Renewable and Sustainable Energy Reviews 91 (2018) 720–728

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Estimation of the optimal government rebate for promoting the photovoltaic system in multi-family housing complexes

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ARTICLE INFO

Keywords:
Photovoltaic system
Government rebate
Life cycle cost
Life cycle CO_2
Electricity
Multi-family housing complex

ABSTRACT

The government rebate has become one of the important drivers for implementing the photovoltaic (PV) system. However, it is not as effective for the multi-family housing complexes (MFHCs) in South Korea due to the constant government rebate without considering the electricity generation of the PV system by region and the electricity consumption by MFHC. Thus, this study aimed to estimate the optimal government rebate that guarantees the economic profitability of the PV system within the 4-year target payback period set by the South Korean government to encourage the installation of the PV system in MFHCs. Towards this end, based on the 16 administrative divisions in South Korea and the three types of electricity consumption, this study established 48 scenarios for analyzing the life cycle cost and life cycle CO_2. When the annual electricity generation of the PV system decreased from 357,300 to 302,090 kWh, and when the monthly average electricity consumption per household by MFHC increased from 200 to 600 kWh, the ranges of the optimal government rebate decreased from US$1,406-1479/kW to US$649–838/kW. When the target payback period increased, the optimal government rebate, which guarantees the economic profitability of the PV system within the 4-year target payback period, decreased. This study may be useful for decision-makers (i.e., residents, construction managers, etc.), or policymakers to determine the optimal government rebate that meets the economic profitability of the PV system in terms of the life cycle cost and life cycle CO_2.

1. Introduction

Globally, there is a growing interest in new and renewable energy (NRE) for addressing the environmental problems due to the increased use of fossil fuel [1–7]. The photovoltaic (PV) system has been evaluated as the NRE with the highest potential in South Korea (33.4% of the total NRE potential). The South Korean government has established a plan to expand the proportion of the PV system among the NREs to 14.1% by 2035 [8–10]. To realize this target, since 2004, the South Korean government has implemented a government rebate program that supports some of the initial investment costs (IIC) of the PV system installed in a single-family housing complex [11]. Since 2015, the scope of the government rebate program has been expanded from single-family housing to multi-family housing. This is because South Korea has a high rate of multi-family housing complexes (MFHCs), and the electricity consumption of MFHCs accounts for 68% of the residential electricity consumption [12,13]. Despite the implementation of such government rebate program, however, there are still some limitations to promote the introduction of PV system in MFHCs. First, the current government rebate does not reflect the different rates of electricity generation of the PV system by region. This is because the electricity generation of the PV system varies depending on the regional factor (i.e., meteorological factors like the monthly average daily solar radiation (MADSR) and the monthly average temperature (MAT), and geographic factors like latitude) [14–16]. As a result, despite the fact that PV systems with the same power capacity are installed in MFHCs, there are differences in the electricity generation and electricity bill saving (EBS) by region [11]. Second, the current government rebate does not reflect the different monthly average electricity consumption per household by MFHC. This is because a progressive tax is applied to the electricity bill of the MFHCs in South Korea, and as such, the EBS differs depending on the monthly average electricity consumption per household by MFHC [17–20]. To address this challenge, this study aimed to estimate the optimal government rebate for promoting PV systems considering the electricity generation of the PV system by region, the electricity consumption by MFHC, and progressive tax applied to the electricity bill. Towards this end, 48 scenarios for analyzing the life cycle cost and life cycle CO_2 were established. The optimal

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https://doi.org/10.1016/j.rser.2018.04.058
Received 5 March 2017; Received in revised form 19 March 2018; Accepted 14 April 2018
1364-0321/

Nomenclature

Abbreviations

AEG	Annual electricity generation
AoP	Azimuth of the installed panel
EBS	Electricity bill saving
IIC	Initial investment costs
LCC	Life cycle cost
$LCCO_2$	Life cycle CO_2
MADSR	Monthly average daily solar radiation
MAT	Monthly average temperature
MFHCs	Multi-family housing complexes
NRE	New and renewable energy
PV	Photovoltaic
SoP	Slope of the installed panel

government rebate in the 16 administrative divisions in South Korea was estimated at US$649–1479/kW. Difference between current government rebates and estimated optimal government rate was calculated US$ −691 – US$782/kW. Based on estimated optimal government rebates, this study analyzed the differences between the current rebate and the estimated optimal rebate (Section 4.2), calculated the optimal rebate according to different target payback periods (Section 4.3), and conducted the uncertainty analysis (Section 4.4). The analyses results as follows. First, the optimal government rebates were quite different depending on the annual electricity generation (AEG) of the PV system by region and the monthly average electricity consumption per household by MFHC. Second, in all the regions (16 administrative divisions of South Korea), the current government rebate was inconsistent with the estimated optimal government rebate. Third, when the target payback period increased, the optimal government rebate, which guarantees the economic profitability of the PV system within the 4-year target payback period, decreased. As a result, the results of this study will be helpful for effective budget execution if the government knows where the government rebate is being wasted and where it is scarce, with a reasonable target payback period for meeting the economic profitability of the PV system.

2. Literature review

Various previous studies have conducted an economic analysis of the PV system.

First, several studies have conducted an economic analysis of the PV system by considering the electricity generation including the government rebate. Burns and Kang [21] conducted an economic analysis of the PV system in nine states of the U.S. by considering the regional electricity generation and the government incentives, including the government rebate. Li and Yi [22] analyzed the spread effect of the PV system in the U.S. cities by considering the electricity generation of the PV system by region and the local incentives, such as the government rebate. Lee et al. [23] established a base price for the solar renewable energy certificate (i.e., the minimum price required for guaranteeing the economic profitability of the residential PV system) in nine states in the U.S. by considering the electricity generation of the PV system by region as well as the state incentives, including the government rebate. Swift [24] compared the costs and financial returns of the PV systems in four states of the U.S. by considering the government incentives and the electricity generation of the PV system.

Second, some studies have considered electricity consumption among the considerable factors affecting the economic profitability of

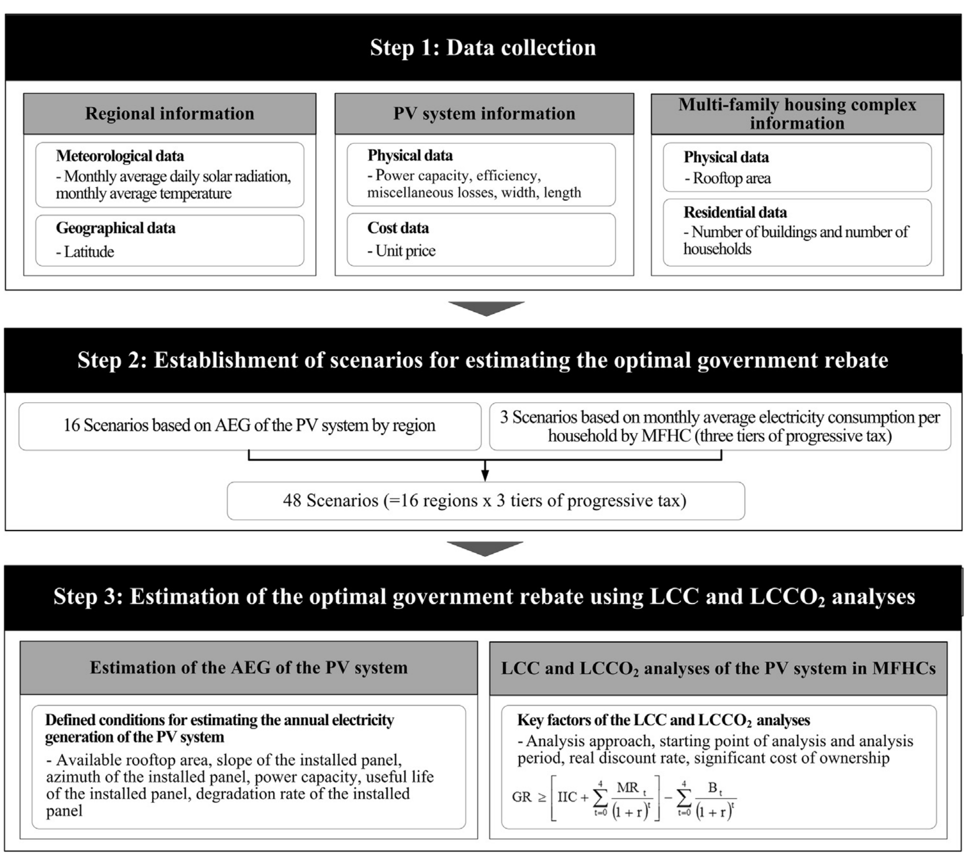

Fig. 1. Research framework.