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Scenario-Based Design and Assessment of renewable energy supply systems for green building applications

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Abstract

This study aims to develop a new approach to design and analyze the feasibility and benefit of renewable energy sources (RES) – based energy supply strategy for green building applications. In achieving the goal, we generated a technology superstructure for the energy supply systems using nine different scenarios by combining three types of building and three representing regions. We then analyzed the proposed systems using an optimization technique for the minimum cost or CO_2 emission. As a result, we identified the feasibility and benefits of the proposed hybrid systems by comparing to the conventional energy supply systems.

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Keywords: CO_2 emission; green building; hybrid energy supply; optimization; renewable energy sources

1. Introduction

Over last decades, the increases of greenhouse gas (GHG) caused by the combustion of fossil fuels have become one of major global issues. In particular, the building sector consumes nearly 40% of primary energy usage and releases 33% of CO_2 emission [1]. To reduce the CO_2 emission in the building sector, many countries have been trying to upgrade an existing building into a namely *green building*, which mainly utilizes renewable energy sources such as

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solar and wind energy with a high recycle system. Furthermore, the green building can contribute to the establishment of the distributed power supply system. The conventional power supply system is centralized and located outside of urbans and cities, and accordingly it requires the long transmission tower which is very expensive. Moreover, nearly 40% of the world's population dwells in villages without any connection to the electric grid [2].

Thus, the development of a stand-alone energy from RES to the green building is a critical issue for the transition to eco-friendly, cost-effectively and sustainable energy system supply system. One of major challenges to develop the stand-alone green building using RES is how to design stable power supply system against the intermittent feature of RES. For instance, neither a solar nor a wind based system is a proper option for a building application, since they cannot continuously provide power supply due to seasonal and periodic variation [3]. Therefore, the purpose of this study is to design the hybrid solar-wind energy supply system for the stable and economically viable power supply.

To achieve the goal, we propose a technology superstructure for power supply to a building, which consists of two renewable resources, and a number of energy technologies. We also generate different scenarios combining the different types of building and regions which have different availability of renewable energy sources. We then apply optimization models (mixed-integer linear programming; MILP) to minimize the total required cost for design and operation of the energy supply system, by employing the HOMER platform, the micro-power optimization model created by the U.S. National Renewable Energy Laboratory (NREL) [4].

Nomenclature

Set

$j \in J$	set of technologies

Variable

N_j	number/size of technology j
R_j	number of replacement of technology j
TC_j	total cost of technology j
TSC	total system cost

Parameter

CC_j	capital cost of technology j
CCF_j	capital charge factor of technology j
n	lifetime
r	interest rate
RC_j	replacement cost of technology j
OMC_j	operation and maintenance cost of technology j

2. Stand-alone hybrid energy supply system

2.1. Technology superstructure

Fig. 1 shows a superstructure of the stand-alone hybrid energy supply system for the building applications, which starts from different renewable energy resources. Note that this superstructure is a convenient representation of all the possible energy supply ways by connecting energy flows from primary resources to the final energy form. The RES is converted to the final energy form to meet the energy demands to operate the building (e.g., electricity for lighting and heating). As primary energy resources, we include two RESs that are available at typical building sites: solar light and wind. Meteorological and terrain data are used to estimate the RES potentials such as solar radiation and wind speed. As the final demand of the green building, we assumed only electricity.