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An economic and environmental assessment for selecting the optimum new renewable energy system for educational facility

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ABSTRACT

With the world's attention focused on climate change, the United Nations Framework Convention on Climate Change provides the basis for global action to encourage sustainable development. A wide variety of measures are being taken in South Korea in line with this trend, but new and renewable energy (NRE) have been highlighted as sustainable energy sources. This study aims to assess the economic and environmental effects of the use of NRE for selecting the optimum NRE system in educational facilities. Towards this end, the following were done: (i) selection of facility and its applicable NRE system type; (ii) calculation of the energy generation by the NRE systems via energy simulation; (iii) life cycle cost analysis for the economic evaluation on the NRE systems; (iv) life cycle assessment for the environmental evaluation on the NRE systems; (v) using the net present value and the savings-to-investment ratio, comprehensive evaluation of the economic and environmental effects on the NRE systems.

The results of this study can be used to (i) determine which NRE system is most appropriate for educational facilities; (ii) calculate the payback period for a certain investment; (iii) decide which location is proper for the implementation of an NRE system considering the characteristics of the regional climate; and (iv) select energy- and cost-efficient elementary schools where the NRE system can be applied.

Contents

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1. Introduction

Faced with the problem of global warming and climate change, efforts to save energy and to reduce carbon dioxide (CO_2) emissions are being exerted all over the world. Under such circumstances, researches on new and renewable energy (NRE) are also actively being done [1]. As radioactive pollution and energy storage problems were highlighted in the wake of the nuclear-power-plant accident in Fukushima, Japan, the interest in NRE has been increased. Germany enacted the Renewable Energy Source Act in 2000, established the Sustainable Energy Supply Scenario, and set the target of replacing 50% of its total energy generation with NRE by 2050 [2]. China proposed the use and development of renewable energy as a prior task to be promoted in the energy area, and established a plan to invest US$740 billion in the next 10 years to increase the proportion of NRE by 2020. The U.S. established a plan to invest US$150 billion to achieve its target of replacing 25% of its total energy generation with NRE by 2025 [3–5]. For South Korea, the South Korean government is promoting various programs to expand the distribution of NRE, such as the 1 Million Green Homes Program, Regional Deployment Subsidy Program, Loans and Tax Incentive Program, and Mandatory Renewable Energy Installation Program. In particular, the implementation of the Mandatory Renewable Energy Installation Program was limited to new construction projects but was expanded in April 2011 to include the extension and reconstruction works of existing buildings [6–8].

In South Korea, NRE has been introduced to education facilities through programs for the improvement of the educational environment and the establishment of green schools and eco-schools. As the floor area ratios of educational facilities are relatively smaller compared to those of other facilities, such as multi-family housing or offices, the effect of the introduction of NRE to educational facilities is expected to be greater. Nevertheless, as it is being promoted only as part of the educational-facility improvement program, there is a limit to the expansion of the distribution of NRE. Further, there is no clear general method for assessing the economic and environmental effects of the introduction of NRE.

The previous studies on NRE system have been conducted from a variety of perspectives. First, the life cycle cost (LCC) and the life cycle cost CO_2 ($LCCO_2$) analyses of NRE systems have been conducted [9–17]. The application of the photovoltaic (PV) system to the roof of a hotel reduced the $LCCO_2$ emissions by 13–21% compared with the conventional system [9]. The energy payback period was analyzed through the sensitivity study of the electricity generation of stand-alone and grid-connected PV systems [10]. In another study, LCC and $LCCO_2$ analyses of the ground source heat pump (GSHP) system and the existing oil boiler system were performed. As opposed to the existing oil boiler system, it was determined that about 50% of the $LCCO_2$ emissions can be saved by applying the GSHP system, and that LCC savings amounting to over 50,000–90,000 Japanese yen/year can be attained [11]. These studies simultaneously considered the economic and environmental effects by calculating the energy generated by NRE system and converting it to CO_2 emissions. The amounts of CO_2 emissions generated in the construction, operation and maintenance phases of NRE systems, however, were not considered.

Second, a life cycle assessment (LCA) on the materials used in each NRE system has been conducted to assess the environmental effects of the NRE systems [18–22]. To assess the environmental effects of the renewable electricity systems (e.g., PV system, wind system, geothermal, steam turbine, etc.), the renewable heat systems (e.g., heating plant, central heating, solar thermal collectors, etc.), and the conventional system, the amounts of CO_2 emissions were analyzed via LCA [19]. LCA was also conducted to assess the environmental effect of the PV system by type such as polycrystalline, mono-crystalline, and thin films [20]. LCA was performed to assess the environmental impacts of the PV and maize-biogas systems. From the long-term point of view, the appropriate strategies of the aforementioned two systems were also proposed [21]. These studies deal with the CO_2 generated in the process of material production for the NRE system. After the introduction of the NRE system, however, the amounts of CO_2 emissions in the operation and maintenance phases were not considered.

Third, the techno-economic analysis, experimental evaluation, and future outlook of NRE system have been conducted [23–29]. To analyze the technical feasibility and financial viability of grid-connected or stand-alone PV system, a computerized renewable energy assessment tool '*RETScreen*' was used [23,24]. To conduct the techno-economic appraisal of heat pump systems (e.g., ground-coupled, air-coupled, biogas, and solar heat pump) for space heating and cooling, experimental system was installed and tested [25–27]. To establish the introduction strategy of PV system, a study was conducted to predict the scenarios in terms of the pessimistic, optimistic and realistic, and very optimistic views for three factors: initial investment cost, market penetration, and environmental performance [28]. Further, the economic effect of the introduction of an NRE system was assessed considering the price of the NRE system and the volatility of carbon price [29]. Although these studies conducted a validity test reflecting the uncertainty of the introduction of the NRE system from various perspectives, the economic and environmental effects of the introduction of the NRE system were not demonstrated.

Nevertheless, there have been insufficient studies providing a comprehensive method of assessing the economic and environmental effects of the NRE systems, and executing LCA based on such effects. In this study, an economic and environmental assessment for selecting the optimum NRE system was conducted. Educational facilities were also selected as a case study because their NRE introduction effects are expected to be large as their floor area ratios are small compared to the other facilities included in the Mandatory Renewable Energy Installation Program.

This paper consists of the following five steps: (i) selection of facility and its applicable NRE system type; (ii) calculation of the energy generation by the NRE systems via energy simulation; (iii) life cycle cost analysis for the economic evaluation on the NRE systems; (iv) life cycle assessment for the environmental evaluation on the NRE systems; (v) using the net present value and the savings-to-investment ratio, comprehensive evaluation of the economic and environmental effects on the NRE systems.