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# Evaluation of R&D investments in wind power in Korea using real option

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In recent years, many countries put an emphasis on the development and deployment of renewable energy to cope with the global environmental crisis such as depletion of fossil energy, climate convention to control emissions of greenhouse gases. Among the various new and renewable energy sources, the Korean government selected wind power energy as one of the core areas for R&D investments. In this paper, we evaluate the economic value of the investment in wind power energy R&D in Korea and optimal deployment timing of wind power technology by using the real option approach. The real option model adopted in this paper assumes that a decision maker has a compound option to abandon, deployment, or continue the R&D. As a result by using empirical data of Korea, it is found that there exists a considerable amount of positive economic value of investments in wind power energy R&D.



**Contents**



## 1. Introduction

The accelerating depletion of fossil fuel resources and volatility of oil prices, coupled with regulatory responses to environmental changes such as the Climate Change Convention for reduction of greenhouse gas emissions, has made clear the importance of utilizing renewable sources of energy such as wind, photovoltaic, thermal heat, and biological organisms. In recent years, sources of renewable energy have come to be perceived no longer as simple alternatives to fossil fuels, but rather as basic and indispensable sources of energy that provide a solution to the energy crisis the planet is facing.

Developing and commercializing new and renewable energy sources requires huge initial investments. Nevertheless, developed

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**Table 1**
Trend of annual R&D investment in renewable energy technology development projects in Korea (1988–2011) (Unit: Billion KRW).

| Year | Total renewable energy | | | Wind power | | |
|---|---|---|---|---|---|---|
| | Public | Private | Total | Public | Private | Total |
| ~2002 | 152 | 98 | 250 | 14 | 9 | 23 |
| 2003 | 33 | 18 | 51 | 4 | 2 | 6 |
| 2004 | 59 | 32 | 91 | 8 | 2 | 10 |
| 2005 | 79 | 43 | 122 | 11 | 4 | 15 |
| 2006 | 116 | 77 | 193 | 17 | 6 | 23 |
| 2007 | 121 | 93 | 214 | 17 | 10 | 27 |
| 2008 | 195 | 173 | 368 | 18 | 9 | 27 |
| 2009 | 206 | 137 | 343 | 38 | 33 | 71 |
| 2010 | 240 | 129 | 369 | 41 | 32 | 73 |
| 2011 | 243 | 214 | 457 | 42 | 33 | 75 |
| Total | 1445 | 1012 | 2456 | 209 | 140 | 349 |

countries are aggressively investing in related R&D programs and undertaking policies to expand the use of renewable energy sources. This is also the case in Korea, where there is a keen awareness of the critical importance of new and renewable energy sources. Indeed, the Korean government has had a 'basic plan for technological development, utilization and deployment of renewable energy' in place since the late 1990s. In the process of designing and implementing the basic plan, the Korean government came to understand that continuous investment in R&D is indispensable for developing advanced technologies and facilitating the commercialization of renewable energy technology. Indeed, funding by both the public and private sectors of Korea towards R&D programs is continuously increasing as shown in Table 1.

Among the various new and renewable energy sources, the Korean government selected wind, photovoltaic, and fuel cell based energy as the three core areas for R&D investments. In particular, wind power has attracted increasing attention in Korea not only because it is the most technically advanced and economical source of renewable energy, but also because numerous places in Korea experience heavy winds on a year-round basis. Starting with the wind farm on Jeju Island (9795 kW capacity) constructed as a governmental pilot project in 1997, 17 wind farms are now in operation in Korea. While a total of 272 wind-power generation systems were installed as of 2012 with a total capacity of 448.35 MW [1], Korea still has a low level of wind power deployment compared with that of the US (60.0 GW), Germany (31.3 GW), China (75.3 GW), and Spain (22.8 GW) [2]. Hence more aggressive investment in wind power technology is required in Korea.

Indeed, as the scale of R&D investment in wind power in Korea increases, the demand for studies to analyze and justify the efficiency of investments has increased. Furthermore, since R&D investments are considered high risk and include various kinds of options in the decision making process such as delay, abandonment, and expansion, it is important to consider uncertainty and these options simultaneously when evaluating economic values and deciding when to deploy the results of R&D for wind power energy. However, there is a paucity of empirical research on economic evaluation of wind power energy R&D in Korea performed using real option analysis.

The aim of this study was to provide an empirical calculation of economic values of R&D investment in wind power energy technology of Korea based on a real options model taking into consideration the uncertainty of fossil fuel prices. To quantify the economic values of managerial decision options with respect to wind power energy R&D, we identified optimal decision-making choices and timing of options under various situations of uncertainty. Specifically, we used empirical data and government plans to evaluate the economic values of wind power energy R&D using both a traditional DCF model and a real options model. We performed a comparative analysis on the results obtained by both models. In addition, we derived an optimal decision path as a function of time according to energy market uncertainty by analyzing a binomial lattice model in which the optimal timing of R&D and deployment were identified. Sensitivity analysis with respect to important model parameters was also performed. Finally, we present relevant policy implications based on the results obtained from this study.

The rest of this paper is organized as follows: Section 2 provides a short review of relevant literature. In Section 3, we present the two models employed in this study to evaluate wind power energy R&D. In Section 4, we briefly describe the data used in this study, describe the results of our evaluation using the two models as well as the results of the sensitivity analysis, and discuss the policy implications of these findings. Lastly, we present our conclusions in Section 5.

## 2. Literature review

In order to make informed decisions concerning the allocation of public funding for wind power energy R&D, the ability to accurately assess the economic effects of R&D programs is critical. Menegaki [3] reviewed the literature on valuation or evaluation of renewable energy resources and summarized existing methods of analysis. In their review study, the authors argued that it is important to consider the values of renewable energy, which are difficult to evaluate in the perspective of traditional valuation methods. Along these lines, the accuracy of discounted cash flow (DCF) analysis, a traditional method widely used for estimating the economic effects of R&D, is often called into question. Indeed, it has been pointed out that this method tends to underestimate the value of R&D activities [4,5] as well as renewable energy projects including wind power [6–8]. The consequences of inaccurate assessment of the economic effects of wind power energy R&D programs on funding prospects for related projects are bound to be negative. The main reason why the economic value of wind power energy R&D under the DCF method tends to be underestimated is that DCF analysis fails to adequately reflect the flexibility of decision-making in the face of uncertainty in the energy market, and more particularly, uncertainty linked to fluctuations in the price of fossil fuels. Thus, there is a need for more accurate methods for estimating the economic effects of wind power energy R&D that take into account the flexibility of decision-making. Indeed, flexibility of decision-making is an important variable to consider, because it allows organizations and governments to respond promptly to market uncertainties and rapidly commercialize new technologies.

Several attempts have been made in recent years to employ a technique known as *real option analysis* for economic valuation of R&D programs for renewable sources of energy, including wind power. In an early application of real option analysis used to evaluate the benefits of R&D with respect to new and renewable energy sources, Davis and Owens [6] estimated the value of renewable energy generation technologies using a continuous real option model, taking into consideration the price uncertainty of fossil fuels. In their study, which was directed at quantifying the benefits of federal renewable energy generation R&D programs funded by the US government, Davis and Owens [6] stressed that the main goals of federal non-hydro renewable electric R&D programs are to facilitate the development of stable energy supply technologies. Similarly, Siddiqui et al. [7] assessed the economic value of renewable electric power R&D programs using a method