

Zhou, Wei; Kou, Aiqing; Chen, Jin; Ding, Bingqing

## Article

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## Research paper

## A retrospective analysis with bibliometric of energy security in 2000–2017

Wei Zhou<sup>a,b</sup>, Aiqing Kou<sup>a</sup>, Jin Chen<sup>a,\*</sup>, Bingqing Ding<sup>c</sup><sup>a</sup> Business School, Yunnan University of Finance and Economics, Kunming 650221, PR China<sup>b</sup> Business School, Sichuan University, Chengdu 610064, PR China<sup>c</sup> Business School, East China University of Science and Technology, Shanghai 200237, China

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## ABSTRACT

In recent years, some countries are facing the problem of energy security. Energy security is an important factor affecting the national economy and environment. There are many investigations about energy security, but few of them are bibliometric analysis, including co-citation analysis, hot topics, burst detection, and emerging trends. Therefore, this paper adopts a bibliometric method to address the above issues and provide a general picture of the research field. By downloading 2845 articles from Web of Science and analyzing the results given by CiteSpace, the main conclusions of the most productive countries, institutions, sources, authors, and interesting research directions in the energy security researches are visually demonstrated. For instance, *Energy Policy*, *Renewable Sustainable Energy Reviews*, and *Applied Energy* are the major sources for energy security researches. The emerging trends in energy security researches are energy security, the exploring proposition, the integrated assessment. This paper provides an overall analysis of energy security researches and gives some inspirations for the researchers in this area to do further investigations.

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## 1. Introduction

Energy security is considered as an important driving factor for sustainable socio-economic growth in every country. It also significantly reflects the stable energy supply, energy efficiency, and environmental protection in sustainable development (Chung et al., 2017). As a result, some measures of evaluating energy security were proposed, such as the “energy security assessment instrument” (Vivoda, 2010), the integrated simulation model (Prambudia and Nakano, 2012), the geo-energy security evaluation model (Hu and Ge, 2014) and the energy supply chains (Rafique et al., 2017). Besides, it is found that there is a strong relationship between energy security and climate change, then the energy security related to climate change is further investigated (Huntington and Brown, 2004; Chalvatzis and Hooper, 2009; Mccollum et al., 2013; Dellano-Paz et al., 2016). Energy security has become significant due to the growth of environmental change which proved greatly impacts on human living. In addition, some scholars also study how to enhance energy security. In recent years, some measures were taken to enhance energy security, such as utilizing the completely closed fuel cycle scheme (Kim et al., 2009), increasing the diversity of renewable energy (Aslani et al., 2012), reducing dependence on

gas import (Dyson and Konstadinides, 2016). It is found that energy security has been a hot issue.

With the increasing concern about energy security, some researchers have been analyzing the development of this research field. The bibliometric analysis is a scientific research technique and it is getting growing attention (Alvarez-Betancourt and Garcia-Silvente, 2014). Indeed, the field can be traced to prior quantitative studies in the early 20th century, which aimed to find out the rules of scientific activities, such as exploring the characteristics of the literatures on the production of bioenergy (Konur, 2012) and observing in macrology biomass as a source of biofuel feedstock (Coelho et al., 2014). These articles help researchers to find out the focuses and hot topics in the future. Meanwhile, many methods can be applied to further investigate energy security from the perspective of bibliometric analysis, such as CiteSpace, UCINET, VOSviewer and global maps of science. Among these bibliometric methods, CiteSpace is one of the most popular tools (Chen, 2006; Chen et al., 2010). It is particularly designed to support the analytic process of visualizing with the advantage of producing co-citation networks based on article citations to reveal the structure of a particular research field (Chen et al., 2012). Thus, the new method has been applied widely, such as the bioinformatics (Song et al., 2014), the big data (Prathap, 2014), the renewable energy research progress in Mexico (Alemán-Nava et al., 2014), the geographic information systems (Wei et al., 2015), the carbon tax (Zhang et al., 2016), the hospitality research (Li et al., 2017), the low carbon

\* Correspondence to: No. 2374, Longquan Road, Kunming, 650221, PR China.  
E-mail addresses: [zhouwei907@ynufe.edu.cn](mailto:zhouwei907@ynufe.edu.cn) (W. Zhou), [437805809@qq.com](mailto:437805809@qq.com) (A.Q. Kou), [monkiis@163.com](mailto:monkiis@163.com) (J. Chen), [1446202654@qq.com](mailto:1446202654@qq.com) (B.Q. Ding).

development transformation (Wang et al., 2017), the carbon emissions trading (Yu and Xu, 2017), and the organic Rankine cycle technology (Imran et al., 2018). Therefore, CiteSpace has inspired scholars in various fields, telling them that there are still some new areas needed to be explored.

Even though many researchers have analyzed energy security research from different perspectives with various methods, few of them attempted to investigate the mapping knowledge domain of energy security research. Meanwhile, due to the reason that most of the research fields are dynamic with the change of the society and the environment, it is necessary to utilize an effective method to analyze the current status and the emerging trends of these areas. It is believed that the results given by CiteSpace can be more intuitionistic and comprehensive. Besides, some useful information of energy security research will be known to enable beginners to learn about this area and to help researchers with their further investigations. Therefore, the motivation of this study is to fill the gap between scientometric analysis and energy security research. Due to the growing number of publications about energy security, it is significant to make a good summary of the current status and the development trend in energy security. Using CiteSpace to analyze energy security would help provide a clear picture on how knowledge and theories change as time goes by. Therefore, this paper analyzes all the related articles downloaded from Web of Science by CiteSpace. According to the statistics of keywords, authors, countries and cited references, this paper illustrates the corresponding graphs and tables for the further researches based on modern bibliometrics to introduce the overall situation of the research on energy security and give some inspirations for scholars about their research directions.

To achieve the above aims, the paper is organized as follows: Section 2 mainly introduces the researches about energy security and citation analysis, in which the source of data and corresponding operational process are discussed. The current status, the research focuses and the hot topics are included in Section 3. Section 4 demonstrates the burst detection in the energy security research field and informs the potential research directions. Finally, Section 5 is the summary part based on the above results.

## 2. Research method and citation analysis of the energy security research

Before using CiteSpace, analyzing the step of building a database is necessary. Then, the productive countries & territories, institutions, hotspots, research trends, keywords and bursts of various papers in energy security research area are identified by CiteSpace. Several different visualization graphs can be generated.

### 2.1. Constructing database for citespace

There are two steps in building a database for CiteSpace analysis. The first step is to choose the database. The database should contain the most complete literature as suggested by Chen et al. (2010), co-citation networks as indicated by selection articles' references should also be included in the database. Cited references by a given article provide valuable information regarding intellectual connections between various concepts and theories (Small, 1973). To fully capture the knowledge map and the evolution process of energy security discipline, WoS is selected as the data source for bibliometric analysis, because it is a huge platform that provides an access for readers to know specific information about the articles published in roughly 12,000 leading journals worldwide (Leeuwen, 2006). The Science Citation Index (SCI), the Social Sciences Citation Index (SSCI), and the Conference Proceedings Citation Index-Science (CPCI-SCIENCE) databases are included in it. Second, choose appropriate keywords to select articles from the

database. Researchers should pay more attention to the validity and representation of keyword and check performed to assess the relevance of each study returned. By researching the topic “clean energy”, a total of 2845 articles (published from 2000 to 2017) were retained which exclude the conference proceeding citation index-science. There are two major reasons for this study to choose the research period: (1) many publications with significant theoretical and practical contributions were published after 2000; (2) the study focused on the recent research of energy security, so the latest papers of this research field are taken into account.

### 2.2. Mapping knowledge using CiteSpace

After choosing the database, the mapping knowledge of clean energy is introduced by using CiteSpace. First, in order to observe the trend of publications and citations over time, the number of publications and citations about clean energy from 2000 to 2017 are analyzed. Second, CiteSpace is utilized to investigate the evolution of energy security researches. The analytical process consists of categorizing knowledge clusters in the energy security research area, identifying major clusters in the energy security knowledge map, and conducting a timeline analysis on significant keywords in terms of origin, development and current status. Based on the frequency of keywords in articles, the hot research topics and emerging trends in the energy security field can be found. A further step is to identify the most productive countries & territories and institutions in energy security research development. For example, comparative analysis of knowledge evolution could be performed between 2000 and 2017. Then, contributing authors, sources and research direction were tabled. This can help identify major contributing factors for the evolution of the energy security knowledge map. Last but not least, the burst of certain references, authors, and keywords can be used to analyze the evolution and the most recent research trends in energy security research. The burst refers to a significant change of a variable's values in a relatively short time. CiteSpace considers this type of change as a way to identify the front line of this research field. Next, a citation analysis of energy security studies will be investigated in detail.

### 2.3. Citation analysis of the energy security research

The literature data of energy security researches are downloaded from Social Sciences Citation Index (SSCI) and Science Citation Index Expanded (SCI-E) via Web of Science on Dec 31, 2017. Based on 2845 papers published from 2000 to 2017, the number of publications in each year of energy security researches can be seen in Fig. 1.

The term “energy security” firstly appeared in 1973 after the first oil shock. Moreover, the signing of the Kyoto Protocol marks a redefinition of energy security in countries around the world in 1997. In order to analyze the current status and the development trends in energy security research field, the paper sorts out the publications and citations primarily in this area. Fig. 1 illustrates the number of publications from 2000 to 2017. It is obvious that the literature about energy security are increasing as time goes by. In order to analyze the change of publication amount, this paper divides the whole period into two phases: the development phase and the rapid growth phase. The number of published articles prior to 2006 was below 30 and increased slowly. Although some researchers claimed that energy security could significantly impact on economy and environment, most articles presented an extensive analysis of the environment rather than deep analysis of energy security.

After 2000, many energy accidents happened around the world, for example, Davies Beas nuclear power station in the United States had happened coolant leakage accident in 2002, Japan Mei Bang

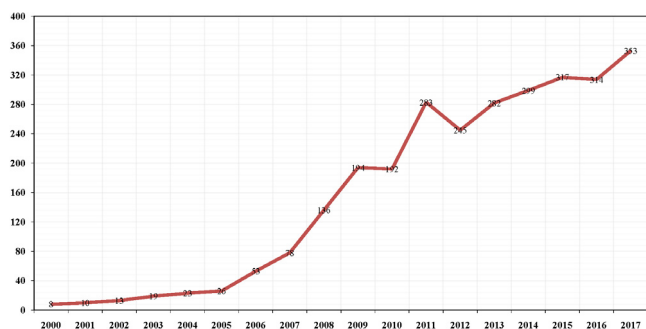


Fig. 1. Number of publications in the energy security researches from 2000 to 2017.

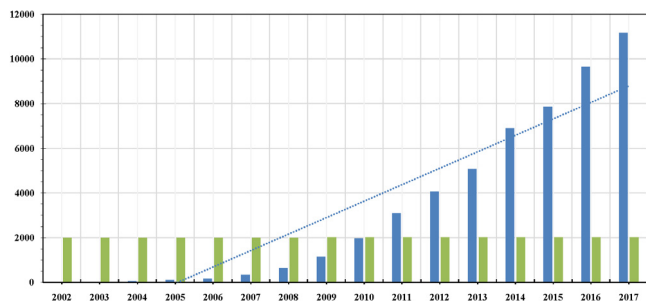


Fig. 2. Number of citations per year in energy security research field from 2002 to 2017.

nuclear power station had serious accident caused by the reflection heap in 2004, and Japanese Fukushima Daiichi nuclear power station experienced the melting of the core in 2011, so the number of publications was increased rapidly. On the other hand, some researchers explored and discussed energy supplies and energy technologies which have significant impact on energy security research. For instance, Turner (2004) analyzed hydrogen production and agreed that hydrogen can address the issue of energy security. Herbert et al. (2007) reviewed wind energy technologies. Besides, Demirbas (2007) also reviewed the progress and recent trends in biofuels.

Then, the publication number of energy security entered the rapid development period. There are little fluctuations in the rapid growth phase. Since 2009, energy security research issues have become one of the most significant concerns among related energy, energy policy, and national environmental organizations. Especially, the number of papers has researched to 283 in 2011, with a growth rate of 47.4% compared to the figure in 2010. In this phase, the energy accidents mentioned above have also been investigated. Vivoda (2012) pointed out energy policy recommendations for the Japanese government. Visschers and Siegrist (2013) investigated people's attitude and acceptance of nuclear power. More importantly, some papers that focus on improving energy security have attracted increasing attention in this research area. Fernandez et al. (2011) evaluated the distribution networks of plug-in electric vehicles. Biofuels, bioenergy, and energy challenges are also frequently discussed in this time period. Lin et al. (2011) analyzed the opportunities and challenges for biodiesel fuel. Also, Lam and Lee (2012) critically summarized the issues and the way forward of microalgae biofuels. Meanwhile, the effect of bioenergy expansion (Popp et al., 2014) and the energy challenges in the twenty-first century (Pfenninger et al., 2014) are investigated, which have importantly influenced the development of energy security research in recent years.

According to the citation statistics in Fig. 2, an obvious upward trend over time can be observed. Specifically, the number of the

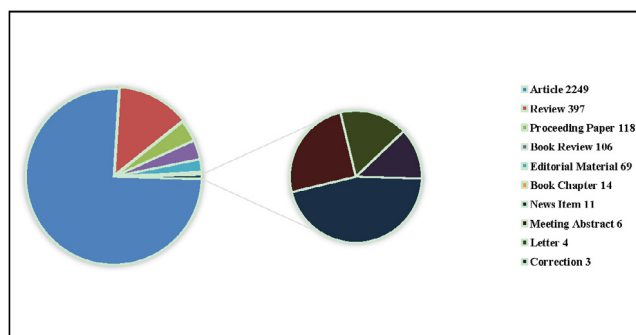


Fig. 3. Documents types in WOS area from 1993 to 2017.

2845 articles' citations per year from 2002 to 2017 is shown in Fig. 2. In total, the 2845 articles are cited for 52230 times apart from the self-citations until Dec 31, 2017, and 19 times for an average article. The number of articles expected to reach 13000 in 2018 because the average rate of increase reached 0.16 in each year from 2016 to 2017 in the field of energy security.

A total of ten different document types constitute all the documents in the energy security research area, such as article, review, proceeding paper, book review, editorial material, book chapter, news item, meeting abstract, letter, and correction. The detailed document types are illustrated in Fig. 3. There are more than 2977 documents which are downloaded based on the search strategy described in the above section, in which 132 articles can be classified into two different documents types simultaneously. It is critical and urgent to make a good summary of the current status and analyze the future development directions in energy security research.

### 3. Current status of the energy security research

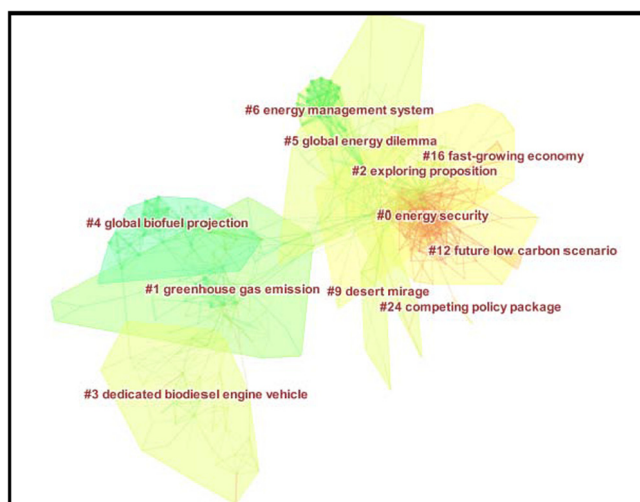
In order to clarify the current state of the energy security research, this section sorts out the research focus and hot topics of energy security, then analyzes the significant topics and productive sources, authors, countries, and institutions in energy security research area to give a detailed illustration.

#### 3.1. Research focuses and hot topics of energy security

The development of new subject needs to be based on the knowledge accumulation of relevant subjects. Similarly, no single research paper can be developed solely on the basis of its own content. The paper uses past literature and research results from its subjects or other related subjects for reference. In general, the research papers published in leading journals represent the frontiers of certain disciplines. This section illustrates the research focuses and hot topics of energy security through cluster analysis. With the assistance of computer software, the Document Co-citation Network (DCN) for the energy security shows the position of clusters and the association among clusters in co-citation network. It is easy to take a clear view of the whole picture in this field.

Co-citation analysis is more reliable to provide important insights into knowledge domains compared with citation-only analysis because citation-only analysis would risk excluding articles that hold promise. In addition, the half-life of an article is defined as the number of years that more than 50% of the total citations were made during these years since its publication. This is aimed to measure the frontier development of a research. Fig. 4 shows the clusters in the energy security research field. The clustering function was performed by choosing 'T' as the labeling source and log-likelihood ratio as the method. These clusters are labeled by





**Fig. 4.** Cluster network in the energy security research field. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

terms from their own cites. Therefore, a total of 25 significant co-citation clusters were divided by the cited references of the documents cited in each cluster and the log-likelihood ratio (LLR) algorithm. While only 10 clusters are represented in the cluster network. By analyzing the clusters, we can find out the major research areas about energy security.

The second column, Size, in Table 1 demonstrates the number of the publications in the corresponding cluster. For example, the cluster (#0) has 85 members, which is one of the largest clusters in the energy security research field. The second cluster (#1) has 57 members and the third cluster has 75 in this field. The Silhouette value in Table 1 is an index that indicates the reliability of a cluster. If this score is higher than 0.5, then the corresponding result is reliable. In this paper the silhouette scores of 7 clusters ranged from 0.749 to 0.975, suggesting that the members of each cluster were consistent enough.

The LLR (Log-likelihood ratio) value means a kind of algorithm according to the probability density function to determine the maximum likelihood and find the most likely words. The index of Mean (Year) in Table 1 represents the mean cite year for each cluster, it implies whether it is formed by recent documents or old documents. Thus, cluster #4 is formed by older documents than other clusters. It can be learned that the cluster #0 “energy security” is the newly emerging cited cluster and the average year of citation is 2011. Therefore, it can assume that the most recent research topics of energy security are “energy security” and “exploring proposition”. “Energy security” is the first cluster, with 85 members. The clusters #2 “Exploring proposition” is the third one, which indicates that the study of exploring proposition is more popular. A total of 41 citing documents formed the fifth largest cluster (#4), it was marked as global biofuel projection by LLR. This indicates a high-quality cluster analysis of the energy security knowledge mapping.

In general, the results of the clusters are reliable according to the Silhouette values in Table 1 and the classification of colors in Fig. 4. The yellow arc represents journals mainly include physics, chemistry, ecology, molecular, biology and etc. The green arc means medical aspects, such as dentistry, dermatology, surgery, medicine. It is clear to define the specialties in science mapping in terms of co-citation clusters. Moreover, the topic of “energy security” is more potential for further research due to the size and mean year of this cluster.

Moreover, the double figures overlay analysis in energy security research is shown in Fig. 5. It indicates the disciplines in this area are very extensive, including veterinary, science, physics and animal. Besides, energy security research became more interdisciplinary over time. The ellipse on the right of the chart shows the disciplines of cited papers, the most cited disciplines are veterinary, ecology and physics. There is a path starting from the left circle which can be considered as its original to the right circle which is the terminal. For example, the disciplines of cited papers about environmental, nutrition and toxicology are mostly cited from veterinary, animal and science.

Therefore, the research of energy security is multidisciplinary. With the increasing number of connections among different disciplines, there have been diverse methods researching on energy security.

In addition, analysis of keyword timeline is an effective way to show emerging trends and hot topics of research over time because the timeline of keywords gives a succinctness and accurate high-level summarization of a document. The changes in research topics have become an important research issue, which can help researchers to gain deeper insights into the development of a particular research field. The function of keywords to timeline analysis based on CiteSpace is to acquire keyword timeline matrix used for analysis of keyword timeline in this paper, so a timeline of keywords in the energy security research is illustrated in Fig. 6 and this visualization view arranges keywords in correspondence to the time of their publication or their peak time.

In Fig. 6 the purple circles represent the key studies that are high in between centrality. It can be found that there are many keywords from 2000 to 2017. In recent years, most researchers focus on the cluster (#0) “Energy security” and the cluster (#1) “Crop residue”. Diversification and energy security are the significant keyword in the cluster (#0) “Energy Security”. The topics “energy” and “bioma” are the focuses in the cluster (#1) “Crop Residue”. Earlier keywords tended to focus on national sustainable development, such as “energy”, “environment” and “technology”. In recent years, this research area pays more attention to the cluster (#1) “Crop Residue”, the cluster (#2) “UK Energy Scenario” and the cluster (#4) “South Africa”, meanwhile, the study on cluster (#0), cluster (#3), and cluster (#5) are reduced. This change may be partly caused by the development of the national economy, which leads many countries to take more measures to promote it.

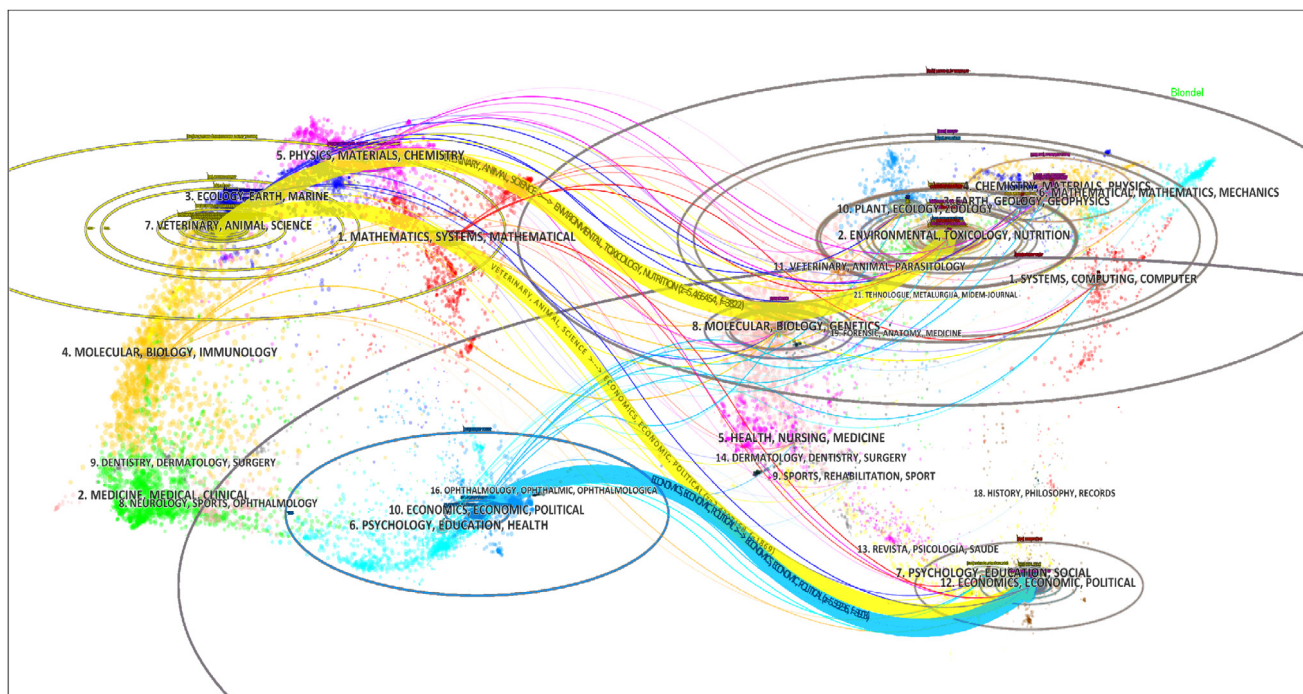
### 3.2. Most cited countries & territories/institutions in the energy security research

It is obvious that the more a country & territory or an institution publish its research findings, the more contributions it will make in the certain research area. The results tell that the most productive counties & territories are at their prosperous stages of energy security, and the most productive institutions are mainly from those countries & territories.

For the analysis of the characteristics of energy security, Google earth was adopted to visualize information based on authors' geographical position. It can be found in Figs. 7 and 8 that the scholars who research on energy security are mainly from North America, Europe, and Asia. Figs. 7 and 8 show that the countries in North America, Europe, and Asia form close academic networks with other countries. Additionally, the scientific collaboration network among countries & territories is analyzed by CiteSpace.

Based on the results given by WoS and CiteSpace, further discussion can be seen below. scientific collaborations have been increasing frequency in recent years, many articles are collaborated by authors who from different continents, such as Searchinger et al. (2008), Chen et al. (2010), and Song et al. (2014). The collaboration has the potential to solve complex scientific problems, promote

Cluster ID	Size	Silhouette	Label (LSI)	Label (LLR)	Mean (Year)
0	85	0.776	Energy security	Energy security	2011
1	57	0.855	Biofuels	Greenhouse gas emission	2006
2	45	0.795	Energy security	Exploring proposition	2009
3	44	0.930	Environment impacts	Integrated assessment	2008
4	41	0.960	Biofuels	Global biofuel projection	2004
5	41	0.749	China	Global energy dilemma	2007
6	28	0.975	Energy security	Energy management system	2006

[illegible]

various agendas, and knowledge creation (Small, 1973). As a result, there should be more international collaborations to help researchers consider research issues from multiple perspectives.

At the institutional level, many institutions around the world are engaged in the energy security researches, and the top 10 productive institutions are presented in [Table 2](#). Among these 10 institutions, there are three institutions in England, the two are from the USA, and China, Singapore, Malaysia, Denmark, and Japan each have one. China has one institution in top 10 productive institutions in the energy security research. Chinese Academy of Sciences is ranked 1st in terms of research outputs in the institution. Generally, the number of outputs is related to the number of research institutions, availability of research funding, and the



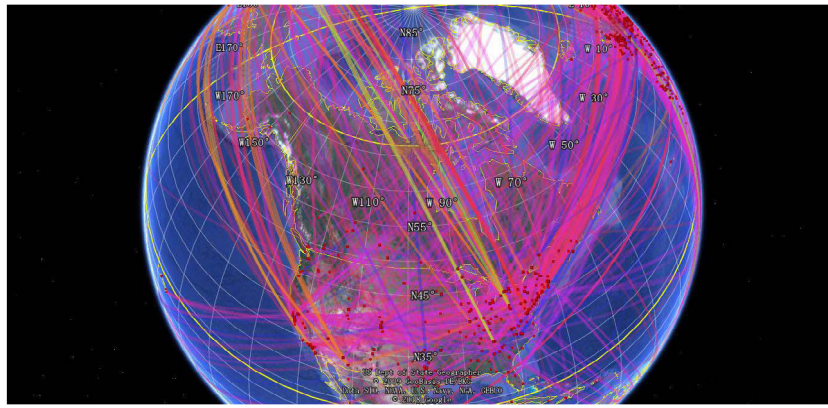


Fig. 7. The author collaboration networks in North America.

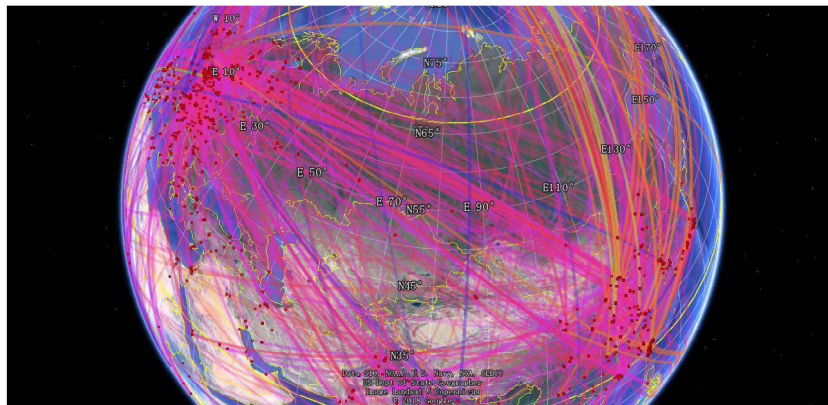


Fig. 8. The author collaboration networks in Continental Europe and Asia.

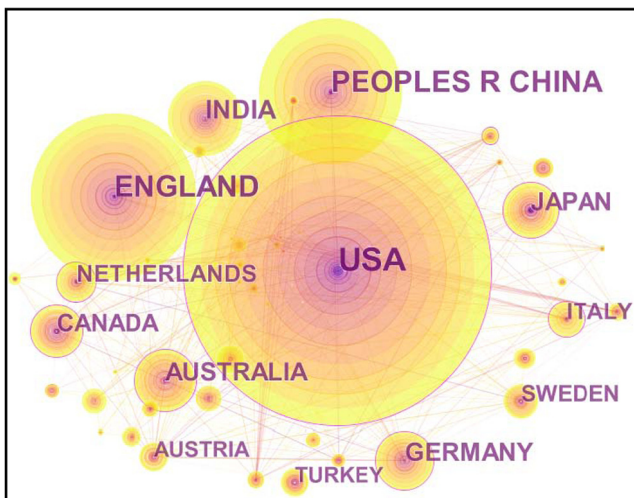


Fig. 9. Top 13 productive countries in the energy security research.

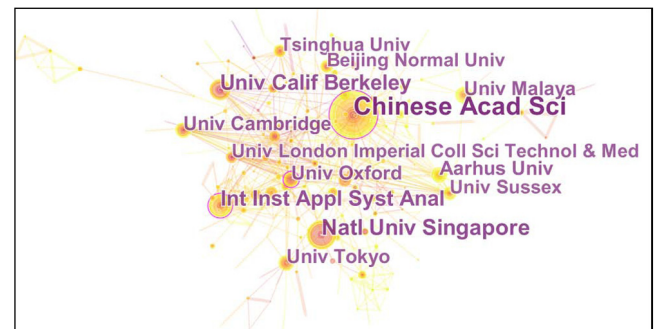


Fig. 10. The top 13 productive institutions in the energy security research.

proportion of those that have energy security focus. Another significant reason for the high outputs is that some countries, such as England, the USA and China, are highly focused on energy security.

Those institutions presented in Table 2 made the majority of contributions to the total research development. According to Table 2, it can be found that among the top 10 productive institutions, three institutions are in England, such as the University of Cambridge, University of Oxford and the University of Sussex. Chinese Academy of Sciences takes the first place with 70 articles,

followed by National University of Singapore and the University of California, Berkeley. The total publication number of USA is ranked 1st, so there is no doubt that the USA is the most productive country in the energy security research field. The Fig. 10 showed that the development and refinement of an academic research discipline depend greatly on the cooperation among institutions.

### 3.3. Most cited sources/authors in the energy security research

As shown in Table 3, the top 10 journals research in energy security is identified, according to the statistics from the WOS core collection database. It shows that Energy policy is the most productive source with 384 publications which account for 13.497% of the total publications, followed by Renewable Sustainable Energy Reviews and Applied Energy. The main studies of Energy Policy

**Table 2**

Top 10 productive institutions in energy security research area.

Institutions	Publication number	The percentage of total
Chinese Academy of Sciences (China)	70	2.460%
National University of Singapore (Singapore)	46	1.617%
University of California Berkeley (USA)	38	1.336%
International Institution for Applied System Analysis (USA)	38	1.336%
University of Cambridge (England)	28	0.984%
University of Malaya (Malaysia)	27	0.949%
University of Aarhus (Denmark)	27	0.949%
University of Oxford (England)	27	0.949%
University of Tokyo (Japan)	26	0.914%
University of Sussex (England)	25	0.879%

**Table 3**

Top 10 productive sources in the energy security researches.

Sources	Publication number	The percentage of total
<i>Energy Policy</i> (England)	384	13.497%
<i>Renewable Sustainable Energy Reviews</i> (USA)	233	8.190%
<i>Applied Energy</i> (England)	114	4.007%
<i>Energy</i> (England)	108	3.796%
<i>Journal of Cleaner Production</i> (USA)	41	1.441%
<i>International Journal of Hydrogen Energy</i> (England)	38	1.336%
<i>Energy Economics</i> (England)	35	1.230%
<i>Energy Sources Part B Economics Planning and Policy</i> (USA)	35	1.230%
<i>Oil &amp; Gas Journal</i> (USA)	33	1.160%
<i>Renewable Energy</i> (England)	29	1.019%

**Table 4**

Top 10 productive authors in the energy security researches.

Authors	Publication number	The percentage of total
Sovacool BK	53	1.863%
Anonymous	16	0.562%
Ren JZ	16	0.562%
Fan Y	12	0.422%
Hughes L	12	0.422%
Jewell J	12	0.422%
Riahi K	12	0.422%
Cai YP	11	0.387%
Huang GH	11	0.387%
Kumar S	11	0.387%

**Table 5**

Top 10 research direction in energy security area.

Research direction	Publication number	The percentage of total
Energy fuels	1349	47.417%
Environmental sciences ecology	873	30.685%
Business economics	587	20.633%
Engineering	509	17.891%
Science technology others topics	480	16.872%
Government law	170	5.975%
Thermodynamics	170	5.975%
International relations	163	5.729%
Chemistry	111	3.902%
Agriculture	100	3.515%

are energy supply policy, economic policy, social policy, and environmental policy. According to Table 3, among these 10 journals, more than half journals are published in the England and the rest are published in the USA. Therefore, the results above could explain why the England and USA are the important contributors. Meanwhile, the main directions of these journals are energy.

Table 4 illustrates the top 10 productive authors in this field. Sovacool BK is the most productive author with many contributions on the aspects of theoretical and empirical detection. Therefore, it is obvious that Sovacool BK is a leading scholar in the energy security research. Apart from Sovacool and Ren also writes many papers that investigate the influence factors and results.

With the growing concern about energy fuels matter in history, it is significant to explore this issue from different perspectives. To clearly show the hot topics in different years and evolutions, a screening process of research direction is performed. Table 5 illustrates the top 10 research directions in this field. It can be seen that “energy fuels” takes the first place with 1349 articles, followed by “environmental sciences ecology” and “business economics”. The top three directions are the hot spots in the energy security research area. There are many authors focus on them, such as Sovacool BK, Anonymous and Ren JZ. Furthermore, the bursts still exist, which are the new directions of this research area. More information can be seen below.

#### 4. Burst detection in the energy security research

Citation bursts, which refer to articles that have received sharp increases in citations, can in part reflect the dynamics of a field. Burst detection is a useful analytic method to find the articles that receive particular attention from the related scientific communities in a certain period of time. Therefore, several interesting points can be found by analyzing the results given by CiteSpace. In this section, the burst detection on the references and the keywords of energy security research are illustrated to show articles that have received rapidly increasing citations and explore research directions intensively.

The articles that have received rapidly increasing citations can be analyzed to reflect the emerging trends in the specific research field. The citation burst suggests that the scholars have paid special attention to the corresponding publications. In order to know the emerging trends of energy security researches, the reference burst detection is utilized in this study. As shown in Table 6, it is obvious to see that the earliest reference citation burst in this research field started from 2007. This paper investigates energy security on the aspects of the relationship of energy security with global climate changes (Corner et al., 2011), renewable energy strategies (Nie and Yang, 2016), and economic efficiency (Wieczorek et al., 2004). In other words, these topics are the research directions in 2007–2011. These studies presented in-depth analyses of energy security and provided a theoretical basis for the further research.






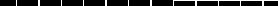



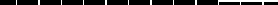


Table 6

Top 10 references with strongest citation bursts.

References	Year	Strength	Begin	End	2000–2017
Ragauskas et al. (2006)	2006	5.6193	2007	2011	
Hill et al. (2006)	2006	6.4269	2007	2011	
Farrell et al. (2006)	2006	14.2326	2007	2010	
Pimentel and Patzek (2007)	2007	6.5729	2007	2010	
Ma and Hanna (1999)	1999	4.4087	2007	2009	
Schmer et al. (2008)	2008	4.3572	2008	2010	
Lelieveld et al. (2007)	2007	3.3971	2008	2009	
Demirbas (2007)	2007	3.3971	2008	2009	
Searchinger et al. (2008)	2008	12.5834	2009	2011	
Hammerschlag (2006)	2006	3.2784	2009	2010	

Table 7

Top 10 keywords with strongest citation bursts.

Keyword	Year	Strength	Begin	End	2000–2017
Environment	2000	5.4997	2000	2009	
Efficiency	2000	4.6292	2000	2011	
Russia	2000	4.4451	2006	2010	
Cost	2000	5.0784	2006	2012	
Hydrogen	2000	8.6974	2006	2011	
Thailand	2000	3.4452	2007	2009	
Biodiesel production	2000	4.1985	2007	2011	
Ethanol	2000	12.1789	2007	2011	
India	2000	7.9442	2007	2012	
Vegetable oil	2000	5.2228	2008	2011	

In recent years, energy security has become a vital element that affects the national economy and climate.

In consideration of the sudden detection of keywords, the fast-growing topics in this research field are given in this paper. There are a number of keywords with bursts and the top 10 are listed in Table 7. The keyword “environment” is firstly proposed in energy security. “vegetable oil” was proposed in 2008 which has attracted great attention from 2008 to 2011. Consequently, this keyword burst started from 2000 to 2012. Some topics show that the theme of the study changes quickly as time goes on.

## 5. Conclusions

In this study, we have made a bibliometric analysis on the evolution and development of the energy security research field by CiteSpace based on 2845 articles from Web of Science. According to the above analyses, some useful conclusions are derived as follows: In the past 17 years, there were 2845 journal articles related to energy security. The published articles in 2009 are up to 194, which indicates people are paying increasing attention to this research field. Further, the USA is the biggest contributor with more publications compared with other countries. At the institutional level, Although the Chinese Academy of Sciences takes a leading position, there are two institutions come from the USA rank at the third and the fourth of the most prolific institutions in the world. Therefore, the productive institutions of energy security research are possibly from the prolific countries. The research on energy security covers a quite wide range of topics, from environmental science to economy, ecology and physics. Thus, various methods can be taken to effectively investigate energy security. With growing disciplines involved in this area, there are more possibilities of the collaborations among scholars in different research fields which in turn provides them with more useful information for the further research.

In earlier years, the research of energy security focuses on national sustainable development such as “energy”, “environment” and “technology”. In recent years, people pay more attention to “crop residue”, “UK energy scenario” and “South Africa”. The keywords of energy security might reflect different focuses of the society. During the development process, energy security has attracted

attention from different countries' governments. As the improvement of this research field, scholars started to investigate the measures taken to deal with energy security. Some specific countries have become the research objects in recent years. In addition, the future research trends of energy security are the energy security, the exploring proposition, the integrated assessment and etc., suggesting that this research is still at an exploration stage. Standard and comprehensive assessments related to energy security are also what researchers pursuing. According to the aforementioned visualization analysis and the review of energy security research papers, it is easy for readers to get a better understanding of its further development trends. Through different aspects of research, scholars are inspired to find more efficient and innovative methods to further investigate energy security.

Admittedly, there are some limitations to this study. First, energy security is a broad concept, it is better to narrow down the research topic and make it more specific in the further study. Second, the range of research time in this paper is only from 2000 to 2017. More dynamic trends of this research are can be seen in the range of research time is broader. In sum, this paper provides an overall analysis of the current state and emerging trends in energy security researches, which helps people to learn more about energy security and makes this research field step into a mature development stage.

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