Energy Policy 87 (2015) 505–516

Contents lists available at ScienceDirect

Energy Policy

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

Financial assessment of government subsidy policy on photovoltaic systems for industrial users: A case study in Taiwan

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HIGHLIGHTS

- Analyzing the benefit of installing a PV system impacted by the government subsidy.
- Analyzing the role of policy in the financial model of PV system.
- Estimating the performance of PV system under the real weather condition.
- Methods to select the policies which satisfy demands of both government and users.
- Methods to select the policies which ensure cost-effectiveness of government's support.

ARTICLE INFO

Article history:
Received 16 June 2015
Received in revised form
20 September 2015
Accepted 27 September 2015

Keywords:
Renewable energy
PV system
Policy
Feed-in-tariff
Tax abatement
Taiwan

ABSTRACT

Due to Taiwan's limited energy resources, the development of solar photovoltaic (PV) in Taiwan has become one of the most important solutions for meeting future energy supply needs and ensuring environmental protection. A huge amount of researches about renewable energy sources has emerged recently in response to these issues. However, the amount of researches considering the effects of various influential parameters on the efficiency and performance of PV systems remains small, and is still limited to some specific parts of PV systems. In particular, researches considering thoughtfully the influence of government subsidies on PV financial assessment are still in development. This paper proposes an approach to analyze the benefit of installing a PV system under the impact of government financial subsidies, focusing especially on feed-in-tariff (FIT) and tax abatement policies for industrial users in Taiwan. In addition, a method for selecting the most appropriate policies is proposed for the government through the analysis of both user demand and the government's PV installation capacity target.

1. Introduction

In recent years, renewable energy has been developed robustly in many countries, and has become a future trend due to its environmental benefits in comparison to conventional energy sources. Among various renewable energy (RE) sources (such as wind power, biomass, geothermal heat, hydropower, wave and tidal energy (Chen et al., 2010)), solar PV energy has been considered as the most promising option for industrial use (Ren21, 2014). Solar energy is abundant, free, clean, and does not make any noise or contribute any kind of direct pollution to the environment (Mekhilef et al., 2011).

Due to the recent explosive economic and industrial development in Taiwan, energy security and environmental protection issues have been emerging among other important issues for Taiwan's government. More specifically, according to the Taiwan energy statistical handbook published by the Bureau of Energy (Ministry of Economic Affairs, 2014), energy imports increased from 97.8% in 1999 to 98.1% in 2005, and remained high (98%), in 2014. Meanwhile, total carbon dioxide (CO_2) emissions rose significantly from 1.76×10^8 tons to 3.3×10^8 tons within the eleven years from 1996 to 2014 (Ministry of Economic Affairs, 2014). The detailed data representing the amount of imported energy and the CO_2 emission in Taiwan is shown in Figs. 1 and 2 respectively. In recent years, the requirements for reducing CO_2 emissions and ensuring energy security have driven Taiwan government to move forward in promoting the development of renewable energy. Relying on the unquestionable benefits of solar PV systems and Taiwan's geographical location in a low-latitude zone, Taiwan's government is strongly promoting the development of solar PV energy. In particular, Taiwan's government has

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http://dx.doi.org/10.1016/j.enpol.2015.09.039
0301-4215/

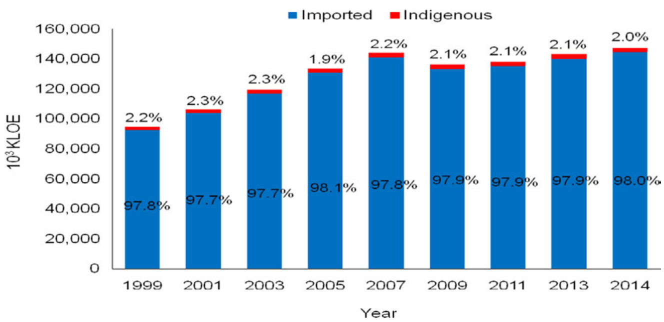

Fig. 1. Imported energy in Taiwan.

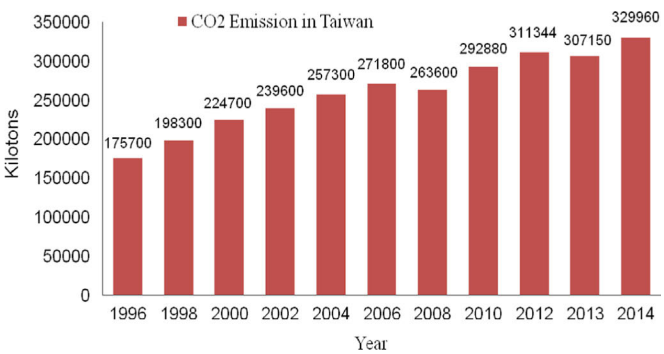

Fig. 2. CO_2 emission in Taiwan.

actively implemented a variety of policies, laws, regulations, projects, and subsidy operations for promoting solar PV energy development since 2000. Recently, the MOEA has set a new PV installation capacity target in a renewable energy plan for the period from 2015 to 2030. The PV installation capacity target was established as 492 MW, 1020 MW, 2500 MW, and 3100 MW in 2015, 2020, 2025, and 2030, respectively (MOEA, 2015). In order to meet the new target, a new energy policy and regulation system will be required (Cossent and Gómez, 2011), prompting the need for valuable research which the government can use as consulting documentation.

As a result of the Taiwan government's requirement for the new energy policy and regulation system, a huge number of studies of solar PV energy have been proposed. For example, a list of 121 research publications on solar power generation by the PV technology was reviewed by Singh (2013). Nevertheless, only a limited number of approaches have considered the effect of various influential parameters such as material, design, dust, humidity, air velocity, and ambient conditions on the performance of the PV systems (Mekhilef et al., 2012). Lack of consideration of these influential parameters results in system vulnerabilities such as unstable supply, low-energy density, and high cost. For example, most studies of PV systems merely used the values provided by manufacturers to design the PV systems. In fact, there is a significant difference between the theoretical power generation estimates and the actual power generated when the PV system is operated under real weather conditions (Almonacid et al., 2009). Consequently, in order to install any kind of renewable energy system effectively, various environmental factors such as ambient temperature, solar radiation, wind speed, and suitable site, must be considered carefully.

While the technical feasibility of solar PV energy system may be visible in most studies of solar PV energy, its economic competitiveness with alternative electricity is still a controversial issue since the capital cost resource of purchasing a PV system is expended in the present, while the benefit expectation from the generated electricity can only be evaluated in the future. In addition, the capital cost of installing a PV system is still high, while the benefit achieved by the electricity generated will not be realized until ten to thirty years later. Consequently, in order to promote the installation capacity of PV system, the basic challenge is how to measure the value of future benefit from present expenditure on a PV system, in relation to government subsidy, based on the performance of PV systems under real weather conditions.

This paper proposes an approach to analyze the benefits of investor when installing a PV system in Taiwan's industrial sector. The benefit of investor is examined under the government's financial subsidies, specifically focusing on feed-in-tariff (FIT) and tax abatement policies. The proposed method considers various factors impacting the PV system's efficiency directly, including environmental factors (properties of sunlight and wind speed), PV materials, system equipment (inverters and cable efficiency), and outdoor temperature. In addition, by analyzing the user's demand and the government's target installation capacity, this paper arrives at a method for choosing the proper policy to satisfy both the government's target installation capacity and the user's demand.

This paper is organized in four sections, of which section one is the general introduction, a review of the literature concerning government subsidies on PV energy, FIT policy, and some countries' experiences with PV energy system. The policies for PV system in Taiwan are also introduced briefly in this section. Section two provides a detailed representation of model development. The efficiency of the model applied to Taiwan can be evaluated specifically in section three. Finally, the conclusions and policy implications are drawn in section four which provides a summary of this paper.

1.1. Literature review

Solar PV energy is clean, totally natural, and has great potential as the best energy supply source in the future. However, the installation cost for a PV system is still high, while the benefits are lower in comparison to alternative electricity sources. Consequently, major policy incentives must be encouraged in order to promote the development of PV energy.

Currently, different countries apply different policies to encourage PV energy system investment. A huge number of different policy instruments have been invented and applied worldwide. However, as presented in Table 1 (Liao, 2010), the objectives of all the sustainable energy policies are applied to three topics: Economical and Energy, Social and Environmental. Each country has its own set of policies for promoting the development of the renewable energy. Consequently, a large number of policy instruments have been proposed and applied. As summarized in (Avril and Mansilla, 2012; Mossavian et al., 2013) and shown in Fig. 3

Table 1
A large number of policy objectives.

Range	Policy objectives
Economical and Energy	1. Economically efficient energy supply. 2. Efficient energy use. 3. Energy supply technology research. 4. Diversity of energy sources.
Social	5. Consistency between energy policies and other policy objectives. 6. Energy security. 7. Cost and availability of energy resources to low income earners.
Environmental	8. Conversion of energy resources. 9. Reduce the environmental impact of the energy sector. 10. Place energy supply on a sustainable basis.