieving thermal comfort. *Renew. Sustain. Energy Rev.* **2015**, *49*, 736–755. [CrossRef]
43. Nicol, J.F.; Humphreys, M.A. Adaptive thermal comfort and sustainable thermal standards for buildings. *Energy Build.* **2002**, *34*, 563–572. [CrossRef]
44. Berardi, U. A cross-country comparison of the building energy consumptions and their trends. *Resour. Conserv. Recycl.* **2017**, *123*, 230–241. [CrossRef]
45. Voïta, T. The Power of China's Energy Efficiency Policies. In *Études de l'Ifri*; Ifri: Paris, France, 2018.