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China's solar photovoltaic industry development: The status quo, problems and approaches

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HIGHLIGHTS

- China's PV industry's development history and status quo were introduced.
- The existing problems and challenges were analyzed based on field studies.
- Policy recommendations and possible implementation incentives were provided.

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ABSTRACT

With its rapid economic development, China has already become the largest emitter of carbon dioxide in the world, facing the pressure from environment and clean energy. In the last decade, the solar photovoltaic (PV) industry in China has developed rapidly, with the joint promotion of the market and policies. China's PV modules' production is ranked top in the world, making a significant impact on the world's renewable energy development and solar PV industrial sector. Meanwhile, China's solar PV industry is facing several challenges, including international trade conflicts and market competition, as well as domestic problems, such as the vicious competition between enterprises, financial issues such as loan-withdrawing and stint loans by banks, and business triangle-debts. The focus of this paper is on China's PV industry's development history and status quo, the most dynamic aspect of current renewable energy development. The PV sector's existing problems and challenges have been analyzed by several field studies of the PV industry's major manufacturers covering four of world's top PV module producers. Recommendations regarding the policy framework and implementation incentives will also be provided with the aim of improving market forces as a catalyst for transforming future renewable energy development.
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1. Introduction overview

With its rapid economic development, China is facing a double pressure related to energy and the environment, such as the traditional fossil energy shortage and emissions problems. Since 2007, China has been the largest emitter of carbon dioxide in the world. In 2012, the additional emission load in China was 300 million tonnes, which is expected to continue to rise [1,2]. China is a huge importer of not only crude oil (with a 56% reliance on imports) but also raw coal (raw coal net imports reached 240 million tons in 2012) [3]. China also ranks first in the world with regard to electricity consumption and installed electricity capacity. Regarding the environment, the local emissions associated with, for example, SOx, NOx and acid rain are also presenting challenges for future sustainable development. With the growing demand for energy and increasing environmental concerns, it is necessary to restructure the energy mix. With regard to energy and the environment, renewable energy sources development in China, such as photovoltaic (PV) and wind power generation now forms the basis of the national, long-term sustainable development and has already developed rapidly [4,5].

In view of international development, the solar PV energy supply is destined to become one of the main global energy supply carriers by 2030 and a leading energy source by 2050 [2]. The EU plans to expand the gross installed capacity of the PV industry to 397 million kW, with power generation occupying 15% of EU gross power generation; while the US plans to achieve 300 million kW, with power generation occupying about 11%. The EU and US plan to expand the gross installed capacity of the PV industry to over

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1500 million kW by 2050, with power generation occupying 30% of this [6,7]. With reference to the EU vision, China aims to create a PV industry with a gross installed capacity of 1050 GW by 2030. However, by the end of 2012, the gross installed capacity of its PV industry was only 6.5 GW,[2] indicating the great potential of China's market.

PV power generation offers significant benefits in terms of energy supply, environmental protection and economic growth. The power generation is about 15–25 times greater than the power consumption within the full lifecycle. The energy payback time is about 1.1–1.6 years. The energy consumption and emission of carbon dioxide involved in the generation of 1 KW h of electricity is about 5% of that of coal-fired power generation [8]. According to the current technology roadmap and cost forecast, China's PV industry will achieve grid parity on the consumption side by 2015 and on the generation side by 2020 [9]. This era of grid parity is anticipated to arrive earlier, if the environment and resource costs of coal-fired power generation are taken into consideration, and coal-fired power generation is levied with carbon tax or the coal resources tax is levied.

Since 2000, the Chinese Government has launched a series of national policies and regulations that actively promote solar PV industry R&D, production and application. Stimulated by the domestic policies and the international market, China's solar PV industry has developed rapidly in recent years. The manufacturing of PV module in China has increased about 1000 times, from 3 MW in 2000 to 23 GW in 2012. In 2011, the shipment of global solar cells was about 37.675 GWp, wherein the shipment of the Chinese Mainland was 21.157 GWp, occupying 56.16% of the global market [10]. The rise of China's solar PV industry sharply reduced the cost of solar energy utilization. The Photovoltaic module (PV module) has decreased, from RMB 45/WP in 2000 to RMB 4.5/WP in 2012, which has made a considerable contribution to global solar energy utilization [11]. However, at the same time, the development China's solar PV industry still faces several challenges, including the EU and US "anti-dumping and anti-subsidy" duties placed on the Chinese solar industry, the re-emergence of the international enterprises, the excessive competition between domestic enterprises, loan-withdrawing and stint loans by banks, and business triangle-debts.

From the international history perspective, three factors have influenced the solar industry's development. The first is the policy-oriented market. The electricity market, PV market, system market and user side market created by the German Renewable Energy Feed-in Law is an example of the application of solar energy [12]. The second is subsidies. In Germany, the Chinese mainland and Taiwan, subsidies and the Feed-in-Tariff have been recognized as the two major policy tools that influence solar industry development [11–13]. Meanwhile, the behavior-orienting policies, such as the time-of-use energy pricing policy [14], and the solar related system's sustainable development utilization policy and approaches [15,16], have also shifted the usability of solar power. The third factor is the social issues, including social interaction and social acceptance. The influence of the media and user perceptions has had a significant influence on solar energy use [17]. In Ghana, Kenya and Zimbabwe, from the 1960s to 2007, social interaction has played a key role in solar PV dissemination [18]. Of these three factors, the policy factor is the most frequently-employed approach in developing countries [19]. The research conducted on China's solar industry shows that the supply-side policy is a key feature for China [20,21].

[2] Note: The accumulative installed capacity of China's PV industry is 6.5 million kW, according to statistical data from the Renewable Energy Society, without formal publication but widely accepted in this industry.

Based on the above background, it is clear that a detailed, first-hand study of the PV industry is required in order to investigate the issues and challenges facing the industrial sector. Therefore, based on the overall survey and research of the PV industry in southern, northern and western China, this paper comprehensively analyzes the current problems and challenges within the solar PV industry there and proposes countermeasures and suggestions to address these issues. The paper presents the first review of the history of PV development in China.

2. Development history of China's solar PV industry

In view of the development history of the international PV industry, the periodical industrial adjustment is quite normal. In 1973, 1990 and 2000, the international PV industry underwent three upsurges, during which the technology advanced rapidly and the market was accelerated, albeit followed by a slowdown. Due to the effects of the capacity surplus and the financial crisis, several international PV enterprises went bankrupt and reorganized around 2012. The PV industry underwent a new round of adjustment. Currently, there are various national planning policies in place seeking to promote a completely sustainable PV development system including a national laboratory, technical standard, investment and financing. With the global economic recovery, the PV industry will certainly soon undergo the next development upsurge.

China's solar PV industry has developed rapidly over the past ten years, turning Yingli Solar, Changzhou Trina Solar and others into PV industrial giants. Among the world's top 15 PV cell industries in 2006, there were four Chinese Mainland enterprises while, by 2012, six Chinese enterprises were listed among the world's top 10 enterprises, as shown in Table 2.1.

In 2012, the capacity of Chinese PV cell packs was about 23 GW, occupying 58% of total global capacity [22]. The milestones in this process are shown in Table 2.2.

Up until 2002, China's PV industry remained in the R&D and production stage, with government funding, and had not yet formed a complete industrial chain; the market developed slowly; and the PV products had not been used for civil applications. In 2002, SDPC initiated the "Power Supply Plan for Rural Areas without Electricity in the Western Provinces and Regions" policy, which indicated that renewable energy technology, such as solar PV and wind power generation, began to be employed to solve the household consumption problem of farmers and herdsmen in the western regions who lacked a power supply, and PV products began to be used for civil applications. In 2004, several countries including Germany implemented a high-level feed-in tariff and PV subsidy policies, which effectively stimulated the investment willingness of PV investors and formed an enormous international PV market. Chinese enterprises seized the opportunity to expand their capacity rapidly and reduce their production costs through

Table 2.1
PV modules manufacturing capacity of the main global cell pack enterprises in 2012. *Source:* 2013 Report on PV Industry Development [10].

Enterprise	Country	Production (MW)	Productivity (MW)
Yingli Solar	China	2300	2450
First Solar	US	1900	2400
Suntech	China	1700	2400
Trina Solar	China	1600	2450
Canadian Solar	China	1600	2400
JA Solar	China	1100	1500
Sharp	Japan	1060	1400
Hanwha	Korea	950	1650
Sunpower	US	925	1000
Jinko Solar	China	900	1500

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