Solar Energy 158 (2017) 898–904

Contents lists available at ScienceDirect

Solar Energy

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

The external benefits of expanding the micro photovoltaic power generation in Korea: A contingent valuation study

Yong-Cheol Cho[a], Seul-Ye Lim[b], Seung-Hoon Yoo[b,*]

[a] Planning & Management Team, Korea Ocean Foundation, 2F, 28, Songpa-Daero 28-Gil, Songpa-Gu, Seoul 05718, Republic of Korea
[b] Department of Energy Policy, Graduate School of Energy & Environment, Seoul National University of Science & Technology, 232 Gongreung-Ro, Nowon-Gu, Seoul 01811, Republic of Korea

ARTICLE INFO

Keywords:
Micro photovoltaic power generation
Contingent valuation
External benefit
Willingness to pay

ABSTRACT

The micro photovoltaic (MPV) is a good alternative for reducing greenhouse gas (GHG) emissions in the residential areas. Therefore, the Korean government has planned to expand the MPV power generation from about 2000 households (6 MW) in 2014 to 25,000 households (61 MW) by 2017. This article aims to assess the external benefits of this expansion in terms of reducing GHG emissions. To this end, we derive the public's additional willingness to pay (WTP) for the expansion through an increase in electricity bill using a contingent valuation survey of 1000 Korean households. For the purpose of mitigating the response effect in eliciting their WTP and increasing statistical efficiency in analyzing the WTP data, we employ a one-and-one-half-bounded dichotomous choice question format. Furthermore, we use the spike model so as to model zero WTP responses. The mean additional WTP for the expansion is computed to be KRW 15.48 (USD 0.01) per kWh. This value amounts to 12.4% of the residential electricity price, KRW 125.14 (USD 0.11). We can conclude that Korean households are ready to shoulder some of the financial burden of expanding the MPV power generation.

1. Introduction

Korea was ranked as the seventh largest emitter of carbon dioxide in 2014, following China, the USA, India, Russia, Japan, and Germany. At the Paris Climate Change Conference in December 2015, Korea, which is under domestic and international pressure to reduce GHGs, announced its commitment to reduce its GHG emissions by 37% from the business-as-usual level by 2030. Of this reduction target, 25.7% applies to the reduction of GHG emissions in the country and 11.3% depends on international GHG emissions trading systems.

In order to mitigate GHG emissions, the Korean government released her goal to increase the share of new and renewable energy in total energy consumption to 11% by 2035, seeking to develop solar energy and wind power as key resources. The government planned to target the rate of photovoltaic (PV) power generation distribution from 4.9% in 2014 to 14.1% by 2035 (Ministry of Trade, Industry, and Energy, 2014). PV power generation converts solar energy directly into electrical energy using a solar cell without the aid of the generator. The PV power does not emit GHGs as well as air pollutants contrary to the fossil fuel-based generation (Liu et al., 2010; Rodrigues et al., 2016).

There are several types of case studies, relating to PV in Korea. Kim et al. (2014) found the most economically feasible hybrid system is a grid-connected wind turbine-PV-battery-converter hybrid system in Jeju island. Kim et al. (2015) evaluated the investment efficiency of PV technology considering the two policy objectives of public investment, technological development and wider dissemination. Hong et al. (2015) dealt with the estimation of the decrease of PV power generation cost. Baek et al. (2016) determined the optimal renewable electricity generation configuration, which includes PV panels, wind facilities, converters, and batteries for one of the largest metropolitan cities. Park and Kwon (2016) explored possible solutions for providing various energy resources such as solar energy to satisfy the load demand at Kyunghee University's Global Campus. Nematollahoi and Kim (2017) investigated the feasibility of using solar energy in different regions. Lee and Huh (2017) showed that wind, solar PV, and bioenergy are projected to replace current waste-oriented sources.

In spite of its merits, the PV power generation has problems to require spacious place and high initial cost to install large-scale PV power facilities (Haas, 1995; Sanden, 2005). Thus, it is difficult to expand PV in urban areas with high population density. On the other hand, building integrated PV (BIPV) offers additional advantages beyond traditional PV systems as they do not require large swatches of land as they are integrated into existing buildings. There are various and efficient application methods regarding to design, performance, and

* Corresponding author.
E-mail addresses: yccho214@naver.com (Y.-C. Cho), sylim@seoultech.ac.kr (S.-Y. Lim), shyoo@seoultech.ac.kr (S.-H. Yoo).

http://dx.doi.org/10.1016/j.solener.2017.10.041
Received 23 July 2016; Received in revised form 7 October 2017; Accepted 10 October 2017
Available online 05 November 2017

assessment method to improve the payback period in the introduction. Ibraheem et al. (2017) addressed the ecological application, and Sivakumar et al. (2015) suggested ecological criteria for optimization of BIPV such as a micro PV (MPV). For example, PV integrated shading devices are installed on façade or wall, which is based on ecological criteria, can prevent natural environment degradation and destruction of eco-system as well as create various values and reduce the installation cost. Choi and Song (2017) reported recent efforts made by the mining industry in adapting and applying PV at operating and abandoned mines around the world. Kim et al. (2017) conducted real-life BIPV project in Daejeon, Korea. Thus, it is possible for BIPV power generation to expand effectively by integrating economics, design elements and architectural elements (Sivakumar et al., 2015; Ibraheem et al., 2017).

In this case, MPV power generation, which is BIPV in the residential sector, can be a good alternative (Oliva et al., 2014). To distribute BIPV, Korean government implemented the micro PV (MPV) project. The representative advantage of MPV power generation is its compactness and convenience for installation at home. The capacity of MPV power generation is as small as 3 kW. MPV power generation is easy to expand widely because it can be installed on the roof or balcony of each household. MPV has two other promising merits in Korea.

First, MPV can reduce the severe energy dependence on foreign countries and increase energy supply security. Energy supply independence is quite an important task for Korea because the country suffers a scarcity of energy and is one of the heavy energy importer countries. For example, the country imported 95.2% of the energy it consumes from abroad as of 2014. However, the sunlight needed for MPV power generation can be obtained from natural energy sources.

Second, MPV power plants can be installed near electricity-consuming areas, and do not require large-scale or long-distance power transmission facilities (Chaurey and Kandpal, 2010; Sigarchian et al., 2015). Nuclear power and coal are presently a base-loaded and dominant power generation source in Korea. All the nuclear power and coal-fired plants in Korea are located around coastal areas in order to obtain sea water for cooling, and they are quite remote from metropolitan areas for safety reasons. Consequently, the nuclear power and coal-fired plants inevitably require large-scale and long-distance power transmission facilities. The rights of way for high voltage lines often run through high-value land and reduce the property values there. This tends to result in a substantial amount of social costs (e.g., Ju and Yoo, 2014).

For these reasons, a number of countries have started and will continue to introduce the use of MPV in various fields. For example, MPV power generation and its storage facilities in Belgium (Mulder et al., 2010), the grid connected MPV plant installed in Italy (Bouzerdoum et al., 2013), and there are the installations of a MPV power generation in Australia (Oliva et al., 2014). The Korean government also plans to expand MPV power generation (Ministry of Trade, Industry, and Energy, 2014). The amount installed MPV was about 2000 households in 2014, but it will reach 25,000 households by 2017 if the plan is successfully completed. The main instruments to achieve this goal include governmental support for the development of MPV technology and the new introduction of a standard mandate for the renewable portfolio using MPV.

Clearly, the public preference for expanding MPV power generation to achieve the aforementioned benefits can be employed as a proper and important reference for further discussion of the expansion of MPV and decisions on establishing power transmission facilities and power generation. Public preference can be investigated by assessing people's additional willingness to pay (WTP) for the expansion through an increase in their current electricity bills. Moreover, WTP can be taken as indicative of an external benefit of MPV power generation with a view to reducing GHG emissions.

Therefore, the prime objective of our paper is to measure the external benefits of expanding the MPV power generation from about 2000 households (6 MW) in 2014 to 25,000 households (61 MW) by 2017. This aim is met using a stated preference technique based on a survey of consumers, that is, the contingent valuation (CV). The remainder of the paper comprises four sections. The methodology employed in this study is described in Section 2. The modeling of WTP responses is addressed in Section 3. The results are explained and discussed in Section 4. The paper is concluded in the Section 5.

2. Methodology

2.1. Method for assessing the external benefits of MPVs: the CV approach

In the context of economics, the benefits of consuming a commodity can be determined by computing the area below the demand curve for the commodity. The area is precisely the consumer's WTP for the commodity. Thus, the first step in evaluating the benefits is to estimate the demand function for the commodity and the next step is to calculate the area under the demand function. However, if the commodity is not traded on the market, in other words, if it is a non-market good, it is somewhat difficult to estimate the demand function. The expansion of MPV power generation is a case for which directly calculating the area under the demand function is a good strategy: this can be done using a stated preference technique such as the CV method.

The CV technique is the one most widely applied in the literature to obtain information on consumers' WTP for consuming or obtaining non-market goods (Kwak and Yoo, 2015). There are no restrictions on the objects that can be valued using the CV method. In particular, it is more useful than other methods because it can capture the non-use or existence value of goods, which cannot be measured through a market mechanism. Non-market goods include environmental goods or public goods such as MPV power generation. Thus, as explained earlier, this study seeks to use the CV approach to assess the external benefits or expansion. Our approach is consistent with the practice of former studies that have measured WTP in relation to expanding the use of new or renewable energies (e.g., Hanley and Nevin, 1999; Zarnikau, 2003; Nomura and Akai, 2004; Wiser, 2007; Li et al., 2009; Solinõ et al., 2009; Heo and Yoo, 2013). It asks randomly chosen respondents a question concerning their WTP for enhancing the amount of electricity consumed from MPV generation using a well-structured survey (Mitchell and Carson, 1989; Lee et al., 2015).

Some may doubt the practicality and usefulness of the CV method because it gathers information from a survey of respondents. In this regard, the blue-ribbon National Oceanic and Atmospheric Administration (NOAA) Panel came to the influential conclusion that the CV method can produce reliable quantitative information that can be used in decision making for both public administrations and judicial bodies, provided that several guidelines proposed by the NOAA Panel are observed (Arrow et al., 1993). Moreover, following the guidelines can secure the validity and accuracy of the CV method.

For example, the goods of concern should be familiar to the public, the CV survey should be administered through face-to-face interviews by professionally-trained interviewers rather than through telephone or mail interviews, a suitable payment vehicle should be adopted and presented to the respondents, and the substitutes for the goods should be explained to the respondents in the survey. The conditions are met in our study, as discussed in detail below.

2.2. CV survey design issues

We commissioned a professional survey firm to arrange the CV field survey. The firm drew a stratified random sample of 1400 households from the national population in order to obtain information on the households' WTP for MPV power generation and their socioeconomic characteristics. A CV survey can be conducted using face-to-face in-person, telephone, or mail interviews. The response rate to a mail survey is usually quite low, and a telephone survey can present only a