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Way to accomplish low carbon development transformation: A bibliometric analysis during 1995–2014

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ABSTRACT

A bibliometric analysis of low carbon related publications is reported in this study in order to depict existing research activities and to identify future directions in this research field. These publications were retrieved from various databases such as: Science Citation Index (SCI), Social Science Citation Index (SSCI), Conference proceedings Citation Index-Science (CPCI-S) and Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH). There is a notable growth associated with the body of knowledge on low carbon research. A total of 5445 records were obtained from these four major academic databases. Journal articles and proceedings papers are two frequently used document types representing 93.24% (5077 records) of the records and English is the dominant language with 5250 records (96.42%). The most productive subject is Energy & Fuels (1282 records) and the most productive journal is Energy Policy (313 records). China has largest number of publications related to low carbon. However, the USA accounts for the highest H-index (50). The Chinese Academic of Science is the organization with the most records (100 records) and the highest H-index (15). Four clusters are identified according to the analysis of co-occurrence keywords. Topics from Cluster (I) (central nodes as "climate change" and "renewable energy") are still vital to the low carbon research. However, their relative popularities declined over the past decade compared to other topics. This indicates more diverse topics from Cluster (II) (central nodes as "low carbon economy"), Clusters (III) (central nodes focusing on "low carbon", "energy" and "sustainability"), and Cluster (IV) (central node as "smart grid" interrelate with Cluster (I)) will be foci of future research endeavor in the coming decade.

1. Introduction

Extreme weather conditions such as record-breaking heat waves, heavy rainfall along with strong winds, tornadoes and floods are now occurring more frequently and severely at the globe scale [1]. According to the Environmental Protection Agency (EPA), the average temperature of Earth will increase up to 11.5 °F in next few centuries if no actions were taken to control the carbon dioxide emissions. The "new" climate conditions with extreme weather will make the world an unsafe place for future generations.

At present, traditional fossil fuels still dominate the energy mix of many countries to satisfy human beings' demands. Hence, a large amount of GHG emissions derived from human activities is responsible for various environmental issues such as haze and acid rain [2–4]. Other critical issues include the changes in land-use such as deforestation [5]. More than 40% of the total emissions are from burning coal [6]. On the other hand, fossil fuel is depleting too severely to meet the long-term sustainable energy consumption requirement of the entire world.

Therefore, the concept of "low carbon" development has attracted an increasingly level of attention as a research focus over the last two decades. It is well recognized that the fossil fuel-driven Industrial Revolution is peaking and human-induced climate damages have motivated the whole society to transit toward a post-fossil carbon era. However, it is undeniable that, as the most crucial characteristic and the biggest target of post-fossil carbon society, low carbon development is considered as an efficient model to deal with global warming and energy crisis [7]. Low carbon development is a new model of development, from the perspectives of optimizing the economic structure, developing the low carbon energy technology, improving the

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energy structure and efficiency of energy utilization and so on [8–10]. It will not only change patterns of energy production and consumption, but also continue to change the approaches of social and economic development. The development path and mode need to be revisited due to complexity nature of low carbon development. Therefore, it is not a surprise that the total number of low carbon related publications has boomed.

Bibliometrics, firstly introduced by Pritchard [11], is a "statistical method of bibliography counting to evaluate and quantify the growth of literature for a particular subject" [12]. Content analysis and citation analysis are two most common bibliometric methods [13]. Bibliometric indicators are used in citation analysis to evaluate publications. Indeed, bibliometrics is a well-recognized method to measure the progress of various areas of science [14]. Compared to other methods, bibliometric analysis have advantages such as: (1) mathematically evaluating a specific research field for a certain period of time; (2) providing a scientific evaluation method to identify the knowledge generation nature of a system [15].

There is no lack of researchers related to low carbon. This is evidenced in the large number of publications in academic journal papers and conferences which cover various aspects of this research field. This calls for a systematic analysis of the fast growing body of knowledge related to low carbon. Bibliometric research has been undertaken in other related fields such as hydrogen energy and fuel cell technologies [16] and carbon cycling research [17].

This study aims to investigate the characteristics of topic of "low carbon" related literatures from 1995 to 2014 via by bibliometric analytical techniques. These include: type(s), language(s), general pattern(s), subject(s), journal(s), performance of countries/territories and institutions and distribution of co-occurrence keywords, etc. These findings provide a better understanding of hotspots in the research field of low carbon. Similarly, these findings provide useful inputs for identifying future research directions which could accomplish low carbon development transformation. Critical questions addressed in this study are:

- Q1: What basic performance and characteristics could be used as a reference for future research?
- Q2: What are geographic patterns in terms of the number of publications? Which country/territory and institution have made the greatest contribution to low carbon research?
- Q3: What main research fields based on the co-occurrence author keywords analysis were investigated in the past and what will be focuses of the future research?

2. Methodology

There are a number of phrases presented the same meaning as "low carbon" from different perspectives. Similarly, this study places focuses on climate-related "low carbon" rather than materials with lower carbon content. To conduct this research comprehensively and accurately, "low carbon" or "low fossil fuel" or "decarbonized" not "steel*" not "alloy*" were used as searching strategy in the database of the Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Conference Proceedings Citation Index-Science (CPCI-S) and Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH) on March 30, 2015. All publication characteristics (e.g. authors, title, document type and keywords) were imported into a spreadsheet in the first instance [17]. The documents were selected within the time span 1995–2014 where 5445 records were obtained. The initial screening shows that the most productive journals are all included in the four databases. We have also searched the Google Scholar and Scopus. However, the information collected is rather informal and complex to analyze, which likely lead to an inappropriate conclusion. Besides, these two databases are largely overlapping with SCI, SSCI, CPCI-S and CPCI-SSH. Therefore, the databases of SCI, SSCI, CPCI-S and CPCI-SSH were chosen in this study.

2.1. The Classical R/S method and The Mann–Kendall test

Through calculating the Hurst exponent H value, the Classical Rescaled-Range (CR/S) provides a useful tool to analyze the long-range dependence for non-stationary time series [18–20]. Different H values mean that the sequence have different future trends. Specifically, a value $0 < H < 0.5$ corresponds to anti-correlated data (anti-persistence behavior) which means the future trend in contrast with the past, the smaller of H value the stronger of the anti-persistence behavior. A value $0.5 < H < 1$ corresponds to correlated data (persistence behavior) which means the future trend in consistent with the past, the bigger of H value the stronger of the persistence behavior and the value $H=0.5$ corresponds to random data (uncorrelated behavior). In this study, the Classical R/S method was used to predict the paper quantity of time series.

The Mann-Kendall test originally due to Mann [21] and rephrased by Kendall [22] is an efficient tool for long-term sequence trend analysis which is widely used in test feature of the meteorology and hydrology fields of rainfall, runoff, temperature and water quality, etc [23–25]. For the Mann-Kendall test, a monotonic trend of increase or decrease is evaluated commendably of a non-stationary time series by means of the calculation of the Z value. If $Z > 0$, there is an upward trend, $Z < 0$ indicates a downward trend. If the absolute value of Z is greater than or equal to 1.28/2.46/2.32, the sequence trend has passed 90%/95%/99% significance test respectively. In this study, the Mann–Kendall test is applied to determine whether there was a positive or negative trend in the amount of annual low carbon publications during 1995–2014 and whether there was obvious trend of increase or decrease.

2.2. The impact factor

Statistical analysis has been considered as one of critical components of document research. Subjects of statistical analysis include subjects, research institutions and the collaborations. Two indicators were adopted in this study. The influence of countries/territories and institutes is measured by H-index. The influence of journals is assessed by the impact factor (IF). The impact factor (IF) is one of the most commonly used assessable technologies for the relative influence of journals. IF is calculated as "the average number of times articles from the journal published in the past 2 years have been cited in the Journal Citation Reports (JCR) year and calculated by dividing the number of citations in the JCR year by the total number of articles published in the two previous years" [26]. The Journal Citation Reports 2014 was the source of impact factors of identified journals. Similarly, H-index is one of common metrics for the impacts of a scholar on a specific research field. It is defined as: "A scientist has index H if H of his/her Np papers have at least H citations each, and the other (Np-H) papers have no more than H citations each," where Np is the number of papers published over n years [27]. The H-index is a single indicator which combines measures of quantity (number of publications) and impact (number of citations). This effectively solves the problem of evaluating results that only responds to quantity with poor quality. In this study, H-index and Impact Factor (IF) were employed to characterize the performance of countries/territories and institutions, and journals related to low carbon respectively.

2.3. Content analysis

Word frequency analysis is a useful and effective method of content analysis. It is a common approach that core words and expressions which indicate the core content of literature are taken as the research object [14,28,29]. As a result, author keywords reflect the research