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Comprehensive evaluation of global clean energy development index based on the improved entropy method

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ABSTRACT

In order to achieve global energy supply security, environment-friendly, coordinated configuration and efficient use, the development of clean energy is imperative. In this paper, a clean energy development index evaluation index system with four grades is established from the two aspects of clean energy installed capacity and clean energy generation. Based on the improved entropy method of the sub-section and sub-dimension comprehensive evaluation model and the clean energy installed capacity and clean energy power generation of the year of 2013 and 2014, the absolute, the relative and the incremental development index of various categories of clean energy in different countries is obtained, and then the overall clean energy absolute, the relative and the incremental development index of every country is calculated. Ultimately, the clean energy composite development index is obtained. According to the descriptive statistics analysis method and combined with the characteristics of clean energy development in studied countries, 231 countries are divided into four categories: A++, A+, A, A−. By changing the weight determination method, the efficiency coefficient entropy method is used to verify the level of clean energy development, and the Spearman correlation of the exponential results calculated by different methods is analyzed. The conclusion is drawn that the top 10 countries in the clean energy development index in 2014 are the United States, China, Germany, France, Spain, Italy, Kenya, the Philippines, Canada and New Zealand. In fully developed countries, the absolute, the relative and the comprehensive development index of clean energy are relatively high. In emerging countries, the incremental development indexes of clean energy are relatively high, and the emerging countries of the clean energy market have great potential for development.

1. Introduction

Since the beginning of the twenty-first century, climate change, energy shortage and air pollution have become three major problems faced by human beings, and the implementation of energy conservation and emission reduction strategies is imperative. Clean energy, or green energy, refers to energy that does not emit pollutants, including nuclear energy and renewable energy. Renewable energy refers to renewable energy sources, such as hydropower, wind power, solar energy, bioenergy and tidal energy. In 2016, at 8% of the installed growth rate, the global clean energy installed capacity increased by 138 GW. The investment in renewable energy generation is about twice that of fossil energy. And the proportion of renewable energy power, excluding large hydropower stations, rose from 10.3% to 11.3%, resulting in a reduction of 1700 Mt of carbon dioxide emissions.

Cheap and clean energy was identified as one of the United Nations goals for sustainable development in September 2015 (United Nations General Assembly, 2015). The current research on clean energy development is mainly focused on three aspects: the clean energy policy and influencing factors study, clean energy technology research and the importance of clean energy in low carbon energy system. First, policy factors are an important factor in promoting the development of clean energy market. Clean energy policy research mainly includes clean energy subsidy policy and clean development mechanism incentive policy (Ming et al., 2008). Second, as an important factor in the development of clean energy, economic factors also have an important impact on the development of clean energy, such as the impact of foreign direct investment inflows and stock market development on the use of clean energy (Sudharshan et al., 2016), and the impact of clean energy investment on clean energy development efficiency and clean technology development (Nevenka et al., 2016) and so on. Clean energy technologies that cost more than fossil fuel technologies require support through Research and Development (R&D). In setting research policy, governments should consider the greater benefits of cost reductions brought about by transformational rather than incremental change (Soheil et al., 2017). In the study of the importance of clean energy in

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low-carbon energy systems, Ensemble Empirical Mode Decomposition (EEMD), a competitive multi-scale analysis tool, is used to capture the meaningful aspects of the clean energy market Characteristics, and based on fuzzy entropy method to analyse the overall and internal characteristics of energy systems, and then study the complexity of the clean energy market (Ling et al., 2017). And through the study of other energy price fluctuations, to a certain extent, predict the development of clean energy changes (Anupam, 2017). As well as the establishment of low-carbon economic development model can be a strong impetus to the development of clean energy (Lan, 2014).

The evaluation of the energy system development has long been related research by domestic and foreign experts, and the typical models include the LEAP (Long-range Energy Alternatives Planning system) model, the MARKAL (Market Allocation) energy model, and the 3E (Energy, Economy and Environment) model. The LEAP (Long-range Energy Alternatives Planning system) model is a bottom-up energy-environment model tool based on scenario analysis developed jointly by the Stockholm Environment Association and the University of Boston. It can be used to do the energy needs and its corresponding environmental impact analysis and cost-benefit analysis. In the environmental impact analysis, the greenhouse gas emissions of non-energy sector can also be joined to do comprehensive environmental impact analysis (Zheng et al., 2016a). MARKAL (Market Allocation) energy model is an energy system analysis tool based on linear programming. At present, the model is widely used in OECD countries and several other developed countries. It can be used to analyse the impact of technological progress on energy demand and energy conversion, interchange mechanisms among energy sources, energy investment and system costs, and the impact of greenhouse gas emissions on energy systems and the economy (Stanislav and van den Bergh, 2016; Aleksandar et al., 2016). 3E (Energy, Economy and Environment) model is a combination of energy, economy and environment to meet the sustainable development needs of the national economy. It is mainly used to support the country's decision-making on sustainable development strategies. It is often used for energy forecasting, assessment and the determination of energy development strategy (Mo et al., 2014; Vijendra Babu and Alamelu, 2010; Zhe and Wei, 2014).

Currently, a variety of energy categories of evaluation indicators have been studied in the world, such as the Climatescope index (UKaid from the British people et al., 2016), also known as the National Clean Energy Competitiveness Index, which is targeted at 58 emerging markets in Africa, Asia and Latin America and the Caribbean, and evaluated by four classification indexes, including the Energy Market Framework Index (0.4), Clean Energy Economy and Investment indicators (0.3), low-carbon enterprises and clean energy value chain index (0.15), and the greenhouse gas index (0.15). The Climatescope index assesses the ability of emerging countries to attract clean energy investments and provide investment basis for investors. The index is designed to quantify the ability of the target to attract clean energy investments and provide investors with a basis for investment. EAPI (Global Energy Architecture Performance Index, 2017) is a comprehensive index developed by the World Economic Forum in cooperation with Accenture to directly reflect the level of development of the country's energy system (The World Economic Forum, 2017). Its research objects include 127 countries; the core is the index system of the 18 indicators that are defined in the "energy triangle" on three sides, namely economic growth and development, environmental sustainability, and energy access and security. The Energy Development Index (EDI) reflects the extent to which a country or region is changing to modern energy and its maturity in terms of energy end use, including per capita commercial energy consumption, the proportion of commercial energy in the total terminal energy consumption and the proportion of people with an electricity supply (International Energy Agency, 2016). The Wind Energy Development Index (WEDI) provides a reference for the development of wind energy resources such as offshore wind power generation and seawater desalination. It can reduce the energy and environmental crisis and promote the sustainable development of human society by accelerating the industrialization and utilization of wind energy (Zheng et al., 2016b).

From the point of view of methodology, as one of the objective evaluation methods, the entropy method is a comprehensive evaluation method which excludes the influence of subjective factors and determines the corresponding weight based on the data provided by the indicators. The comprehensive evaluation model of entropy method includes the following: (1) Entropy Method-Fuzzy Comprehensive Evaluation Model. It is a comprehensive evaluation method combining subjective and objective (Ya and Cai, 2014). According to the membership degree theory of fuzzy mathematics, fuzzy comprehensive evaluation method converts the comprehensive evaluation of qualitative indicators into quantitative evaluation (Bai and Wang, 2012). (2) Entropy Method-Factor Analysis Method Comprehensive Evaluation Model. It is a comprehensive evaluation method which combines the method of dimensionality reduction in principal component analysis and the empowerment strategy of the entropy method. It can solve the problem of subjective bias and the subjective deviation (Wang et al., 2015). (3) Entropy Method –Gray Method Comprehensive Evaluation Model. The gray relational analysis method is used to find the degree of correlation between the evaluation value and the standard value. Based on the mathematical relation between the standard values of the evaluation index, the weight of the evaluation index is calculated by the entropy method. Eventually, the rank of the object being studied is determined (Ren et al., 2013).

In summary, the innovation of clean energy development research is generally focused on the study of influencing factors, and the experts are less from comprehensive evaluation of clean energy development level point of view to explore the development of clean energy issues. One of the innovations of this paper is to build a comprehensive evaluation model of clean energy development index from two aspects of clean energy capacity and power generation, and to evaluate the different development situation of clean energy in different countries and regions, and to guide the formulation of economy's clean energy development strategy and the development of overseas investment strategy.

At present, the relevant international literatures mainly focus on the energy development index study. However, there is relatively little research on the development index analysis for the clean energy sector. For the comprehensive evaluation model, at present, the determination of the comprehensive evaluation weight of energy development index at home and abroad is mainly subjective, and objective weight determination method has not been introduced. Based on the background of global clean energy investment growth, this paper constructs the comprehensive evaluation model of clean energy development index, and deeply studies the absolute, relative and incremental development index of different types of clean energy in different countries by applying objective analysis method such as entropy method and finally calculates the comprehensive development index. The research method and research angle of this paper are innovated in the related field at home and abroad, which makes up the gap in this field.

"Clean energy" is the fundamental global energy interconnection and the core of future energy transformation. In the context of China's " One Belt One Road" program, the overseas business of China's electric power enterprises has been increasing, and the export of clean energy equipment has become an important part of overseas business. At the same time, clean energy export business is also facing a complex market environment and fierce market competition, and the determination of the target market has become one of the important plans for the enterprises to implement the Go-out Policy. The research results of this paper meet the demand of clean energy overseas investment planning of electric power enterprises. At the same time, the research results of this paper can let each country have a clearer understanding of the development situation and stage of its own clean energy, and plays an important role in promoting the policy formulation of clean energy in