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Chinese energy and fuels research priorities and trend: A bibliometric analysis

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A B S T R A C T

This study aims to summarize an overview of Chinese energy and fuels research using comprehensive bibliometric analysis measures based on data extracted from the Science Citation Index Expanded database from 1993 to 2012. Keyword analysis was used to assess and evaluate the priorities, topics and topic shifts using the Thomson Data Analyzer (TDA). In particular, popular topics were demonstrated using bubble charts. The results show that solid oxide fuel cell (SOFC), lithium-ion batteries and hydrogen were the most important topics. The priorities of energy and fuels research in China were hydrogen and fuel cells, lithium-ion batteries, biodiesel and biomass, coal, and solar energy, respectively. Of course, lithium-ion batteries have entered substantive application stages in China in 2012. The hydrogen economy has been formed. Biomass and biodiesel research was the popular topic, as well as hydrogen and fuel cells, lithium-ion batteries. But solar energy was not still "hot". The characteristics of the types of documents, languages, year, journals, institutions and co-publishing countries were analyzed, as well as the keyword occurrence frequencies. It can be stated that 19,089 articles by Chinese authors were published in 106 journals. More than one-third of the articles were published in the *Journal of Power Sources*, the *International Journal of Hydrogen Energy* and *Bioresource Technology*. The Chinese Academy of Science, Tsinghua University, China University of Petroleum, Shanghai Jiao Tong University, and Zhejiang University were the top five institutions. The USA was the leading inter-collaborative country, followed by Japan, the UK and Canada. The findings presented here provide an overall picture of the development of Chinese energy and fuels research and could also help policy makers assess the impact of the resource allocation decisions made in the past to develop energy policies and strategies for the future.

Contents

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1. Introduction

Neither China nor the rest of the whole world can live without energy. In 2011, China's energy production ranked first in the world, reaching 3.18 billion tons of standard coal. Chinese energy self-sufficiency has always remained nearly 90 percent [1]. Energy consumption accounted for 3.48 billion tons of standard coal, 68.4 percent of the total consumption and exceeded two times than the amount in 2002 [2]. The energy supply system, which has excessively relied on coal, has resulted in environmental problems such as haze and high carbon emission. However, China's energy needs will continue to expand due to its rapid economic development. As a result, China has two problems: energy conservation and emission reduction and national energy supply security [3]. Therefore, it was noted in the 12th Five-Year Plan for Energy Development that successful resolutions of the two problems, i.e., energy supply security and environmental pollution, are necessary for the basic realization of modernization by the middle of this century. The Journal Citation Reports' (JCR, 2012) category description of energy and fuels comprises all types of nonrenewable fuels and renewable energy sources except nuclear energy. Thus, it is timely to examine the landscape of Chinese energy and fuels.

China already publishes the world's second-highest number of published papers yearly, after the USA [4]. Accordingly, much attention has been paid to the studies coming from China. There were approximately 212,000 articles with the topic of China in the Science Citation Index Expanded (SCIE) database from 1900 to 2015. China's research performance, as measured using bibliometric methods with the topic of China, has also increased to about 260 papers. The first paper was "The sleeping dragon wakes up: a scientometric analysis of the growth of science and the usage of journals in China" published in 1993 [5]. Disciplinary studies of Chinese research in fields such as economics [6], chemistry [7], chemical engineering [8], biochemistry and molecular biology [9], neuroscience [10] and especially nanoscience and nanotechnology [11,12] have been conducted using bibliometric techniques. Additionally, many authors have focused on energy and fuel research in China [13–19]. For example, Yan et al. presented the status of China's road transport in terms of vehicles, infrastructure, energy use and emissions and provided comprehensive and appropriate strategies in the future [13]. A complete picture of China's energy situation in the new millennium was brought by Ma et al. in 2009 [14]. Liu et al. discussed solar energy of the distribution zone, current developmental situation and application, and the prospect of solar energy in China [15]. Lewis found that the carbon finance had played an evolving role in promoting renewable energy development in China published in Energy Policy [16]. Wang's study evaluated residue quantities and distribution of field crops in the 31 provinces of China mainland. They predicted that the total residue quantity for biofuel production could potentially reach 314 Mt in China [17]. Rout et al. addressed energy demands and emissions of China on the long term (to 2100) by key energy indicators. The results showed that China will require approximately 4 Gtoe of primary energy and results 10 Gt CO_2 emissions by the end of the 21st century [18]. Chen et al. calculated the environmental costs of coal by using input–output model and investigate the effectiveness of the Pigouvian carbon tax applied in developed and undeveloped resource-dependent provinces of China [19]. However, there were only a small number of bibliometric studies of energy and fuels research with topic of China, such as entitle "Way forward for alternative energy research: A bibliometric analysis during 1994–2013" [20] and "Mapping biofuel field: A bibliometric evaluation of research output" [21]. Despite the studies mentioned above, few studies aimed to obtain a comprehensive overview of energy and fuels research in China using bibliometric methods. For example, Haslam et al. assessed fuel cell vehicle innovation and the role of policy in Japan, Korea, and China [22], and Duan analyzed the relationship between international cooperation and scientific publications in energy R&D in China [23]. The characteristics of Chinese energy and fuels research have not yet been discussed. Many energy- and fuel-related issues, such as research priorities, remained unclear, and therefore, a comprehensive bibliometric analysis of China is necessary.

Priorities, topics and topic shifts can provide important insights into the research and map out directions for future researchers. Research priority can be indicated by a country's publishing output [24]. A country's publication of research in different fields of science is not accidental. It is the corollary of past resource allocations and policy decisions in the given fields [25]. Aside from traditional bibliometric methods, other bibliometric indicators have been used in research output analyses, such as international scientific collaboration [3,23,26] and patent analysis [22,27]. Author keywords provide more information about research topics; thus, author keyword analysis has been introduced in trend [28,29] and priority studies [25,30] based on keyword occurrence frequencies. In recent years, the changing distributions of keywords over time have been displayed in tables for different lengths of time, such as two [8], four [31], five [32], six [4] and ten years [30] and they have been used to evaluate research trends. If the interval being analyzed is insufficient, trends can be difficult to determine; in otherwise, trends may be obvious, but they cannot determine the most popular recent issues. Bubble charts compensate for these defects. They enable the rapid visual recognition of pattern changes [33,34]. Articles such as "Using a bubble chart to enhance adherence to quality-of-care guidelines for colorectal cancer patients" [35] and "Effects of an intervention on nutrition consultation for cancer patients" [36] are examples that used bubble charts. In recent years, bubble charts have been found to be simple and useful tools for comparison, but this graphical tool has not been attempted in previous bibliometric analyses.

This study aims to provide an overview of Chinese energy and fuels research based on data extracted from SCIE during 1993–2012. In particular, bubble charts were used to assess and evaluate both the 30 top keywords and the different Chinese institutions by year. Author keyword occurrence frequencies were comprehensively analyzed for different ranges of time, such as twenty years and ten–five–five years. Five bibliometric indicators were employed to analyze document types and languages, annual published document outputs, institutions, journals and international collaborations.

2. Data and methods

The JCR, as published in 2012, indexed 81 journals in the energy and fuels category. The documents used in this study were derived from the online version of the SCIE, the most important and frequently used database for bibliometric analysis. We searched the data using the query TS=China, PY=1993–2012 and SU=energy and fuels. All documents that addressed "P. R. China" in the energy and fuels category from 1993 to 2012 were collected (updated on 9 November 2013). The records were downloaded into .txt format, and a total of 19,759 records were collected. Only 19,089 articles were considered in the further evaluation. Some bibliometric indicators, including document types and languages, annual published document outputs, institutions, journals and international collaborations were used. Unlike previous bibliometric studies, author keyword occurrence frequencies were comprehensively analyzed using the Thomson Data Analyzer (TDA) for different ranges of time, such as 20 years, ten–five–five years, and yearly from 1993 to 2012, to discover priorities, topics and topic shifts in the literature. In addition, a bubble chart was used to assess and evaluate the most popular topics. The impact factors are taken from the JCR (2012).

3. Results and discussion

3.1. Published document types and languages

There were 19,759 documents that matched the choice criteria mentioned above across 12 document types. Articles (19,089) were the most frequently used document, comprising 96.61% of the total production while 6.24% were proceedings papers, followed by reviews (477, 2.41%). Editorial materials, corrections, letters, notes, book reviews, correction additions, news items, biographical items and discussions covered approximately 1% of the published literature. The document types, total papers and percentages of document types are shown in Table 1. We focused on the articles because they not only comprised the majority of the published documents in this field but were also peer-reviewed. The bulk of these articles were published in English (99.96%), same as "The research on energy in Spain: A scientometric approach [37]. The other language was German (only 8 articles). No other languages appeared.

3.2. Characteristics of annual published outputs

One trend that was identified was that the number of studies increased dramatically, from 57 articles in 1993 to 4068 in 2013.

Table 1
Distribution of publication types.

Article types	TP	%
Article	19089	96.61
Proceedings paper	1234	6.24
Review	477	2.41
Editorial material	106	0.54
Correction	43	0.22
Letter	18	0.091
Note	16	0.081
Book review	4	0.020
Correction addition	2	0.010
News item	2	0.010
Biographical item	1	0.005
Discussion	1	0.005
Total	19,759	100

TP total papers, % the percentage of the article type.

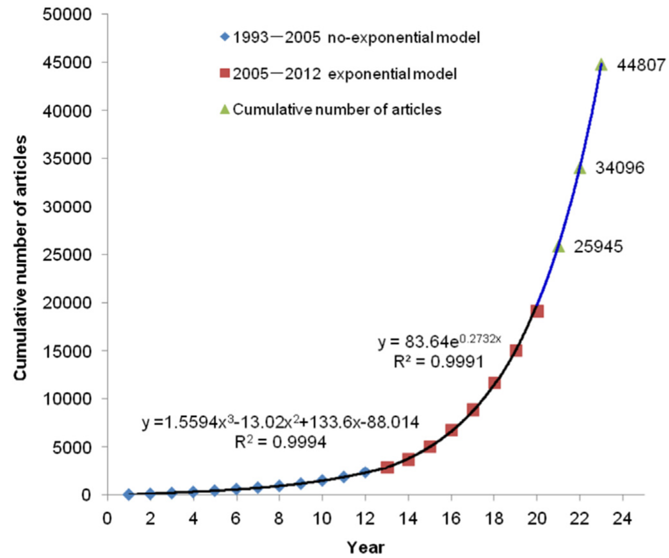

Fig. 1. The cumulative number of Chinese researchers' articles by year during 1993–2012.

The assembled numbers of articles from the past 20 years are presented in Fig. 1. It was notable that a significant correlation was found between the yearly assembled number of articles and the number of years from 1993 to 2012. X represents the year; for example, the number one refers to 1993, and the number six refers to 1998. Y represents the assembled number of articles; for example, the assembled number of articles in 1998 is the sum of the annual publications from 1993 to 1998. The relationship between Y and X was found to be $Y=1.5594X^3-13.02X^2+133.6X-88.014$ ($R^2=0.9994$) for 1993–2005 and $Y=83.64e^{0.2732X}$ ($R^2=0.9991$) for 2005–2012. Based on the formula above, the assembled number of articles on the energy and fuels of China was projected to be 25,954, 34,096 and 44,807 articles in 2013, 2014 and 2015, respectively, which suggests that 6865, 8142 and 10711 articles were likely to be published by Chinese authors in 2013–2015. These predictions should be tempered by existing conditions–for instance, the number of both energy-related journals and authors will simultaneously and sharply increase in those three years. This exponential increase represents rapid growth in the number of articles being published, which can be explained by the phenomenon that China's ratio of gross domestic expenditure in R&D to GDP rose exponentially over the last decade [38]. R&D input has been considered one of the most dominant factors for evaluating a country's investments in its intellectual fields [7].

3.3. Characteristics of published journals

The 19,089 articles that were studied were published in 106 journals. Information about the journals in which Chinese authors most frequently published their research results is presented in Table 2. The 20 most prolific journals together produced 15,469 papers, comprising 81.04% of Chinese authors' contributions during 1993–2012. As the leading journal, the *Journal of Power Sources* published 2513 articles (13.16%) by Chinese authors, followed by the *International Journal of Hydrogen Energy* and *Bioresource Technology*, with 2105 (11.03%) and 2029 articles (10.63%), respectively. The six journals that published the most articles by Chinese authors were the top six global energy and fuels journals [39], but the respective orders of rank differed slightly. This finding indicates that Chinese authors have published their articles in the world's mainstream journals. Fig. 2 shows the percentage of articles by Chinese authors among the total published journal articles

Table 2
The 20 most published journals during 1993–2012.

	TP	TPR%	JTP	JTPR%	IF(2012)	Quartile
Journal of Power Sources (Po-so)	2513	13.16	14214	17.68	4.675	Q1
International Journal of Hydrogen Energy (Hy-en)	2105	11.03	10489	20.07	3.548	Q1
Bioresource Technology (Bio-te)	2029	10.63	10262	19.77	4.750	Q1
Energy fuels (En-fuel)	1299	6.80	7346	17.68	2.853	Q2
Fuel	724	3.79	6524	11.10	3.357	Q1
Energy Conversion and Management (En-co-ma)	720	3.77	4991	14.43	2.775	Q2
Applied Thermal Engineering (Ap-th-eng)	719	3.77	4003	17.96	2.127	Q2
Petroleum Science and Technology (Pe-sci-te)	630	3.30	2069	30.45	0.300	Q4
Applied Energy (Ap-en)	587	3.08	3281	17.89	4.781	Q1
Energy (En)	564	2.96	4603	12.25	3.651	Q1
Fuel Processing Technology (Fu-pro-te)	470	2.46	2717	17.30	2.816	Q2
Energy Policy (En-pol)	459	2.41	6248	7.35	2.743	Q2
Solar Energy Materials and Solar Cells (Sol-en-ma)	426	2.23	5430	7.85	4.630	Q1
Energy and Buildings (En-build)	395	2.07	2952	13.38	2.679	Q2
Journal of Natural Gas Chemistry (Na-gas-che)	367	1.92	543	67.59	1.405	Q3
Petroleum Science (Pe-sci)	362	1.90	394	17.68	0.534	Q4
Renewable Energy (Re-en)	321	1.68	4699	20.07	2.989	Q1
Energy and Environmental Science (En-env-sci)	270	1.41	1489	19.77	11.653	Q1
Energy Sources Part A Recovery Utilization and Environmental Effects (En-so)	260	1.36	1302	17.68	0.516	Q4
China Petroleum Processing Petrochemical Technology (Chi-p-p-p-t)	249	1.30	660	11.10	0.083	Q4

TP total papers, TPR% the percentage of journal's articles, JTP total papers of journals, JTPR% the percentage of articles by Chinese authors among the total published journals, IF impact factor.

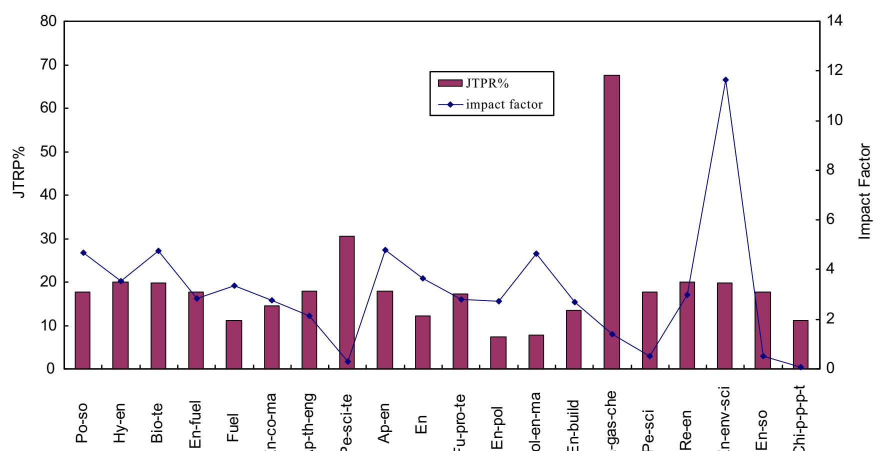

Fig. 2. The 20 most prolific journals in energy and fuels of China. JTPR% the percentage of articles by Chinese authors among the total published journals, IF impact factor.

and impact factor. With regard to the percentage of articles by Chinese authors among the total published journals, the *Journal of Natural Gas Chemistry* ranked first as published the most articles (67.59%) by Chinese authors, followed by *Petroleum Science and Technology* (30.45%), the *International Journal of Hydrogen Energy* (20.07%) and *Renewable Energy* (20.07%); their *IF2012*s were 1.405, 0.300, 3.548 and 2.989, respectively. Looking at impact factor, the journal rankings changed. *Energy and Environmental Science* had the highest impact factor (11.653), followed by *Applied Energy* (4.781) and *Bioresource Technology* (4.750). Aside from the above journals, the journals with impact factors greater than four were the *Journal of Power Sources* (4.675) and *Solar Energy Materials & Solar Cells* (4.630). Nine of the 20 most productive journals were in Quartile 1 (Q1) in the energy and fuels category. However, other journals had lower *IF2012*s, such as *Petroleum Science and Technology*, with an *IF2012* of 0.300; *Petroleum Science*, with an *IF2012* of 0.534; *Energy Sources Part A Recovery Utilization and Environmental Effects*, with an *IF2012* of 0.516; and *China Petroleum Processing Petrochemical Technology*, with an *IF2012* of 0.083. It can be noted that Chinese authors also published their energy and fuels research results in journals with lower impact factors.

3.4. Distribution of output in institutions

During the last two decades, 4160 institutions were devoted to energy research in China (two records did not include the institution field). The 15 most productive institutions and their respective outputs are displayed in Table 3. The Chinese Academy of Science ranked first with the most articles (2483). Tsinghua University followed distantly with only half of the number of papers (1179) published by the Chinese Academy of Science. The third most prolific was the China University of Petroleum (992), which is the most important energy university. It was expected that the Chinese Academy of Sciences would be the leading institution in many fields [38], as well as in alternative energy research [20].

Graphical representation was necessary to simplify the tedious comparison of data. Bubble charts can display data in two [35] and three dimensions [40]. Fig. 3 shows the documents published annually by the 15 most prolific institutions using a bubble chart with one dimension. In general, there was an increasing trend in scientific articles published per institution, but there were also declines in certain years. It can be observed in Fig. 3 that the number of papers published by the Chinese Academy of Sciences increased rapidly since 2006. There was even more explosive growth in 2010–2012. The other six universities, i.e., Tsinghua University, the China University of Petroleum, Zhejiang University, the Harbin Institute of Technology, South China University of Technology and Tianjin University, rapidly increased their total numbers of published works in the most recent three years. In contrast, Shanghai Jiao Tong University's output declined in 2012. These findings may be influenced by the grant periods of the programs in which the institutions participated. It is interesting that the 15 most productive institutions in energy and fuels were also some of China's 20 most productive universities in chemical engineering, except the Chinese Academy of Science and Xi'an Jiao Tong University [8]. This phenomenon may be because scholars in China's university chemistry and chemical engineering departments also studied energy and fuels. For example, Professor Zongjiang Mao, as the chief scientist for the National Basic Research Program (973 Program) hydrogen energy projects at Tsinghua University, devoted himself to fuel cells and hydrogen energy research from his chemical engineering research [41].

Table 3
The 15 most prolific institutions during 1993–2012.

	TP	TPR%
Chinese Academy of Science (CAS)	2483	13.01 %
Tsinghua University (THU)	1179	6.18 %
China University of Petroleum (CUP)	992	5.20 %
Shanghai Jiao Tong University (SHJTU)	980	5.13%
Zhejiang University (ZJU)	820	4.30 %
Harbin Institute of Technology (HBIT)	661	3.46%
Xi'an Jiao Tong University (XAJTU)	657	3.44 %
Tianjin University (TJU)	564	2.95%
University of Science and Technology of China (USTC)	517	2.71 %
East China University of Science and Technology (ECUST)	494	2.59%
South China University of Technology (SCUT)	477	2.50 %
Huazhong University of Science and Technology (HZUST)	461	2.42 %
Hong Kong Polytechnic University (HKPU)	434	2.27 %
Dalian University of Technology (DLUT)	429	2.25 %
Nanjing University of Technology (NJUT)	302	1.58 %

TP total paper, TPR% the percentage of institution's articles.

3.5. Collaborations of countries/territories

China has cooperated with 75 countries in the field of energy and fuels. The eleven most internationally collaborative countries/territories during 1993–2012 are listed in Fig. 4. The number of collaboration was more than 100 published documents. The overall number of cooperatively produced papers from these

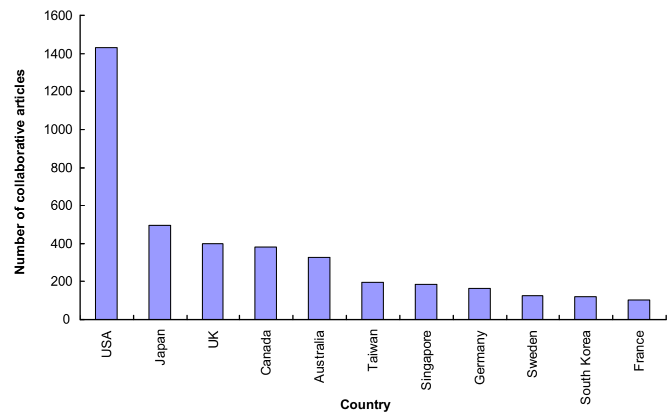

Fig. 4. The most 11 internationally collaborative countries/territories with China.

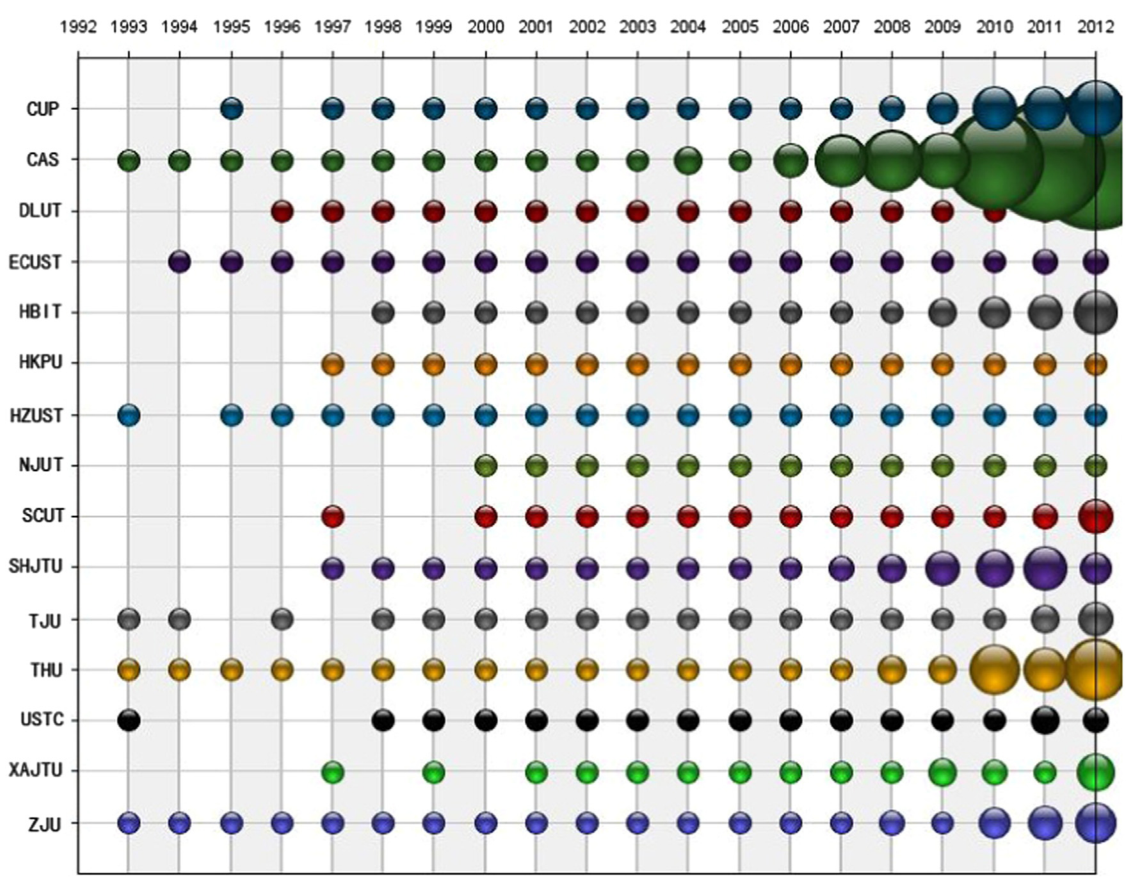

Fig. 3. The 15 most prolific institutions by year using a bubble chart. The size of the bubble represents the number of articles by institution.

countries accounted for 76.7% of the total documents. The USA was China's most important cooperative partner (1433, 45.4%), followed by Japan (498, 15.8%), the UK (398, 12.6%) and Canada (384, 12.2%). The USA also produced by far the most US-China coauthored nanotechnology papers [19]. Six of the top 11 countries belong to the G7 (which are the USA, the UK, Canada, France, Japan, Germany and Italy), except Italy ranked 16th. Three of the top 11 countries are from the Four Asian Tigers. These top 11 countries were also the 10 most prolific international coauthors with China and others [3], except Taiwan. The top five internationally collaborative countries with China were also the five most productive countries worldwide in the energy and fuels field [39]. These findings indicate that China collaborated closely with both western developed countries and the countries/territories that have special relationships with the western developed countries. Finally, it should be noted that the number of cooperation with nearly half of these countries were comparative little, twelve countries were collaborated with 3–6 papers while twenty-one countries collaborated only 1 or 2 papers.

3.6. Author keyword analysis

Altogether, 30,974 different author keywords were used in 19,089 articles from 1993 to 2012. Nearly three-quarters, 22,754 (73.5%), of the author keywords were used only once, 3723 (12.0%) were used twice and 1435 (4.6%) were used three times, indicating that the vast majority of studies were scattered and not sustainable. The 30 most frequently used (≥ 150) author keywords were grouped into one ten-year and two five-year periods. Their rankings and percentages are shown in Table 4. According to the energy types, the top 30 keywords were classified into five types, such as fuel cells, lithium-ion batteries, and biodiesel and biomass, coal, and solar energy. The analysis of these keywords was mainly conducted on three dimensions (major topics and priorities, topic shifts and popular topics) to provide an overview of energy and fuels research in China.

3.6.1. Major topics and priorities

"SOFC" ranked first with 528 topic articles (1.70%), "lithium-ion batteries" ranked second with 396 articles (1.28%) and "hydrogen" ranked third with 319 articles (1.03%), followed by "fuel cell" with 310 articles (1.00%) and "hydrogen production" with 264 articles (0.85%), except for the search term "China". In addition, "biodiesel" and "biomass" ranked 8th and 9th, "coal" ranked 10th, and "Solar energy" ranked 29th.

3.6.1.1. Hydrogen and fuel cells. According to Table 4, there were seven keywords that were related directly to hydrogen and fuel cells in the top 30 author keywords, namely "SOFC", "hydrogen", "fuel cell", "hydrogen production", "PEMFC", "DMFC", "hydrogen storage", which ranked 1st, 3rd, 5th, 6th, 7th, 12th, and 18th, respectively. It obviously reflected that the hydrogen and fuel cells has aroused great concern by Chinese researchers. Hydrogen and fuel cell technology may play an important role in addressing the growing energy demand in the future [42–43]. These promising substantial type of renewable energy has also attracted more attention in China. Since 2000, more and more hydrogen and fuel cell projects supported by the Ministry of Science and Technology (MOST) through the 973 Program and the National High Technology Research and Development Program (863 Program), such as the project "large-scale production, storage and transportation of hydrogen and fuel cells"and "annual thematic program for hydrogen and fuel cells", et al. The concept of the hydrogen economy has been formed in China. Lu et al. [44] summarized

Table 4
Top 30 most frequently used author keywords in one 10-year and two 5-year periods during 1993–2012.

Author keyword	1993–2012		1993–2002		2003–2007		2008–2012	
	TP	R (%)	TP	R (%)	TP	R (%)	TP	R (%)
Solid oxide fuel cell	528	1(1.70)	12	20(0.49)	68	5(0.91)	448	1(1.75)
Lithium ion battery	396	2(1.28)	28	1(1.15)	80	1(1.07)	288	2 (1.12)
Hydrogen	319	3(1.03)	5	74(0.20)	43	10(0.57)	271	3(1.06)
China	317	4(1.02)	24	3(0.98)	70	2(0.93)	223	6(0.87)
Fuel cell	310	5(1.00)	4	97(0.16)	68	4(0.91)	238	4(0.93)
Hydrogen production	264	6(0.85)	N/A	N/A	26	25(0.35)	238	5(0.93)
Proton exchange membrane fuel cell	237	7(0.77)	3	181(0.12)	63	6(0.84)	171	8(0.67)
Biodiesel	224	8(0.72)	N/A	N/A	8	143(0.11)	216	7(0.84)
Biomass	201	9(0.65)	6	41(0.25)	37	14(0.49)	158	9(0.62)
Coal	194	10(0.63)	27	2(1.11)	70	3(0.93)	97	24(0.38)
Modeling	186	11(0.60)	18	6(0.74)	41	12(0.55)	127	17(0.50)
Direct methanol fuel cell	185	12(0.60)	N/A	N/A	59	7(0.79)	126	18(0.49)
Kinetics	183	13(0.59)	12	19(0.49)	30	23(0.40)	141	11(0.55)
Optimization	181	14(0.58)	15	8(0.61)	29	24(0.39)	137	13(0.53)
Pyrolysis	181	15(0.58)	20	4(0.82)	49	8(0.65)	112	20(0.44)
Catalyst	177	16(0.57)	4	85(0.16)	33	16(0.44)	140	12(0.55)
Numerical simulation	175	17(0.56)	7	35(0.29)	33	20(0.44)	135	15(0.53)
Hydrogen storage	167	18(0.54)	3	163(0.12)	23	31(0.31)	141	10(0.55)
Adsorption	163	19(0.53)	14	9(0.57)	35	15(0.47)	114	19(0.44)
Simulation	160	20(0.52)	13	17(0.53)	39	13(0.52)	108	21(0.42)
Cathode	158	21(0.51)	4	86(0.16)	17	52(0.23)	137	13(0.53)
Methane	152	22(0.49)	1	1556(0.04)	18	47(0.24)	133	16(0.52)
Combustion	142	23(0.46)	14	10(0.57)	33	17(0.44)	95	25(0.37)
Heat transfer	137	24(0.44)	14	11(0.57)	33	19(0.44)	90	29(0.35)
Anode	121	25(0.39)	3	129(0.12)	24	27(0.32)	94	26(0.37)
Stability	121	26(0.39)	6	61(0.25)	16	56(0.21)	99	23(0.39)
Electrochemical performance	120	27(0.39)	6	46(0.25)	21	38(0.28)	93	27(0.36)
Electrochemical properties	119	28(0.38)	10	22(0.41)	44	9(0.59)	65	48(0.25)
Solar energy	117	29(0.38)	14	13(0.57)	26	26(0.35)	77	35(0.30)
Performance	115	30(0.37)	14	12(0.57)	18	48(0.24)	83	33(0.32)

TP total papers, R (%) ranking and percentage of author keywords, N/A not available.

drivers, resources, and technologies for building the hydrogen economy in China in 2013. Ren et al. [45] analyzed the situation of hydrogen economy in China and proposed nine effective strategies. Chinese government also supported the hydrogen and fuel cells project through the National Natural Science Fund. These projects have been increased steadily since 2000 [44]. It was just the financial support of government in China which promoted the development of the hydrogen and fuel cell research.

SOFC is one type of fuel cells as well as proton exchange membrane fuel cell (PEMFC) and direct methanol fuel cell (DMFC). In Table 4, fuel cell focuses, including SOFCs, with 528 articles; fuel cells, with 310 articles; PEMFCs, with 237 articles; and DMFCs, with 185 articles, were also frequently used. It was expected that the priorities of fuel cell research would be SOFCs, PEMFCs and DMFCs. The percentage and numbers of documents published on SOFCs ranked first and increased from 1993 to 2012. The ranking of "SOFC" increased from 5th to 1st, in contrast that "PEMFC" decreased from 6st to 8th and "DMFC" from 7th to 18th in the second period (2003–2007) and the third period (2008–2012). This finding indicates that the interest in SOFC research continued to rise in China, but PEMFC and DMFC research are in opposite direction. Fuel cells are energy conversion devices that convert the chemical energy stored in fuel (hydrogen) directly into electrical power. They are expected to replace internal combustion engines because of their clean energy conversion and higher efficiency and to replace batteries because of their higher energy densities and zero recharge time [46]. Fuel cells are considered as an alternative to standard sources of energy [47]. China began its fuel cell research at DICP and CAS in the mid-1950s. Research and development of PEMFCs, SOFCs and DMFCs have been carried out since the 1990s. Fuel cells were used in Passat cars during the 2008 Beijing Olympic Games [44]. National government provided more special financial supports to the SOFC research. In 2011, the 973 Program funded SOFC research project with $5.55 million [44]. These have effectively promoted the development of the technology, and effective results have been obtained in China [48]. SOFCs have been demonstrated to be superior to other fuel cells [49]. Although their cost is higher and the system is complex, SOFCs may replace lithium-ion batteries in the future.

3.6.1.2. Lithium-ion batteries. "lithium-ion batteries" ranked second with 396 articles (1.28%) in the last two decades. Before 2008, it located in the first place. But after 2008, it was replaced by SOFC but still remained in second place. This phenomenon indicated that lithium-ion batteries attracted sustainable attention and verifies the rapid and sustained development of lithium-ion battery technology in China. In the early 1990s, these batteries were first commercially introduced by SONY, and then they were widely used, becoming the ideal rechargeable power supply [50]. Small-scale production began in China using hand operations in the 1990s. When Motorola brought lithium-ion battery assembly lines from Japan to China, the Chinese industry received a substantial boost. Subsequently, China became a leading country in lithium-ion battery production [51]. China's yield of lithium-ion batteries was over 2 billion in 2010, and production increased by more than 20%, accounting for 51.4% of the global market [52]. Lithium-ion batteries, with their high energy density, long life cycles and strong discharge capacities, could become the major options for electric vehicle power supply in the coming decades, in addition to solar, wind and other clean energy storage [53]. Lithium-ion battery research has always been supported by MOST through the 863 Program, from small mobile electronic device batteries to vehicle power batteries. In January 2009, China launched "Thousands of Vehicles, Tens of cities" new energy vehicle demonstration program, which would accelerate China's power battery market [54]. However, China's share of the global high-end market was reduced. China also faced the challenge of resources and the environment along with large-scale industrial development at the same time [52].

3.6.1.3. Biomass and biodiesel. Then, following "hydrogen and fuel cells" and "lithium ion batteries", "biodiesel" and "biomass" ranked 8th and 9th in research attention. The ranking of "biomass" rose from 41st in 1993–2002 to 9th in 2008–2012, and "biodiesel" did not appear in 1993–2002 but ranked 7th in 2008–2012 (Table 4). It is obvious that biodiesel research began later than biomass. The reason is that biodiesel, one type of biofuels, are produced from biomass. The result also showed that biomass and biodiesel had attracted increasing attention in China. Renewable energy consists of biomass energy, hydropower, wind energy, solar energy, nuclear energy, ocean power, and geothermal energy. Biomass, as one of the abundant, environment-friendly, renewable energy resources [55], has received considerable attention [56]. The result is not surprising considering its policy support [57] and huge investment in this research field [58]. In 2006, China first issued Renewable Energy Law [57]. Then, the Mid- and Long-term Development Plan for Renewable Energy was formulated by the Chinese government and has been effective since August 2007. The above law, government plan and another scheme of prices and costsharing encouraged and supported clean and efficient development and utilization of biomass fuels, including biodiesel in China. As a result, the yield of biodiesel reached 0.2 Mt at the end of the 11th Fine-Year Plan (2010), four times higher than in 2005. The installed capacity of biomass energy and biogas was increased from 7000 Mm^2 and 2 GW to 19,000 Mm^2 and 5.5 GW at the same time [57]. Biomass-derived fuel appears to be the most promising and attractive among the various alternative energy, and it is expected to grow in the foreseeable future [59]. In addition, according to bibliometric analysis of the output in biofuel field, the production of biodiesel was the mainstream of biofuels research during 1991–2012 [21]. The preference to biodiesel in the worldwide could be attributed to the properties of biodiesels which are closer to gasoline and petrodiesel [60], same as in China. Biomass and biodiesel was playing and will continue to play an important role in China's energy system.

3.6.1.4. Coal. Coal ranked the position of 10 during the last 20 years. The appearance of the keyword "coal" changed the most, ranking in the top three before 2008 and declining to 23rd in 2008–2012, indicated that the interest to coal research declined. In December 2013, one hundred Chinese cities were shrouded by haze, which was unprecedented in the history of mankind and gave China's energy system a serious warning. China has put forward a plan to control total coal consumption, aiming to reduce CO_2 intensity per unit of GDP by 40–45% from 2005 levels by 2020 [19]. In fact, the growth rate of total China's coal consumption was decreased from 284% over the period 2001–2012 to 136% over the period 2007–2012. Coal consumption in 2014 is a 2.9% negative growth for the first time [61]. It indicated the less consumption, less input and less interest.

3.6.1.5. Solar energy. "Solar energy" , as one of renewable energy, ranked 29th. It decreased in ranking from 13th with 14 articles (1993–2002) to 26th with 26 articles (2003–2007) and then to 35th with 77 articles (2008–2012), indicating that the interest to solar energy studies also declined. It concided with the opinion of Zeng et al. published in 2015 [62]. They pointed out that the "Sun" is not still hot in China. China had paid more attention on solar energy during the first 5 or 10 years, but turned to bioenergy subsequently [20]. China has abundant solar resources. More and more applications have been applied, such as solar energy greenhouse, solar water heater, solar lighting system and photovoltaic (PV) industry [15]. Among them, the photovoltaic (PV) was the major way of utilization of solar power. But the following five reasons, such as an overcapacity situation as relying on international market [63], imperfect fiscal and taxation policies, the high price of PV production, relatively poor research basis, and in particular, the overall level of technological development lagging behind [64] inhibited the development of the PV industry in China. Perhaps these were why solar energy declined.

3.6.2. Topic shifts

Aside from the search word "China", the top five author keywords in 1993–2002 were "lithium-ion batteries", "coal", "pyrolysis", "refrigeration" and "modeling"; in the more recent period of 2008–2012, "SOFCs", "lithium-ion batteries", "hydrogen", "fuel cells" and "hydrogen production" were the top five author keywords. These findings indicate that the most popular issues have shifted from coal to hydrogen and fuel cells related studies, except for lithium-ion batteries research. In the same time, "catalyst", "cathode", "anode", "hydrogen", "hydrogen storage", "hydrogen production" and "electrochemical performance" showed a notable increasing trend, In contrast, the following terms showed decreasing trends, for example: "coal", "solar energy", "heat transfer", "combustion", "pyrolysis". Increased frequency suggests increasing concern, whereas decreasing frequency indicates the opposite. The issue "hydrogen storage" only relate to fuel cells, so the increasing trend of them was same. Other issues, such as "hydrogen" and "hydrogen production" not only relate to fuel cell, but also relate to solar energy, coal, and biomass research. Among them, solar energy and coal research declined, so the increasing trend of "hydrogen" and "hydrogen production" mainly depends on the fuel cell and biomass research. In addition, "Electrochemical performance", "cathode" and "anode" relate to lithium ion battery, solar energy and fuel cell research. "Lithium ion battery" basically remained unchanged as major topic during 1993–2012. In the same way, "Electrochemical performance", "cathode" and "anode" research mainly related to fuel cells research. In conclusion, "Hydrogen", "hydrogen production" and "hydrogen storage" connect more with fuel cells in China. The research of hydragen and fuel cells was in the rising stage.

3.6.3. Popular topics

Using a visualization bubble chart approach, we can got the sequences of new independent drug candidates [65]. In this study,

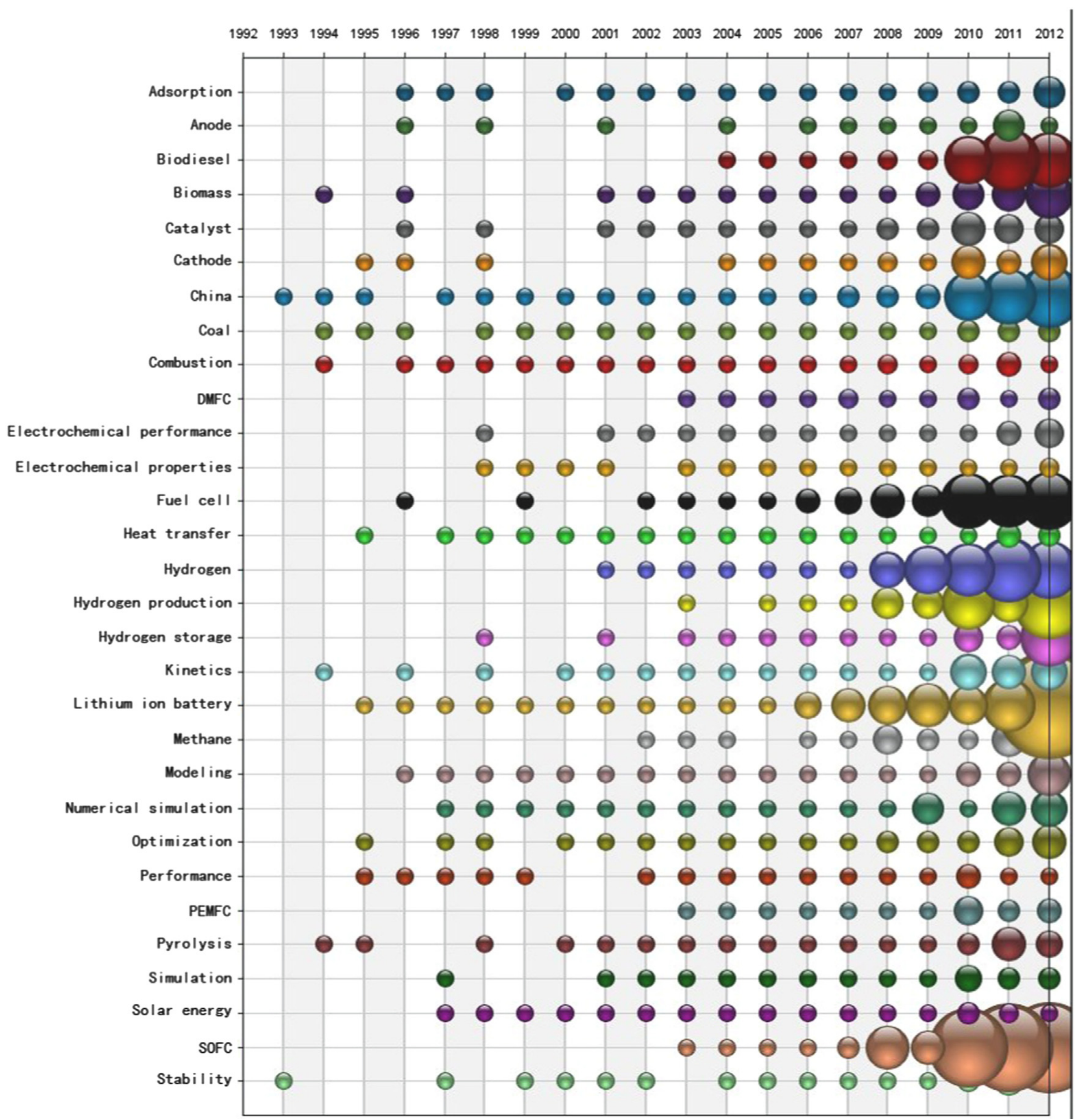

Fig. 5. Top 30 most frequently used author keywords by year using a bubble chart. The size of the bubble represents the occurrence frequencies of author keywords.

the size of the bubble represents author keyword occurrence frequencies and the number of articles. Obvious changes in the bubble size indicate the trending of a popular topic. Fig. 5 shows the top 30 author keywords with their occurrence frequencies in a bubble chart. It can clearly be observed that lithium-ion batteries and fuel cells were popular studied for seven years. Interestingly, SOFC research developed rapidly, it ranked first over the last twenty years. But the occurrences of "lithium-ion battery" published works increased sharply from 2011 (54) to 2012 (111). Doubled research work may be inferred that lithium-ion batteries entered a substantive application stage in China [66]. In 2012, the times distributions of SOFCs, PEMFCs and DMFCs were 60, 26 and 24, respectively. It appears that lithium-ion batteries attracted a great deal more attention than SOFCs, PEMFCs and DMFCs in 2012. Five years ago (2008), the frequencies of "hydrogen", "hydrogen production" and SOFCs changed clearly, especially in the recent three years (2010–2012), the occurrences of "hydrogen storage" and "hydrogen production" also clearly changed from 26, 41 to 59, 75, nearly doubled clearly in 2011–2012. Theses shift may indicate that hydrogen economy has been occured in 2008, and finally formed in 2012. The concept of "hydrogen economy" was introduced by Bockris in 1972 [67]. The research of Chinese hydrogen economy first appeared in 2012 [68]. These supported the above conclusion. In addition, the frequencies of "biodiesel", "biomass" only increased since 2010. The result showed that biomass and biodiesel research has become the focus, but in the early stage of development [57].

4. Conclusion

Nearly all of the documents were articles and reviews that were published in 106 journals. China showed an exponential increase in its number of published articles. However, the journal quality has been uneven; Chinese energy and fuels research results have been published in both mainstream journals and journals with low impact factors. The *Journal of Power Sources*, the *International Journal of Hydrogen Energy* and *Bioresource Technology* were the three journals that published more than one-third (34.72%) of Chinese authors' articles. The Chinese Academy of Science, Tsinghua University, the China University of Petroleum, Shanghai Jiao Tong University and Zhejiang University were the top five institutions that published two-thirds (33.82%) of these articles. The USA was China's leading internationally collaborative country, followed by Japan, the UK and Canada. Unlike in previous bibliometric studies, author keyword occurrence frequencies were comprehensively analyzed across different periods, such as 20 years, ten–five–five years and yearly from 1993 to 2012, to discover priorities, topics and topic shifts in the literature. In addition, bubble charts particularly demonstrated the most popular topics over time. It can be also found from the 30 most frequently used author keyword occurrence frequencies between 1993 and 2012 that China's energy and fuels research priorities were hydrogen and fuel cells, lithium-ion batteries, biodiesel and biomass, coal, and solar energy, respectively. The major topics were SOFC, lithium-ion batteries and hydrogen. Interestingly, lithium-ion batteries have entered substantive application stages in China since 2012. The hot topic was changed from coal in the first ten year to hydrogen and fuel cells in second ten years. Solar energy was "hot" during the first 5 or 10 years, but turned to biomass and energy subsequently. The recently popular topics were hydrogen and fuel cells, biomass and biodiesel and lithium-ion batteries. Hydrogen economy has been occurred in 2008, and finally formed in 2012. It connected more with fuel cells in China. Biomass and biodiesel research has become the focus, but it was only in the early development stage. The financial supports and policy decisions of Chinese government were the main motivation that promoted the development of the renewable energy research. In view of the previous mentioned situation, Chinese government should pay attention to the balanced development of renewable energy to improve the proportion of solar energy in renewable energy, and catch up with the developed countries. Chinese central and local government should increase the research fund of PV to grasp core technology, and establish the grid-connect power plant and reduce the tax, stimulate domestic consumption. Only with the evenly development of all kinds of renewable energy, China will achieve the goal of building clean, lower-carbon energy system to face the challenges of energy security, environmental pollution, climate change and achieve sustainable development in the foreseeable future.

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References

[1] State council information office of China. China energy white paper: China's energy conditions and policies. Beijing: China People Press; 2012.
[2] National Bureau of statistics of China. China statistical year book-2012. Beijing: China Statistics Press; 2012.
[3] Wang Q. Effective policies for renewable energy–the example of China's wind power-lessons for China's photovoltaic power. Renew Sustain Energy Rev 2010;14:702–12.
[4] Wang XW, Xu SM, Wang Z, Peng L, Wang CL. International scientific collaboration of China: collaborating countries, institutions and individuals. Scientometrics 2013;95:885–94.
[5] Arunachalam S, Singh UN, Sinha R. The sleeping dragon wakes up: a scientometric analysis of the growth of science and the usage of journals in China. Curr Sci 1993;65:809–22.
[6] Du YX, Teixeira AAC. A bibliometric account of Chinese economics research through the lens of the China Economic Review. China Econ Rev 2012;23:743–62.
[7] Zhou P, Leydesdorff L. Chemistry in China–a bibliometric view. Chimica Oggi–Chem Today 2009;27:19–22.
[8] Fu HZ, Long X, Ho YS. China's research in chemical engineering journals in Science Citation Index Expanded: a bibliometric analysis. Scientometrics 2014;98:119–36.
[9] He TW, Zhang JL, Teng LR. Basic research in biochemistry and molecular biology in China: A bibliometric analysis. Scientometrics 2005;62:249–59.
[10] Li T, Ho YS, Li CY. Bibliometric analysis on global Parkinson's disease research trends during 1991-2006. Neurosci Lett 2008;441:248–52.
[11] Guan JC, Ma N. China's emerging presence in nanoscience and nanotechnology–a comparative bibliometric study of several nanoscience 'giants'. Res Policy 2007;36:880–6.
[12] Shapira P, Wang J. From lab to market? Strategies and issues in the commercialization of nanotechnology in China Asian Bus Manag 2009;8:461–89.
[13] Yan XY, Crookes RJ. Energy demand and emissions from road transportation vehicles in China. Prog Energy Combust Sci 2010;36:651–76.
[14] Ma HY, Oxley L, Gibson J. China's energy situation in the new millennium. Renew Sustain Energy Rev 2009;13:1781–99.
[15] Liu LQ, Wang ZX, Zhang HQ, Xue YC. Solar energy development in China–a review. Renew Sustain Energy Rev 2010;14:301–11.
[16] Lewis JI. The evolving role of carbon finance in promoting renewable energy development in China. Energy Policy 2010;38:2875–86.
[17] Wang XY, Yang L, Steinberger Y, Liu ZX, Liao SH, Xie GH. Field crop residue estimate and availability for biofuel production in China. Renew Sustain Energy Rev 2013;27:864–75.
[18] Rout UK, Voss A, Singh A, Fahl U, Blesl M, Gallachior BPO. Energy and emissions forecast of China over a long-time horizon. Energy 2011;36:1–11.
[19] Chen ZM, Liu Y, Qin P, Zhang B, Lester L, Chen GH, et al. Environmental externality of coal use in China: welfare effect and tax regulation. Appl Energy 2015;156:16–31.
[20] Mao GZ, Liu X, Du HB, Zuo J, Wang LY. Way forward for alternative energy research: a bibliometric analysis during 1994–2013. Renew Sustain Energy Rev 2015;48:276–86.

[21] Xu YY, Boeing WJ. Mapping biofuel field: a bibliometric evaluation of research output. Renew Sustain Energy Rev 2013;28:82–91.
[22] Haslam GE, Jupesta J, Parayil G. Assessing fuel cell vehicle innovation and the role of policy in Japan, Korea, and China. Int Hydrog Energy 2012;37:14612–23.
[23] Duan LP. Analysis of the relationship between international cooperation and scientific publications in energy R&D in China. Appl Energy 2011;88:4229–38.
[24] Uzun A. A scientometric profile of social sciences research in Turkey. Int Inf Libr Rev 1998;30:169–84.
[25] Uzun A. National patterns of research output and priorities in renewable energy. Energy Policy 2002;30:131–6.
[26] Huang LM. A study of China–India cooperation in renewable energy field. Renew Sustain Energy Rev 2007;11:1739–57.
[27] Kim H, Huang M, Jin F, Bodoff D, Moon J, Choe YC. Triple helix in the agricultural sector of Northeast Asian countries: a comparative study between Korea and China. Scientometrics 2012;90:101–20.
[28] Jamshidi AR, Gharibdoost F, Nadji A, Nikou M, Habibi G, Mardani A, et al. Presentation of psoriatic arthritis in the literature: a twenty–year bibliometric evaluation. Rheumatol Int 2013;33:361–7.
[29] Ho YS, Satoh H, Lin SY. Japanese lung cancer research trends and performance in science citation index. Intern Med 2010;49:2219–28.
[30] Chen HQ, Wan YH, Jiang SA, Cheng YX. Alzheimer's disease research in the future: bibliometric analysis of cholinesterase inhibitors from 1993 to 2012. Scientometrics 2014;98:1865–77.
[31] Mao N, Wang MH, Ho YS. A bibliometric study of the trend in articles related to risk assessment published in science citation index. Hum Ecol Risk Assess 2010;16:801–24.
[32] Cao Y, Zhou SX, Wang GB. A bibliometric analysis of global laparoscopy research trends during 1997–2011. Scientometrics 2013;96:717–30.
[33] Welthagen W, Schnelle-Kreis J, Zimmermann R. Search criteria and rules for comprehensive two-dimensional gas chromatography-time-of-flight mass spectrometry analysis of airborne particulate matter. J Chromatogr A 2003;1019:233–49.
[34] Adahchour M, Beens J, Vreuls RJJ, Brinkman UAT. Recent developments in comprehensive two-dimensional gas chromatography (GCXGC) –IV. Further applications, conclusions and perspectives. TrAC-Trend Anal Chem 2006;25:821–40.
[35] Chien TW, Lin YF, Chang CH, Tsai MT, Uen YH. Using a bubble chart to enhance adherence to quality-of-care guidelines for colorectal cancer patients. Eur J Cancer Care 2012;21:712–21.
[36] Tu MY, Chien TW, Lin HP, Liu MY. Effects of an intervention on nutrition consultation for cancer patients. Eur J Cancer Care 2013;22:370–6.
[37] Montoya FG, Montoya MG, Gomez J, Manzano-Agugliaro F, Alameda-Hernandez E. The research on energy in spain: a scientometric approach. Renew Sustain Energy Rev 2014;29:173–83.
[38] Fu HZ, Chuang KY, Wang MH, Ho YS. Characteristics of research in China assessed with Essential Science Indicators. Scientometrics 2010;88:841–62.
[39] Konur O. The evaluation of the global energy and fuels research: a scientometric approach. Energy Educ Sci Technol Part A–Energy Sci Res 2012;30:613–28.
[40] Rhourrhi-Frih B, West C, Pasquier L, Andréb P, Chaimbaultc P, Lafossea M. Classification of natural resins by liquid chromatography-mass spectrometry and gas chromatography-mass spectrometry using chemometric analysis. J Chromatogr A 2012;1256:177–90.
[41] Li W. Hydrogen energy times–the new energy revolution of fuel cells. Power Source Technol 2006;30:251–4.
[42] Barreto L, Makihira A, Riahi K. The hydrogen economy in the 21st century: a sustainable development scenario. Int J Hydrog Energy 2003;28:267–84.
[43] Winter CJ. Into the hydrogen energy economy–milestones. Int J Hydrog Energy 2005;30:681–5.
[44] Lu J, Zahedi A, Yang CS, Wang MZ, Peng B. Building the hydrogen economy in China: drivers, resources and technologies. Renew Sustain Energy Rev 2013;23:543–56.
[45] Ren JZ, Gao SZ, Tan SY, Dong LC. Hydrogen economy in China: strengths–weaknesses–opportunities–threats analysis and strategies prioritization. Renew Sustain Energy Rev 2015;41:1230–43.
[46] Kakac S, Pramuanjaroenkij A, Zhou X. A review of numerical modeling of solid oxide fuel cells. Int J Hydrog Energy 2007;32:761–86.
[47] Stambouli AB, Traversa E. Fuel cells, an alternative to standard sources of energy. Renew Sustain Energy Rev 2002;6:295–304.
[48] Li LH, Qi SB, Li K, Xian CB. Solid oxide fuel cell application status and prospects. Guangdong Chem 2013;40:122–3.
[49] Stambouli AB, Traversa E. Solid oxide fuel cells (SOFCs): a review of an environmentally clean and efficient source of energy. Renew Sustain Energy Rev 2002;6:433–55.
[50] Armstrong AR, Bruce PG. Synthesis of layered $LiMnO_2$ as an electrode for rechargeable lithium batteries. Nature 1996;381:499–500.
[51] Vikström H, Davidsson S, Höök M. Lithium availability and future production outlooks. Appl Energy 2013;110:252–66.
[52] Liu YL. Analysis to the development of China's lithium battery industry. China Electr Equip Ind 2011;12:39–42.
[53] Vayrynen A, Salminen J. Lithium ion battery production. J Chem Thermodyn 2012;46:80–5.
[54] Gong HM, Wang MQ, Wang HW. New energy vehicles in China: policies, demonstration, and progress. Mitig Adapt Strateg Glob Change 2013;18:207–28.
[55] Alonso DM, Bond JQ, Dumesic JA. Catalytic conversion of biomass to biofuels. Green Chem 2010;12:1493–513.
[56] McKendry P. Energy production from biomass(part1): overview of biomass. Bioresour Technol 2002;83:37–46.
[57] Shen L, Liu LT, Yao ZJ. Development potentials and policy options of biomass in China. Environ Manag 2010;46:539–54.
[58] Liu WS, Gu MD, HuGY Li C, Liao HC, Tang L, et al. Profile of developments in biomass-based bioenergy research: a 20-year perspective. Scientometrics 2014;99:507–21.
[59] Srirangan K, Akawi L, Moo-Young M, Chou C. Towards sustainable production of clean energy carriers from biomass resources. Appl Energy 2012;100:172–86.
[60] Melero J, Iglesias J, Garcia A. Biomass as renewable feedstock in standard refinery units. Feasibility, opportunities and challenges. Energy Environ Sci 2012;5:7393–420.
[61] National Bureau of statistics of China. The national economic and social development statistical bulletin-2014. 2015, 〈http://www.stats.gov.cn/tjsj/zxfb/201502/t20150226_685799.html〉.
[62] Zeng M, Ouyang SJ, Shi H, Ge Yu J. Is the "Sun" still hot in China? The study of the present situation, problems and trends of the photovoltaic industry in China Renew Sustain Energ Rev 2015;43:1224–37.
[63] Tan ZF, Zhang HJ, Xu J. Photovoltaic power generation in China: development potential,benefits of energy conservation and emission reduction. J Energy Eng 2012;138:73–86.
[64] Fang XD, Li DK. Solar photovoltaic and thermal technology and applications in China. Renew Sustain Energy Rev 2013;23:330–40.
[65] Blau GE, Pekny JF, Varma VA, Bunch PR. Managing a portfolio of interdependent new product candidates in the pharmaceutical industry. J Prod Innov Manag 2004;21:227–45.
[66] Docin. China's lithium ion battery industry analysis report. 2013, 〈http://www.docin.com/p-455480933.html〉.
[67] Bockris JO. A hydrogen economy. Science 1972;176:1323.
[68] Lee DH, Chiu LH. Development of a biohydrogen economy in the United States, China, Japan, and India: with discussion of a chicken–and–egg debate. Int Hydrog Energy, 37; 2012. p. 15736–45.