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Analysis of feed-in tariff policies for solar photovoltaic in China 2011–2016

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HIGHLIGHTS

- We show the increasing of NPV/IRR values and the failure of quota instrument.
- We show the dynamic interactions of FIT system.
- The tariffs should be adjusted frequently to keep IRR values at 8–12%.

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ABSTRACT

In 2011 China initiated policies to promote the adoption of solar photovoltaic (PV) using feed-in tariff (FIT) policies. Since then the PV domestic market expanded substantially. In the past six years, the FIT policies were updated (adjustment of tariff levels, division of three FIT regions, setting of installation quotas) to address emerging problems such as PV waste, explosive installation, unbalanced spatial distribution. This paper aims to investigate the historical development and implementation of FIT policies in China from 2011 to 2016. The tools of net present value (NPV)/internal rate of return (IRR), learning curve and the system dynamics are employed to show the degree of economic incentives of FIT policies, to understand the learning rate of centralized PV systems, and to study the dynamic mechanism of the FIT system. We conclude that in the near term the tariff levels should be adjusted more frequently to keep IRR values in the range of 8–12%, and a tight quota combined with the deployment of ultra-high voltage (UHV) lines should be continued for the provinces with severe PV waste.

1. Introduction

The Chinese government set as a target that by the end of 2020 non-fossil energy should account for at least 15% of national primary energy consumption [1]. The motivations behind this target include dealing with climate change and other environmental problems, improving competitiveness in the field of new energy technologies and promoting national energy security. Solar photovoltaic (PV) is a promising technology to meet that goal.

In China, policies for solar PV were started in 1990s [2]. In the early stage, the China's PV policies mainly focused on R&D (research and development) and product popularization and application stage [3,4]. The central authority invested in R&D mostly through 863 Programs, 973 Programs and Key Technologies R&D programs [5]. As Lei et al. [6] pointed out that investment in China PV was mainly focused on manufacturing and application, insufficient in R&D. Because of technology transfer from western countries to China, large European market and low resource costs (labor, land and material resources), China's PV industrial activities started to replace western production capacity [7]. Since 2007 the production of Chinese PV cell has topped the world [3]. However, the development of domestic PV market was really slow, only 140 MW of cumulative installation in 2008 [4]. After 2008, the policies were gradually transferring from supply-side policies to demand-side policies to expand domestic market. In 2009, the central authority initiated the Solar Roofs Program and the Golden Sun Demonstration Program and by 2012 these two programs supported a total capacity of 3423.2 MW [5]. The central authority also sponsored two rounds of public tender for solar power projects in 2009 and 2010 with a total capacity of 290 MW, which aimed to test the benchmark price of domestic PV power generation [8]. Those programs promoted the domestic adoption of PV technology. In July, 2011, in order to deal with the severe manufacturing capacity surplus and the deteriorating international market, China

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started implementing feed-in tariffs (FIT) policies, marking a new era in the development of solar PV. FIT policies are instruments designed to attract investment in solar PV generation by offering long-term guaranteed purchase prices to generators for selling their electricity to the grid. With the stimulus of long term guaranteed tariffs, the domestic market expanded rapidly, reached a total of 77 GW cumulative installation in 2016 [9]. Today China is a dominant global player in the PV supply chain, including manufacturing of silicon, ingot, wafer, cells and modules [10].

In China, the development of solar PV has experienced two phases. In the initial phase (2011–2013) the domestic PV market was suddenly stimulated by the FIT policies. However, most capacities were installed in the western area of highest resource endowment. In the second phase (2014–2016), the rapid expansion continued, but combined with serious waste of PV electricity (see PV waste rate in Table A.5). The PV waste was mainly because most PV power generations located in the less developed western area and no long-distance transmission line existed to connect the solar resource centers to the consumption centers in the central and eastern provinces. In this phase, the FIT polices were updated by setting three FIT regions to encourage investments in the eastern and central China. The quota instrument was introduced to control the PV waste in the western China. Therefore tariffs and quotas worked together to contribute to a balanced spacial deployment, to control PV waste and to contain policy cost. Fig. 1 shows the annual new installation of centralized and distributed power generations. As in China most PV power generations come from centralized systems, our study mainly focus on centralized PV power generations which usually have a capacity of at least 20 MW.

This paper aims to investigate the historical development and implementation of FIT policies in China from 2011 to 2016. We study the economic incentives of FIT policies of seven representative provinces from 2011 to 2016 by calculating NPV/IRR values. We reveal the facts that the policy incentives were increasing in the past 6 years and the quota instrument failed to control the actual installations in the past 3 years. A system dynamics approach is adopted to explain the mechanism behind these two facts. It incorporates economic approach and technology learning curve to show the dynamic interactions between FIT policies (tariff and quota) and other import factors such as NPV/IRR values, PV technology progress, PV waste and cumulative installation. Finally, our analysis shows that in the near term the central authority should adjust the tariff levels of three FIT regions more frequently to keep IRR values in the range of 8–12%, and a tight quota combined with the deployment of ultra-high voltage (UHV) lines should be continued for the provinces with severe PV waste.

The paper is organized as follows: Section 2 gives a thorough literature review. Section 3 introduces the FIT policies in China. Section 4 describes the methods and data collection. Section 5 shows the historical NPV/IRR values and dynamic mechanism of the FIT system. The last section gives conclusions.

2. Literature review

Worldwide, FIT policies have been the most implemented policy to stimulate the deployment of PV technology [13]. The FIT policies guarantee fixed prices and long contractual periods, which lowers the perceived risks for investors. Compared with other policy mechanisms such as renewable portfolio standard (PRS), FIT policies are more efficient to increase the capacity and stimulate R&D input to reduce costs [14]. However, FIT policies may inhibit a healthy market competition by giving preferential treatment to certain technologies and increase financial burden on taxpayers [15].

In previous studies, Hoppmann et al. [16] investigated the evolution of Germany's FIT policies and shown how the characteristics of socio-technical systems affect policy interventions. Gao et al. [17] developed a step-by-step guidance for late and prospective FIT comers to fine-tune their scheme. For the evaluation of the FIT policies, the economic approaches had been widely adopted. For example, Jenner et al. [18] used economic approaches to assess the success of the FIT policies in 26 European Union countries. Callego-Castillo et al. [19] investigated the effects of FIT policies on wholesale electricity markets and the effects of FIT policies in increasing taxpayer's burden. Ahmad et al. [20] and Shahmohammadi et al. [21] used system dynamics approach to evaluate the impacts of FIT policies on solar PV investments and the generation mix in Malaysia. Also the tool of learning curve is usually adopted to represent the technology progress which is a key component in the optimal FIT models [22,23].

Focusing on the PV development in China specifically, Huang et al. [7] presented an overview of how China became a world leader in solar PV. Kayser [24] pointed out the risk factors that inhibit demand-driven PV market development. Hui et al. [25] identified that high generation costs and inadequate grid transmission capacity impede the development of clean generation technologies. Zhang et al. [26] proposed a real option model for evaluating PV investment under uncertainty. For the FIT policies specifically, Ouyang et al. [27] calculated the levelized cost of electricity of solar PV for the year of 2011 and compared with corresponding feed-in tariffs. Wang et al. [28] studied the effects of FIT policies on China's upstream and downstream PV firms. Lin et al. [29] demonstrated a method to combine FIT policies with emissions trading scheme for a cost-effective climate policy package. Li et al. [30] calculated the annual return on investment and payback period of integrated PV greenhouses systems. Rodrigues et al. [31] calculated the NPV, IRR and payback period of residential PV systems for the year of 2015. However, to our best knowledge so far no one has calculated a series of historical NPV/IRR values of different areas in China for centralized PV system and investigated the dynamic mechanism of FIT system. In this paper, we assess the strength of FIT policies of seven representative provinces from 2011 to 2016 by calculating NPV/IRR values. Moreover, a system dynamics approach incorporating economic approach and technology learning curve is used to show the dynamic interactions of between FIT policies (tariff and quota) and other factors such as investment profits, technology progress and PV waste.

3. The PV FIT system in China

Usually, the elements of FIT policies include: tariff levels, the degression mechanism of tariffs, contract duration and (soft or hard) cap. Compared with the major FIT countries in Europe such as Germany, Spain and Italy, there are several differences in China. As China is a huge country and the distribution of solar resource is highly uneven, the central authority set three FIT regions where areas with higher irradiations will get lower tariff levels. There is no automatic degression mechanism in China and the period of tariff adjustment, almost 30 months, is much longer than other countries. Also the quota instrument in China is different from the hard cap in other major FIT countries (see the detailed analysis in the results section).

3.1. Tariff levels

In July 2011, the National Development and Reform Commission (NDRC) announced a nationwide FIT policy for the development of solar PV. It stated that (1) non-bidding projects approved before 1-7-2011 and starting with operation before 31-12-2011