Renewable and Sustainable Energy Reviews 93 (2018) 439–450

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Crowdfunding for solar photovoltaics development: A review and forecast

Yujie Lu[a,c], Ruidong Chang[b,*], Suxann Lim[a]

[a] Department of Building, School of Design and Environment, National Unive rsity of Singapore, 4 Architecture Dr, 117566 Singapore
[b] Centre for Comparative Construction Research, Faculty of Society and Design, Bond University, 14 University Dr, Robina, Queensland 4226, Australia
[c] School of Public Administration, Guizhou University, 550025, China

ARTICLE INFO

Keywords:
PV
Crowdfunding
Solar power
Renewable energy
Financing
Singapore

ABSTRACT

Solar Photovoltaics (PV) has become one of the major trends in the energy sector for the past decade. Due to the high upfront capital expenditure needed for solar installations, new investment models and financing options have emerged in recent years. While solar financing has received increasing attention, little research has been done to explore the use of crowdfunding for PV development. This study presents a review of the crowdfunding concepts in general and crowdfunding of renewable energy specifically, and provides a system dynamics model to simulate the development potential of Solar Crowdfunding (SCF) by taking Singapore as an example. The model simulated a three-stage SCF development including the determination of potential SCF adopters, factors affecting the adoption of SCF, and factors affecting the success of SCF. The results show that under different scenarios, SCF can potentially generate a cumulative amount of $177–278 million US Dollars by the end of 2050, accounting for 2.5–4% of the total cumulative funds needed for PV installations expected in the year 2050 in Singapore. This study enriches the existing studies on solar financing and provides references for policy makers, academics and industry practitioners interested in SCF.

1. Introduction

Growing environmental concerns have motivated policy makers to propose incentives and plans to diversify their energy portfolio by shifting from the dominant use of non-renewable to renewable energy. Many countries have also been supporting the use of these technologies by providing public financing and subsidies [1–3]. Hence, significant progress in the development of renewable energy in terms of production and consumption has made the industry prominent in recent years [4,5].

Among the various renewable technologies, photovoltaics are the most popular, followed by the wind and to a much lesser extent biomass and hydropower [6]. Solar photovoltaics (PV) technology is the conversion of sunlight into energy without the use of mechanics and does not produce environmental emissions. Hence, it has been recognized as a clean and renewable energy source with huge potential. An increasing number of countries has tried to promote the use of this energy source within their borders. Solar PV adoption has grown significantly in the year 2014, whereby an estimated amount of 40 GW of solar PV was installed among the total global energy capacity of 117 GW. The majority of new adoptions came from countries like Japan, China, and the United States, with Latin America, Africa and the Middle East experiencing growth in the solar PV market as well [7].

In Singapore, due to various constraints, other renewable energy sources including geothermal energy, hydroelectric power, or wind energy does not hold as much potential as compared to solar PV technology [1]. Fig. 1 illustrates the annual installed capacity and the cumulative installed PV capacity in Singapore from 2009 to 2015. In 2014, the Singapore government announced the plans to increase the amount of solar energy adopted by governmental agencies. The target was to hit 350 MWp by 2020, which would amount to 5% of the forecasted electricity demand in Singapore [8]. As such, several initiatives have been set up by Singapore, including solar test bedding to be conducted by the Housing and Development Board (HDB) to gather technical knowledge on the installation of extensive solar systems in its precincts [9], and the SolarNova Singapore program launched to assist in the coordination and the collation of demands for solar PV adoption across the Government buildings involved [10]. It has been discovered that HDB buildings in Singapore have good PV integration potentials [11].

The downside to this technology, however, lies in the fact that its cost has been less competitive as compared to other electricity

Abbreviations: PV, Photovoltaics; SCF, Solar Crowdfunding; HDB, Housing and Development Board; FiTs, Feed-in tariffs; MAS, Monetary Authority of Singapore; BAS, baseline scenario; ACC, accelerated scenario

* Corresponding author.
E-mail address: rchang@bond.edu.au (R. Chang).

https://doi.org/10.1016/j.rser.2018.05.049
Received 18 July 2017; Received in revised form 10 May 2018; Accepted 21 May 2018

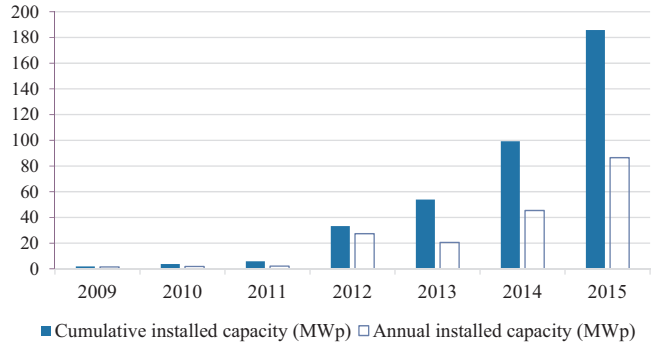

Fig. 1. Annual and cumulative installed capacity for solar PV electricity in Singapore (2009–2015) [12].

generation options [13]. Traditionally, Solar PV projects have been driven significantly by policy support such as PV Feed-in Tariffs (FiTs) provided by governments [7]. As such, studies have been made to determine if alternative solar financing methods such as Power Purchase Agreements (PPA), Solar Leasing, Crowdfunding or other hybrid models that leverage on private capital are feasible compared to the traditional PV FiTs. Alternative solar financing methods have been established over recent years. One relatively new solar financing method that has seldom been studied is Solar Crowdfunding (SCF). Several studies have been conducted on crowdfunding for other applications of renewable energy. For instance, based on qualitative methods, Dilger [14] explored the potential of crowdfunding for the business model of energy cooperatives, indicating that although most cooperatives are not familiar with crowdfunding, the potential exists for crowdfunding to support energy cooperatives, especially the equity-based crowdfunding. Zhu et al. [15] developed a game model to investigate the potential of crowdfunding in supporting the construction of charging piles for electric vehicle (EV). Similarly, Zhang et al. [16] employed the SWOT analysis to examine the potential of using crowdfunding to support the development of distributed PV water pumping systems in China. However, there are few studies specifically investigating crowdfunding for solar PV.

More importantly, even though the studies above contribute to the understanding of crowdfunding in the energy-related area, there are few quantitative studies on crowdfunding. The several available quantitative studies on crowdfunding mostly utilize data from crowdfunding platforms, with few studies forecasting the development potential of crowdfunding [17,18]. It has been argued that more research on the mechanisms, including the potential factors influencing the success of crowdfunding campaigns is urgently needed [19]. It seems that although millions of crowdfunding investors have generated over a billion dollars in crowdfunding investments and donations [20], there is still lack of the academic knowledge in the dynamics of successful crowdfunding, [21] the potential of crowdfunding, and specifically the crowdfunding for solar PV, namely SCF.

To respond to the above gaps of knowledge, this study aims to review the concepts and various models of solar crowdfunding in general and propose a system dynamics model to simulate the potential of SCF by taking Singapore as an example. The focus of this study is to explore the various factors that impact the success of solar crowdfunding and create a system dynamics model that would not only show the causal relationships between the various impacting factors, but also could predict the development potential of solar crowdfunding. By doing so, this study contributes to the policy-making of financing for solar PV.

2. Solar crowdfunding

2.1. Crowdfunding concept and development

Governments across the globe have been offering incentives to encourage solar installations on private properties. For instance, the Non-business Energy Property Tax Credit [22] offering incentives of 10% of the cost up to US$500 or a specific amount from $50-$300 for an existing home is just one of the many schemes provided by the US government. Table 1 below summarizes the various financing models supporting solar systems in buildings [23].

Among the above financing approaches, solar crowdfunding has received increasing attention. In recent years, crowdfunding has emerged as a new and non-traditional way for securing funds without having to seek out traditional sources of investment [21]. Crowdfunding refers to the effort made by individuals or groups to generate funds for their projects by collecting small contributions from a large group of individuals through the use of the internet, and without the intervention of financial intermediaries [21]. In other words, crowdfunding users tap the crowd by raising money directly from individuals [24], usually through the use of the Internet. It involves two-sided market dynamics where the crowdfunding platform essentially brings together two different but interrelated groups of customers [25]. The platform could be in various forms such as the website or even an intermediary or broker who could connect the investors with the

Table 1
A review of solar financing methods.

Solar financing method	Description	Advantages
Municipalities / Local Government	• A government funds solar project where the source of funds come from government bonds • Government funds solar developer through funds gathered from government bonds. Solar developer design, install and operate the system and sell the electricity produced to the government through a solar power purchase agreement	• Low cost, longer repayment period, no upfront cost • Low cost, no upfront cost, no operation & maintenance costs of solar systems for site hosts
Third Party Ownership: Solar Leasing / Solar PPAs	• Solar developer buys and installs solar PV system. The solar lessee does not pay the upfront cost but pay fixed monthly installments over a specific period (typically 15 – 20 years) to consume the electricity generated	• Reduction or elimination of upfront cost, reduction of technological risk, and elimination of maintenance cost
Utility-Sponsored Model	• Utility company install and maintain solar PV and sell electricity to consumers	• Low-cost capital due to economies of scale • Lower transaction costs as customers pay through utility bill • Grid integration benefits based on an assessment of good and more efficient sites to install solar
Volume purchase	• Homeowners around a neighborhood come together to install solar PV as a community	• Economies of scale (higher discounts) • Increased willingness due to joint decision making
Solar Crowdfunding	• Funds for solar installation raised by individual investors through a platform	• Individual investors are independent of financial market conditions • Useful for small projects that cannot attain bank loans • Low-cost capital