



## Recent progress on emergy research: A bibliometric analysis



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### ARTICLE INFO

#### Keywords:

Emergy  
Bibliometric analysis  
Web of Science  
H-index  
Social network analysis  
Co-word analysis

### ABSTRACT

Emergy-related studies have been widely conducted worldwide in order to evaluate the total environmental support and sustainability of one system from both natural and economic sides. Aiming to depict the characteristics of emergy-related literatures, recognize global research foci, and forecast future research directions, a complete review on the related research progresses by using a bibliometric analysis approach was performed in this study. H-index is applied to evaluate the influence of most productive journals, countries/territories, and institutions in emergy-related fields. Social network analysis is also performed to evaluate the interaction among different countries/territories and institutions. A holistic picture of the primary performance of emergy-related literatures published from 1999 to 2014 is presented. Co-word analysis reveals that emergy-based sustainability research and the integration of emergy synthesis with other methods (especially life cycle assessment) will be future research directions in emergy-related fields. Results obtained from this study can provide valuable information for researchers to better identify future hotspots in emergy-related fields.

### 1. Introduction

Human's production and consumption is solely dependent on the continuous support from our natural ecosystem [1]. However, such a system has been seriously damaged by human-dominant activities, especially with rapid economic development and urbanization, and increasing population. In order to identify a feasible pathway on human's future sustainable development, it is necessary to uncover the key problems so that sustainability can be integrated into product design [2,3] and policy making [4,5]. Many evaluation methods have been proposed, such as life cycle analysis (LCA), material flow analysis (MFA), ecological footprint (EF), and input-output analysis. However, these methods mainly focus on individual parameters and therefore cannot provide a complete picture of regional development. Consequently, an innovative evaluation method that can address such concerns should be raised.

Emergy analysis (EMA) is one method that can address these concerns. It is defined as the total amount of available energy needed directly and indirectly to generate a product or service [6,7]. Since solar energy is the original form of all energy, it is commonly used as equivalent to quantify other forms of energy and expressed as solar emjoules, abbreviated as sej. The amount of emergy needed to generate one unit of product or service is defined as UEV and expressed with the

unit of sej/unit (i.e., sej/g, sej/J, and sej/\$). Measuring all forms of energy, resources, and human services based on solar energy equivalent allows the direct comparison of input and output flows. Correspondingly, a series of emergy-based indicators could be calculated to quantify the economic benefits, environmental impacts, and evaluate the overall sustainability of one system.

Emergy theory was first proposed in the late 1980s and then gradually applied to study natural ecosystem or human-dominated systems. Particularly, with the increasingly mature theoretic progresses, updated emergy transformity (UEV) database, more emergy scholars worldwide, and an international emergy research organization (International Society for the Advancement of Emergy research, ISAER), emergy study has become one hot spot and received more attentions globally. As a useful tool for environmental management and planning policies [8], EMA has been extensively applied in other systems, such as agricultural systems [9–11], industrial systems [12–14], and urban systems [15–17]. Moreover, EMA has been widely applied at micro levels, such as computer production [18], power generation [19,20], construction materials production [21,22], as well as waste treatment [23].

Academically, studies on various aspects of EMA have been published in the international journals. For instance, Amaral et al. [24] addressed the theory, application, and last development of emergy

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research. However, only two energy-related review papers based on bibliometric analysis have been published until now [25,26]. One was published in a peer-reviewed international journal and authored by Chen and his colleagues [25], in which they conducted a bibliometric and visualized analysis to present the performance of energy-related publications. Another one was published in a Chinese journal and was authored by Liu and her colleagues, in which they summarized the recent progress of energy study both in China and in other countries. However, no comprehensive energy-related review papers based on bibliometric analysis have been published. Bibliometric analysis can help search for academic materials and analyze their merit by tracing relationships amongst academic journal citations, guiding readers to better understand the current research progress and future research directions. In order to fill such a research gap, this paper aims to investigate the performance of energy-related literatures published from 1999 to 2014. Social network analysis (SNA) and co-word analysis are also performed to further provide a holistic picture on energy-related publications and point out future research direction. The whole paper is organized below. After this introduction section, we first present our research method. We then show our research findings in Section 3 and conduct our discussions in Section 4. Finally, we draw our conclusion in Section 5.

## 2. Methods

### 2.1. Bibliometric analysis

Bibliometric analysis is a systematic approach which could quantitatively analyze scientific publications in order to identify particular research phenomena [27]. The application of bibliometric analysis has been extended from the initial area of library and information science to measure scientific progress in various fields [28]. Mathematical and statistical techniques are applied in bibliometric analysis, aiming to investigate the distributed architecture, mathematical regularities, varying patterns, and quantitative management of studied information, and then analyze the structure, features, as well as patterns of the underlying science and technology [29–31].

### 2.2. Impact factor and *h*-index

Impact factor was first proposed in Science by Garfield in order to measure the impact a journal receives citations to its papers over time [32,33]. Impact factor is assessed by dividing the total citations of papers from a journal published in preceding two years cited in the Journal Citation Reports (JCR) by the total amount of papers published in that journal in the same previous periods. As a standardized indicator, impact factor has been widely applied to measure the quality of journals, research papers, as well as researchers [28]. In this study, impact factors from 2014 JCR were used to evaluate the influence of different relevant journals.

Proposed by Hirsch in 2005, *h*-index is another indicator to evaluate the research achievement of a scholar from both quality and quantity aspects [29,34]. According to Hirsch [34], the definition of the *h*-index is that a scholar with an index of *h* has published *h* papers, each of which has been cited in other papers at least *h* times. In this study, *h*-index was employed to assess the influence of journals, countries/territories, authors and institutes.

### 2.3. Social network analysis

Social network analysis (SNA) is a quantitative approach to evaluate the relationship among the social actors [29]. SNA has been extensively applied due to the development of network theory and computer processing capacities [35]. In this study, SNA was applied to investigate the academic collaboration among the most productive countries/territories and institutes.

### 2.4. Data sources

The Institute for Scientific Information (ISI) Web of Science (WoS) published by Thomson Reuters are extensively used for searching scientific literatures [36]. As a widely accepted database of different scientific fields, WoS has been regarded as a significant source of data for bibliometric analysis [37,38]. Including more than 100 subjects, WoS could provide more consistent and standardized records compared with other databases such as Scopus [29,39]. Falagas et al. [40] found that detailed information and relative good graphics could be obtained from the citation analysis provided by WoS. Although the sub-field database Science Citation Index Expanded (SCIE) and Social Sciences Citation Index (SSCI) include the most influential publications, some publications or “grey” literatures (e.g., report and conference proceedings) are not covered [29]. Therefore, SCI, SSCI, Conference Proceedings Citation Index–Science (CPCI-S), and Conference Proceedings Citation Index–Social Science & Humanities (CPCI-SSH) are all selected as the data sources in this study. “Energy accounting”, “energy analysis”, “energy evaluation”, or “energy assessment” were selected as the keywords under the “topic” option to search energy-related literatures published during the period of 1999–2014 in the aforementioned databases. Data analysis was performed based on the data which was obtained on September 7, 2015.

## 3. Results

Among 722 publications obtained from the abovementioned databases, approximately 98.75% were published in English, followed by Chinese (0.83%) and French (0.42%). Only those literatures published in English (713 publications) were considered in this study since English is the common academic language worldwide. Among them, journal papers (517 publications) and proceeding papers (151 publications) are the major contributions, accounting for approximately 72.51% and 21.18% of the total published English-language literatures, respectively. In addition, other contributions include review papers (4.63%), editorial papers (0.84%), letters (0.70%), and corrections (0.14%), which are insignificant. Therefore, 668 publications (i.e., research papers and proceeding papers) were finally selected for further analysis in this study.

### 3.1. Primary performance of selected publications

Table 1 presents the primary performance of energy-related literatures published during the period of 1999–2014. Results show

**Table 1**  
Primary performance of energy-related publications from 1999 to 2014.

Year	TP	AU/TP	CR/TP
1999	3	3.67	17.00
2000	10	2.30	31.60
2001	15	2.73	24.40
2002	13	2.54	23.08
2003	18	2.78	19.22
2004	27	3.04	23.70
2005	17	3.59	21.18
2006	32	2.94	37.69
2007	33	3.21	35.67
2008	44	3.43	39.52
2009	65	3.57	40.17
2010	65	3.51	39.69
2011	84	3.60	40.52
2012	68	3.60	40.78
2013	85	3.89	44.31
2014	89	4.13	54.12

TP, AU, and CR represent the amount of publications, the amount of authors, and the amount of cited reference, respectively.

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