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## Way forward for alternative energy research: A bibliometric analysis during 1994–2013

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## ABSTRACT

The alternative energy plays a crucial role in the sustainable energy development. The alternative energy related literature had attracted a growing attention with the research outputs expanding substantially. Based on the Science Citation Index-Expanded (SCI-E) and the Social Sciences Citation Index (SSCI), a bibliometric analysis of the research output was carried out to depict existing research activities on alternative energy and future directions. The article was the main type of publications with the English as the dominate language to explain their results. With the publications increasing rapidly since 2008, the researches mostly focused on the fields of Energy & Fuels and Environmental Sciences. Energy Policy was the journal that published the largest number of research articles on the alternative energy. The bioenergy and solar energy were popular items in the commonly used 20 journals. Among the countries, the USA was leading on alternative energy related research, publishing the largest number of articles (TP=2368) and being the most influent (*h*-index=90). The USA played a key role in the academic collaborations with China, UK, Canada, Germany, Italy, South Korea and Spain. The National Renewable Energy Lab (the USA) contributed most in the alternative energy field and more specially, the School of Electrical & Computer Engineering (TP=36) was the most productive subordinate in the National Technology University of Athens. It was interesting to note that more attention was paid to solar or wind energy during the first 5 or 10 years, then turned to bioenergy subsequently except for Spain, Canada and Australia. In addition, bioenergy received the most attention in the 7 types of alternative energy. The forest/wood biomass, energy crops and switchgrass were the main bioenergy resources and fermentation was the commonly used conversion technology. The production of biogas, biodiesel and bioethanol was most popular in the bioenergy related studies. Wind energy and solar energy related researches were mainly on the energy utilization approaches such as the wind generation, wind farm, photovoltaic and solar thermal. The conversion devices such as the wind turbine and solar cell were paid most attention in order to improve the production efficiency. The most cited article, published in *Desalination* in 2009 with 1562 citations until 2013, was about wind power utilization in the reverse osmosis desalination plant.

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## 1. Introduction

The demand for energy is expected to expand continuously, more than tripled by the end of the century [1]. At present, about 80% of the world's energy is supplied by traditional fossil fuels. The combustion of traditional fossil fuels leads to emission of carbon dioxide and other pollutants into the atmosphere, which is responsible for environmental issues such as smog and acid rain [2–4]. There is a growing conflict between fulfilling the energy requirements of sustainable economic development and the reduction of the environmental impacts of fossil fuel combustion. As a result, policy makers, business leaders, consumers and researchers have increasingly turned their attention to the alternative energy sources such as solar, wind, and biomass [5–10]. For example, the Energy Policy for European Countries proposes to achieve a 20% share of renewable energies in the energy mix by 2020 [11]. Indeed, it presents one of the greatest challenges to human beings for the access to safe and clean energy supplies.

Accordingly, with the recognition of importance and availability of technologies for the alternative energy, the associated body of literature has grown substantially. The research related to the alternative energy has become multidisciplinary covering a wide spectrum including studies in energy and fuels [12], environmental sciences [13], environmental studies [14], engineering and chemical [15] and so on. Therefore, it is necessary to evaluate the growing body of literature on the alternative energy. Bibliometric techniques can offer an important quantitative perspective to assess the development and growth of research related to the alternative energy.

Bibliometrics is a set of methods to quantitatively analyze scientific and technological literature [16]. It was defined by Pritchard (1969) as “the application of mathematics and statistical methods to books and other media of communication [17]. Two most common bibliometric methods are citation analysis and content analysis. Bibliometric methods have been widely employed to investigate the impact of research fields, the impact of scholars, and the impact of a particular publication [18]. The bibliometric technique is mainly qualitative by transforming something intangible (scientific quality) into a manageable entity. It has been widely adopted in quantitative research assessment exercises of academic output. Two advantages associated with bibliometric analysis are: (1) it uses indicators and the calculation of certain classical laws to assess the research or the scientific production in a specific area over a period of time; (2) it offers an assessment approach which recognizes the knowledge generation nature of science as a system [19]. Indeed, bibliometric techniques have become an indispensable instrument to measure the scientific progress in various fields [20].

The aim of this study is to quantitatively and qualitatively evaluate the global trend of research literature related to alternative energy from 1994 to 2013. Using bibliometric method, various

publication characteristics will be obtained such as publication types, the subject categories, institutions, countries, citation patterns as well as content analysis of keywords and titles. In addition, focus is placed on the development patterns of energy types, e.g. bioenergy, wind energy, solar energy, nuclear energy, geothermal, hydropower, and ocean power in different countries. These results not only provide a better understanding of global hotspots in the research related to the alternative energy, but may also influence researchers' future research directions.

## 2. Methodology

### 2.1. The bibliometric method

Bibliometrics is a multifaceted endeavor covering structural, dynamic, evaluative and predictive scientometrics [21]. Used in the field of library and information science initially, it has spread to other areas, especially in the quantitative research assessment exercises of academic outputs aiming at evaluating the impact of the researchers, the institutions and so on. Containing the most extensive quantitative analysis of science, bibliometric method is an effective method of quantitative analysis method to measure the contribution of different aspects within a given topic [22–24]. It offers a useful tool to shift from micro (scientist and institute) level to macro (national and global) level. Furthermore, the research trends and popular issues at the present, past or future can be identified by means of the bibliometrics analysis [25]. In this paper, many quantitative characteristics of science were obtained by employing the bibliometric method, such as publication counts of the journals and the subject categories.

### 2.2. The social network analysis

The social network is a set of people or groups each of which has connections with others. The people or groups, and the connections are called “actors” and “ties”, respectively [26]. Collaboration is a common social interaction which includes many actors and relationships between them. The social network analysis (SNA) method has been widely employed in various fields where the social network is visualized from a statistical and mathematical perspective [27]. In the SNA, a square array of measurements is used to represent the network [28]. Similarly, it is suggested to measure the strength of collaborative ties based on the distance calculation [29].

Among various software tools, the UCINET containing Netdraw and Pajek is used frequently in the SNA for the visualization of networks and the mathematical calculation, respectively [28]. In addition, bibexcel is another software tool to perform several bibliometric and network analysis [30].

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