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Forecasting new and renewable energy supply through a bottom-up approach: The case of South Korea

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ABSTRACT

This paper introduces the forecasting model for a new and renewable energy supply utilized in the Fourth Basic Plan for New and Renewable Energy of South Korea in 2014 and presents the estimated results. The Korean government formulated a plan for raising the new and renewable energy deployment rate to 11% by 2035, and this paper presents the development of the corresponding plan. The proposed model essentially uses a bottom-up method to reflect the characteristics of each renewable source. In addition, a competitive diffusion model, a logistic growth model, a linear regression model, and data from government planning and companies' planned projects are used. The forecasts are classified and presented by renewable source and output type (i.e., electricity, heat, and transportation fuels). The results show that Korean new and renewable energy production will reach about 37 million tonnes of oil equivalent by 2035. In addition, the renewable electricity sector has become mainstream since the 2012 implementation of Renewable Portfolio Standard policy, and is expected to account for 60% of total new and renewable energy supply in 2035. Furthermore, wind, solar photovoltaic, and bioenergy are projected to replace current waste-oriented sources.

1. Introduction

Global energy demand has been increasing continually, and it is expected to rise 37% from 2013 to 2040 [1]. Although it is natural that energy consumption increases in accordance with a region's economic growth, such increases also entail an increase in carbon emissions [2]. As such, many countries are making efforts to reduce their carbon emissions [3] and are promoting the adoption of new and renewable energy (NRE) sources [4]. NRE has the potential to offer economic and environmental benefits, such as increasing GDP, creating new jobs, enhancing human welfare, and reducing greenhouse gas emissions [64]. Thus, there has been a steady increase in global demand for NRE. The total primary energy supply provided by renewables reached 76 EJ/year in 2013, 30% higher than 57.7 EJ/year in 2004 [5].

Despite much interest worldwide, the NRE industry and market are still in infancy compared with conventional energy sources and thus, are accompanied by great uncertainty, which has been addressed in previous studies [6–9]. The International Energy Agency (IEA) [10] pointed out that such uncertainty could hamper future growth of the NRE sector. Therefore, reducing uncertainty is a crucial component of an effective NRE policy [8] and development of the related industry. It is essential to have the most accurate forecasts in order to reduce such uncertainty and make better decisions regarding the operation of the NRE system. Moreover, NRE targets should be on a sound knowledge base, such as accurate forecasts [11].

Given the increasing importance of accurate forecasts of NRE, such as supply forecasts, several relevant studies have been undertaken. Many studies focus on a specific NRE source, such as solar photovoltaic (SPV) [12] or wind power [13], as their target for empirical analysis and forecast the future supply of the selected source. As most countries are mainly interested in expanding the supply of renewable electricity [14,15], most existing studies make forecasts based on the electric power sector. By contrast, only a few studies propose a supply forecasting method to fit the particular characteristics of each energy source, or make long-term forecasts by NRE source and sector.

This study proposes a novel bottom-up approach to forecast NRE supply by source and sector in a comprehensive manner. The proposed method is applied to South Korea, and the resulting empirical analysis yields forecasts for Korea's annual NRE supply up to 2035. This information can be used to forecast which specific sources have the highest chance of success and which sector can best lead future expanded NRE supply. In addition, this study examines Korea's NRE

Abbreviations: NRE, new and renewable energy; IGCC, integrated gasification combined cycle; RPS, Renewable Portfolio Standards; RFS, Renewable Fuel Standards; RHO, Renewable Heat Obligations; SPV, solar photovoltaic; LCOE, levelized cost of energy; REC, renewable energy certificate; RDF, refuse-derived fuel

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supply targets, comparing supply to potential to suggest relevant policies. The methods and forecasts presented in this study were used to design the Fourth Basic Plan for Renewable Energy of South Korea in 2014 [16].

The remainder of the paper is as follows. Subsection 1.1 summarizes the current status and policy trends in Korea's NRE sector and examines relevant issues. Section 2 outlines previous studies of NRE supply outlook, examines their contributions and limitations, and describes the method of this study. Section 3 presents the results for Korea's long-term NRE supply forecasts until 2035 by applying the proposed methods to the Korean market. Based on the forecasting results, the average annual increase rate, penetration rate, and the possibility of achieving the Korean government's NRE supply target are examined. Lastly, Section 4 concludes by summarizing the results, discussing several policy implications, and presenting the limitations of the study and future research directions.

1.1. Current status of the Korean new and renewable energy sector

The Korean government defines NRE as energy converted from conventional fossil fuel (new energy) and energy from natural resources, including sunlight, water, and terrestrial heat (renewable energy, RE) and notes 11 types of NRE sources: SPV, solar thermal, wind power, geothermal, hydropower, ocean energy, bioenergy, waste-to-energy, fuel cell, integrated gasification combined cycle (IGCC) from coal, and hydrogen energy [17].

After the oil crisis of the 1970 s, the Korean government realized the need to diversify energy sources and improve its energy consumption structure, and in 1987, the government started full-scale development of NRE [65]. Since formulating the Third Basic Plan for New and Renewable Energy of South Korea [18] in 2008, the government had a strategy for promoting relevant industries and bolstering market functions. In addition, the government has established specific strategies to follow through on deployment objectives agreed in the Basic Plan for Energy, its highest-level energy-related plan. Presently, the Korean government has selected six major implementation objectives[1] from the Second Basic Plan for Energy [19] of February 2014 and the Fourth Basic Plan for New and Renewable Energy of South Korea [16] of September 2014. It is implementing a strategy for expanding NRE use and promoting the industry.

The Korean government set targets for the ratio of NRE to primary energy of 5% by 2020, 7.7% by 2025, 9.7% by 2030, and 11% by 2035 [16]. These targets would achieve 6.2% average annual growth of NRE supply from 2014 through 2035, exceeding the expected average annual growth of primary energy demand of South Korea over the same period, which is about 0.7%. By source, the Korean government plans to reduce the waste-to-energy ratio in favor of SPV and wind energy.

In South Korea, the NRE accounted for 3.52% of total primary energy demand and 3.86% of total power generation in 2013 [20]. However, these figures include fuel cells, byproduct gas, and industrial waste, in accordance with Korean NRE standards. According to the IEA standards, Korea's ratio of RE to primary energy was 1.9% in 2012, placing it last among the 34 Organisation for Economic Co-operation and Development (OECD) members [21]. South Korea's NRE industrial sector grew between 2008 and 2012, as the number of related manufacturers increased from 134 to 200, the number of employees in the industry grew from 6,496 to 11,836, and sales increased from Korean Won (KRW)[2] 3.268 trillion to KRW 6.467 trillion [16]. After the global NRE industry entered a restructuring period in 2012, the Korean NRE industry shrank considerably; however, it has since grown again, particularly by relying on wind power and SPV industries, which have a great ripple effect on related industries.

Thus far, the Korean government has implemented various policies and projects to boost NRE penetration, such as supporting housing and building projects, providing financial assistance, and implementing projects to mandate installation. However, the policies most conducive to increasing penetration are quantitative policies with strong regulatory components, such as Renewable Portfolio Standards (RPS) in the electric power sector, Renewable Fuel Standards (RFS) in the transportation sector, and Renewable Heat Obligations (RHO) in the heating sector. RPS and RFS have been in place in Korea since 2012 and 2015, respectively, whereas RHO implementation is scheduled for 2017.[3]

While there is social consensus for the expansion of NRE in Korea, conditions seem to be lacking for policy implementation. In particular, due to environmental and geographic restrictions and a fall in local residents' acceptance, there has been delayed penetration of NRE use. Furthermore, there are conflicts of interest among stakeholders due to differing views on nationwide implementation of policies, such as RFS and RHO. Moreover, there is increasing uncertainty over the profitability and investment value of NRE because the recent drop in global oil prices has led to a fall in the cost of power generation, which has lowered the system margin price and renewable energy certificate (REC) prices. Given the current status of Korea's NRE sector, the supply forecasts presented by this study can provide key information to policymakers and investors and contribute greatly to reducing market uncertainty.

2. Methods

2.1. Literature review: renewable energy forecasting

RE forecasting studies began in earnest in the 2000 s. Given the large amount of uncertainty related to RE, these studies exhibit large diversity in perspectives. It is not easy to categorize the existing studies accurately since each selectively forecasts certain factors, such as technologies, policies, supply, installed capacity, and unit costs of production. Despite this, summarizing and reviewing previous research can help highlight the aspects that differentiate this study.

Some of the different approaches used to forecast RE include dealing with the current status or future outlook by source from a technical perspective [22,23], forecasting with a focus on a specific source or sector [24,25], forecasting future investment directions [26], considering job creation [27], and examining the role and availability of RE sources in specific areas [28].

Most studies comprehensively present the status and prospects for a target country or region, and suggest policies and systems for expanding future penetration. Studies in this category mainly consider developing countries, such as Mexico [29], Bangladesh [30], Pakistan [31], India [32], Turkey [33], Oman [34], and Iraq [35]. These studies present the comprehensive status of RE in the nation of concern and provide policy implications relevant to that country.

Previous studies most similar to the present one are those that forecast the annual RE supply or power generation capacity by source. Uyterlinde et al. [36] examined European countries' RE supplies up to 2020 using a market simulation model, and different technology learning scenarios were reflected in the forecast process. Kumbaroğlu et al. [37] presented a forecast model that combined learning curves with real options modeling and forecast RE power generation capacities up to 2025 for the Turkish electricity supply industry. Resch et al. [38] proposed future renewable electricity deployment for several industrialized countries up to 2030 based on scenarios from the results of the IEA [39]. Azadeh et al. [40] suggested ways of forecasting RE

[1] The objectives are implementing customized distribution/expansion policies, operating market-friendly systems, expanding foreign market entry, creating new markets, enhancing R & D capabilities, and putting in place systemic support.

[2] In 2014, 1 USD was equal to approximately 1053KRW.

[3] For details regarding Korea's RPS, RFS, and RHO, refer to [14].