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Short communication

Economic analysis of photovoltaic systems for the residential market under China's new regulation

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ABSTRACT

China has recently changed its regulation for producing energy from photovoltaic solar panels in order to encourage the use of the solar resource. This new regulation started with offering subsidies at a national level and this was later followed by local subsidies in addition to the national one. Being a large country, China has regions with good solar exposure and others with poor exposure. Each region has a different electricity price and the energy is purchased based on the Grid Coal Power electricity price that also varies throughout the country. In this work we analyze the economic profitability of different regions considering the solar radiation levels, savings in self-consumption, cash flows from injecting power into the grid and local prices for installations to show that the best return is obtained in the places with better solar radiation or where the electricity price is higher. The regional Feed-In tariffs help to compensate for lower radiation levels but do not make these regions very attractive from an investment perspective.

1. Introduction

In 2013, the National Development and Reform Commission (NDRC) of China released a new regulation for producing energy from photovoltaic solar panels in order to encourage the usage of solar energy (National Development and Reform Commission, 2013). This regulation covers PV Power Plants (PVPP) and Distributed PV (DPV) systems. The PVPP refers to the installations of large-scale commercial electricity generation while DPV refers to small installations that focus on residential use. The PVPP kWh's value is based on a reverse auction process and an undefined subsidy is mentioned. For the DPV a subsidy is defined to cover even the self-consumed energy.

The new regulation was applied on the 1st of September 2013 and was later linked to the local regulations of the individual provinces. On the national level there is a 0.057€[1] subsidy for every kWh of electricity produced. Meanwhile, the electricity produced by the DPV systems can be sold without VAT (value added tax) to the national grid with local "Grid Coal Power (GCP)" electricity price, which varies across the country. In 2011, the GCP prices ranged between 0.0381€ and 0.0685€ per kWh (National Development and Reform Commission, 2013) throughout all the provinces in China.

GCP prices vary from 0.0381€/kWh to approximately 0.057€/kWh in the northern part of China and above that to 0.0685€/kWh in the southern part. Considering that a line was drawn above the provinces of Tibet, Chengdu, Henan and Shangdon, dividing the North of China from the South of China, Guizhou presents a low 0.0520€/kWh price compared to all the other provinces in the South of China. The prices of the Coal Power Grid were largely determined by the Government until the 2015 reform.

Statistics show that Coal Power Grid prices increases over time by an average of 5.573% every year which is the value used as the electricity evolution rate in this work mentioned in Section 4. This value was calculated based on the evolution rate of the grid prices from the past 25 years.

The regulations for the provinces can add feed-in tariffs of different forms:

- Per kWh produced
- Per kWh injected into the grid
- Per installed kW
- Including phase out stage, with fixed duration or undefined

According to NDRC, the regulation covers a 20-year period starting from the date of installation. The subsidy will, in principle, be decreased gradually after this period and selling the energy to the national grid tax-free.

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[1] Throughout this paper the currency conversion rate is 0.136 Euro to 1 Chinese Yuan, value obtained on January 9th, 2015.

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For China, the regular prices of energy are low compared to numerous other countries around the world presented in Table 3 of reference (Rodrigues et al., 2016), but so is the price per installed kW since China is the biggest manufacturer of PV modules (De la Tour et al., 2011).

In terms of location, the subsidy tends to compensate for the lower levels of solar radiation present mostly in the southeast part of the country. On the other hand, the highest solar radiation levels are obtained in the southwest part where no regional subsidy was issued.

In 2015, the NDRC released the solar PV system regulation to encourage the use of solar energy in China, and around the same time the new version of the "Energy Efficiency and Emission Reduction" policy was put in place. This policy has the goal of promoting energy efficiency and emission reduction measures throughout China, in which one of the measures is to include PV system installations in the projects some of which are financed by the World Bank (2016). One of the previous versions of this policy was announced in 2005 and had an energy efficiency and emissions reduction target of 20% by 2010 (Zhang, 2012) and 40–45% by 2020 while the target for this new policy announced in 2015 is to reach 48% by 2020 (Henderson et al., 2016), using the 2005 CO_2 emission levels as a reference. All over China, PV system projects have been implemented in: Industry sector (Asian Development Bank, 2011; Asian Development Bank, 2015), schools by implementing the Rooftop Solar Photovoltaic Scale-Up project (Beijing Municipal Audit Office of the People's Republic of China, 2016), and also in the rural residential sector (German Industry and Commerce Greater China Beijing, 2016).

The policies contained in these two regulations are meant to cooperate in the direction of producing cleaner energy and have less impact on the environment but will have a small immediate effect and specially because even after 2 years of the release of the PV system regulation, many electrical utilities companies are still refusing the connection of these systems to the electrical grid.

In this paper we compare the current situation for the different regions of China considering the payback time and economical analysis under the new regulation. To do so, we analyze five cities, which have either the best solar radiation situation or the best possible economical subsidy conditions and are chosen to show the best possible investment condition.

2. Methods

2.1. China's current energy situation

The Chinese electricity industry has evolved from being centrally planned, tightly controlled and state owned to a "dual system" industry. It still has dominant state planning at the core but the decentralized generation system at the periphery is owned by government organizations at different levels and by private enterprises. This new industry structure gradually introduces a competitive atmosphere between the companies so that the end-client gets a better deal on the price of electricity (Cherni et al., 2007).

The demand for electricity in China has risen rapidly, and one would think that it is driven by massive economic growth but according to (Shiu et al., 2004) the increase in electricity consumption raises the real Gross Domestic Product (GDP) but not the reverse. Generation capacity does not meet the demand and power shortages cause power cuts during peak hours preventing economic growth and making it a necessity to increase the generation substantially in the near future (Cherni et al., 2007).

China has the second largest electricity industry in the world and is playing an important role within the global economy and environment. The primary fuel mix is dominated by coal, which is contributing to significant local, regional and global environmental pollution. China is the second largest emitter of greenhouse gases in the world, just behind the USA (Zhengming, 2000; Liu et al., 2002), and is coming under increasing international pressure to control its emissions (Cherni et al., 2007).

The solar energy resource in China is abundant but significantly under-exploited and has an important role in increasing electrification levels thereby protecting the environment by alleviating the reliance on coal, and providing for economic and social needs (Cherni et al., 2007). In the southeast part of China the daily solar insolation ranges from less than 2 kWh/m^2/day while in the west part daily radiation can reach more than 9 kWh/m^2/day (Junfeng et al., 2007; Liu et al., 2011). Most parts of the country receive an annual solar radiation of more than 5.02×106 kJ/m^2 and more than 2000 hours of sunshine a year. In Rodrigues et al. (2016), 13 countries are compared and Table 3 shows that China has the highest solar production values, which consequently presents the highest solar insolation value. According to Peidong et al. (2009) the areas in China with the largest amount of radiation include Tibet, Qinghai, Xinjiang, southern Inner Mongolia, Shanxi, northern Shaanxi, Hebei, Shandong, Liaoning, western Jilin, middle and southwestern Yunnan, southeastern Guangdong, southeastern Fujian, eastern and western Hainan Island and southern western Taiwan, in which Qinghai-Tibet Tableland, in particular, receives the most radiation (Peidong et al., 2009; Solar energy in China).

2.2. Radiation

China is a large country of 9,596,960 km^2 (The World Factbook 2013-14, 2013) that has very different levels of solar radiation in different areas (Fig. 1). Southwest China has the highest annual radiation; the regions that have a local subsidy on top of the national subsidy are generally located in the southeastern part of China. In this study, five cities from Zhejiang, Anhui, Jiangxi, Tibet and Guangdong provinces are chosen according to their subsidy condition as well as the solar resources.

2.3. Subsidy situation

As stated, the national subsidy is 0.057€/kWh. The regional subsidies are added to this value and, in general, are connected to the radiation level of the region and can be based on the installed power or on the energy produced as shown in the next points. New regional subsidies are expected in the near future but the ones that have been published already are:

1. *Zhejiang province*:

At the province level there is an additional value of 0.0136 € for DPV and 0.0409 € for PVPP generation. Some cities have also approved other subsidies:

- In Tongxiang city, 0.0409€ per kWh for the first 2 years, 0.0273€/kWh for the next 3 years. For installations of more than 0.1 MW there is an additional subsidy of 0.2046€ per installed Watt.
- In Jiaxing city, there is a decreasing 3 year subsidy of 0.3819, 0.3751, 0.3682 € per kWh for the years of 2013, 2014 and 2015.
- Hangzhou: Xiaoshan District subsidizes 15% of the electricity price; Fuyang District for installations between 2014 and 2016, 0.0408 €/kWh for the first two years, 0.0272 €/kWh from the third year to the fifth year.

2. *Anhui province*:

Hefei city: One time subsidy of 0.2728 €/kW of installed power for DPV systems and 0.0341€/kWh produced.

3. *Jiangxi province*:

One time subsidy of 0.5455€ that will decrease to 0.4092€ per Watt