Energy Policy 53 (2013) 248–256

Contents lists available at SciVerse ScienceDirect

Energy Policy

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

A support strategy for the promotion of photovoltaic uses for residential houses in Korea

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HIGHLIGHTS

- ▸ The unit cost of electricity from solar PV depends crucially on its capacity factor.
- ▸ We calculated the capacity factor of solar PV at various cities from the clearness index.
- ▸ We estimated the unit cost of electricity from solar PV using thermoeconomic analysis.
- ▸ We examined whether the capital subsidy program in Korea to solar PV is cost effective.
- ▸ This study determined that a measure based on the same payback period is better policy.

ARTICLE INFO

Article history:
Received 18 June 2012
Accepted 25 October 2012
Available online 28 November 2012

Keywords:
Photovoltaic
Payback period
Thermoeconomic analysis

ABSTRACT

Various policies such as feed-in tariffs, quota obligations and capital subsides were enacted to expand the uses of renewable energy (RE) in many countries. This study examined whether capital subsidies are cost effective in relation to the installation of solar photovoltaic (PV) facility. To do this, the capacity factor, which is one of the crucial factors for determining the unit cost of electricity from a solar PV system, was estimated from the monthly average clearness index data collected at various cities in Korea. Thermoeconomic analysis was applied to calculate the unit cost of electricity based on the calculated capacity factor of the solar PV system. Instead of subsidizing the same percent of the capital cost of each PV system installation, it is reasonable for the government to adopt a measure to match the subsidy paid to the payback period of the initial investment for all 5 million potential solar PV users in Korea.

1. Introduction

Many countries have issued laws and regulations for the promotion of renewable energy (RE). Various policies such as feed-in-tariffs, quota obligations, and capital subsidies are common instruments to expand renewable energy use in many countries (Brennand, 2004; Farinelli, 2004; Meyer, 2004; Geller et al., 2004; Kaya, 2006; Wang, 2006; Cherni and Kentish, 2007; Agnolucci, 2007; Ayoub and Yuji, 2012; Schmid, 2012). Various measures taken by some countries to promote the renewable energies were reviewed by Ayoub and Yuji (2012). Generally, the feed-in-tariff has been considered as one of the most successful policies for promoting large-scale market changes (Ayoub and Yuji, 2012). The quota obligation on clean electricity is also known to have had a positive and significant impact on the development of RE (Schmid, 2012). Regarding new technology, the capital subsidy proved to be effective in early stages for Australian and Japanese residential solar photovoltaic (PV) markets (Parker, 2008). Capital subsidies have been applied under the Resident PV Dissemination Program in Japan and the 100,000 Roofs Program in Germany. However, an appropriate strategy for adopting the policies, which are certainly dependent on economic and social conditions such as renewable resources available and the tariff system on conventional electricity, is needed to lower the barrier to market entry and to promote substantial investment in RE (Ayoub and Yuji, 2012).

Among various RE sources such as wind power, solar PV and geothermal heat, solar PV is the most promising and is applicable for residential uses in Korea, but it is also the most costly. On the other hand, the wind power and geothermal heat facilities are very difficult to install in Korean homes. Although biomass from forests is abundant, it is not easy to use due to the steep mountainous

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http://dx.doi.org/10.1016/j.enpol.2012.10.057

nature of the land in Korea. Furthermore, among the total number of households who have installed solar PV, 78.3% of the respondents were satisfied with the facilities in Korea. This satisfaction may be due to the easy maintenance of solar PV the facilities compared to solar thermal equipment and other renewable energy facilities. Solar PV is also the most promising renewable energy in other countries, and annual installations of solar PV might increase 50-fold by 2020 compared with 2005 (Aanesen et al., 2012).

To develop appropriate policies or regulations related to the energy generated system, it is necessary to understand the energy system based on engineering. For example, one must know the thermodynamic efficiency of the energy system as well as the unit cost of the energy produced by the system, which requires detailed engineering calculations. Fortunately, thermoeconomic analysis, also known as the exergy-costing method (Tsatsaronis and Pisa, 1994; Kim et al., 1998), which provides the unit cost of products such as electricity and steam, has been developed at present. This method may be utilized by policy makers to establish energy policies and regulations. Previously, economic analysis for the flat plate collectors of solar energy was performed by Ozsabuncuoglu (1995). Recently technical simulations based on electricity bills paid, monitoring of electricity consumption and solar PV performance using long-term meteorological data were performed by McHenry (2012) to determine whether the installation of peak power for 1 kW and 3 kW solar PV is economically viable. In this study, whether the capital subsidy program for the solar PV facility is cost effective was investigated with the help of thermoeconomic analysis.

The tariff system on electricity and the program supporting for various renewable energies in Korea are briefly introduced in Section 2. Methods used to estimate potential residential solar PV users and detailed procedures to obtain the amount of electricity and the unit cost of electricity from solar PV are described in Section 3. Calculation results based on these methodologies and the discussion on the results are described in Section 4. Finally, conclusions are drawn in Section 5.

2. The tariff system on electricity and programs supporting renewable energy in Korea

Programs supporting the installation of RE systems such as feed-in tariffs and capital subsidies depend crucially on the regional tariff system on electricity. In this section, the tariff system on electricity and programs supporting RE system installation in Korea are briefly introduced.

2.1. The tariff system on electricity in Korea

The tariff system on electricity in Korea was designed to provide a lower rate to those who consume less electricity and a higher rate to higher-demand consumers, as shown in Fig. 1. The cost of electricity is approximately 57.3 ₩/kW h for the first 100 kW h, and 118.4 ₩/kW h, 175.0 ₩/kW h, 258.7 ₩/kW h and 373.7₩/kW h for the increments of 100 kW h up to 500 kW h. If the amount of consumption in electricity exceeds 500 kW h per month, the unit cost of electricity increases to 670.6 ₩/kW h, which is almost 5.4 times higher than the system marginal price (SMP) in Korea. The SMP for the electricity generated by fossil fuels in Korea is approximately 124.9 ₩/kW h in 2011 so that households using less than 252 kW h of electricity per month pay smaller electricity bill compared to the SMP. Specifically, households whose monthly average electricity demands are 252.8 kW h, 376.4 kW h and 500.7 kW h pay electricity bills with unit cost of electricity of 116.8, 176.4 and 252.6 ₩/kW h, respectively. Of course, different tariff systems on electricity with much lower rate than the SMP are applied to industrial and public uses in Korea. Note that 1000 Korean won (₩) is equivalent to US$0.83 at present.

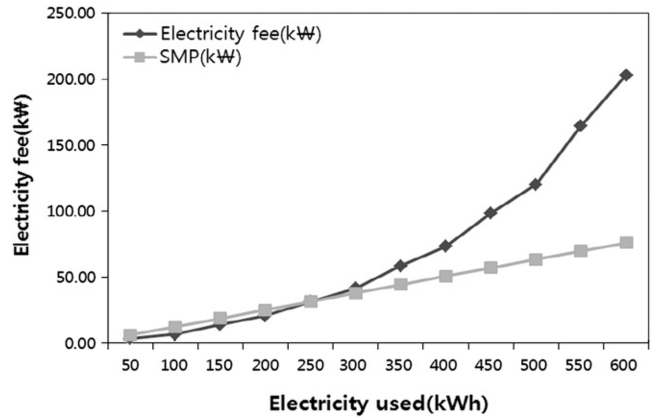

Fig. 1. Electricity fee paid and SMP, depending on the electricity used per month.

2.2. The programs supporting renewable energy use in Korea

The energy supply in Korea is heavily dependent on the import of fossil fuels, including coal, oil and gas, whereby both the economy and life style are seriously affected by the two rounds of oil shock. Because Korea has no significant energy resources, it may be an inevitable choice to adopt nuclear energy as the main energy supply. The Korean government plans to double nuclear energy facilities within the next 12 years, even though nuclear energy supplies approximately 31.6% of the total electricity generation of 469,816 GW h in 2010, which is still a high portion relative to other energy resources. The portion of electricity supplied from RE sources such as solar PV, biogas, wind, and hydro energy, which is approximately 5888 GW h in 2010, is less than 1.3% of the total electricity generated per year at present. This figure indicates that more development and use of RE is necessary for the diversification of energy sources and energy security in Korea.

After two rounds of oil shock, Korea enacted the Alternative Energy Development Promotion Act in 1987 in an effort to decrease its dependence on fossil fuels. Since 1993, the central government in Korea has paid 50% of the installation cost for any RE facilities such as solar PV, solar thermal, geothermal, wind power, and biogas. Three years later, the capital subsidy programs for RE facilities were also started by regional governments in Korea. Although RE cannot be a major energy supplier at present, expanding the RE facilities in Korea has two goals. The first goal is the reduction of greenhouse gas emissions, which is required to ratify the Kyoto Protocol in the near future. The other goal is to prevent the power outages, which may occur at peak hours of electricity use during hot summers or cold winters. For example, the power outages occurred locally for several hours in the afternoon during a hot summer day in Seoul in 2011.

In 2008, Korea established the Third Basic Plans for Developing, Using and Deploying New and Renewable Energy Technologies and launched the ambitious One Million Green Homes project in 2009 as major RE policies. At present, central and regional governments subsidize 60% of the capital for the installation cost of any RE facility. For residential houses the grid-connected solar PV system is allowed to reach the peak power of 3 kW. The same capital subsidy for installation of grid-connected solar PV was applied to independent power producers in Korea. Under the capital subsidy program for the RE, the power producers enjoy economic gain because the installation cost for large-scale solar PV is much cheaper than that of small-scale. Fig. 2 shows the number of houses that installed for solar PV and