RESEARCH ON THE SOLAR PHOTOVOLTAIC (PV) DEVELOPMENT IN CHINA

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Abstract— Over the past decades, the photovoltaic (PV) industry in China has been developed rapidly. The Chinese government has played an important role in this stage of PV development, which has issued a series of policies to support the development of solar energy, and the photovoltaic industry in particular. From 2013 to 2016, the annual installed capacity of China ranked at the top in the world and the accumulated capacity also ranked at the top globally. In this paper we evaluate the changes that have occurred in China over recent years in PV industry, demonstrate the governmental policies in different periods; and changes in the PV industry structure. The analysis section shows how much the PV industry has been diffused and what will make the development process rapidly. In future, the technique experience and advanced management strategies of PV development in China can be good reference for the other countries.

Keywords- China, Photovoltaic, Policy, Development

I. INTRODUCTION

As the renewable energy resources，the photovoltaic (PV) is considered as one of the promising clean power generation in the further. In 2016, global solar power capacity exceeded 300 GW, after it took the 200 GW mark the year before, and the 100 GW level in 2012. The total installed solar PV power capacity increased 33% to 306.5 GW by the end of 2016, up from 229.9 GW in 2015 [1].

China’s PV industry started to rise in 1970s and has now become the largest PV manufacturer and the largest market in the world. China plays advanced role in photovoltaic development and has achieved remarkable achievements compared with other countries in PV industry. From 2013 to 2016, the annual installed capacity of China ranked at the top in the world and the accumulated capacity also ranked at the top globally. 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 [2]. China’s domestic market started to increase obviously under the promotion of China’s PV power generation demonstration projects. The Chinese government has played an important role in this stage of PV development, which has issued a series of policies to support the development of solar energy, and the photovoltaic industry in particular.

Since the 2010s, particularly since the early 2011, China's solar PV sector has seen extraordinary development. At the end of 1994, the PV module manufacturing capacity in China was just 5 MW, although much of this capacity did not meet modern international standards and actual production was only 1.4 MW. There were only about 3 MW of solar PV systems in use, of which about one third was in dispersed household systems [3]. After 2008, the government has introduced a number of policies to support PV industry. Financial assistance, technology support and management improvement are involved. Since 2009, China's PV installed capacity has increased year by year. The growth rate has increased sharply from 2011 to 2016. By the end of 2015, China’s accumulated PV installation reached 43.18 GW to become the largest country in the world in terms of PV installation. Of which, PV power station accounted for 37.12 GW, distributed 6.06 GW, with a total power output of 39.2 billion kWh. The total installed capacity of PV in China has reached 77 .42 GW in 2016 [4].

The purpose of this paper is to demonstrate the policy in different periods from 1990 to 2016 has been carried out, it was found that the policy played a decisive role in the China PV development. This paper will also demonstrate how the powerful energy policies have substantial impact on developing a self-sustaining market. The paper aims to analysis PV development in China, in order to understand the diffusion of PV, and more specifically to identify what is the point factors for further diffusion of the PV development. Key policy issues associated with the blocking mechanism will be noted, and we will hope to contribute to understanding the diffusion of PV in China. In Section 2: we differentiate four phases under the different degrees of development in PV development history which will understand the changes of PV development in China in recent years. Section 3: reviews the Chinese government policy for renewable energy and their impact on the development process of PV. Section4: Conclusion and discussion. How the government policy for renewable energy has a great impact on the diffusion process of PV and what

are the advantages of these policies worth to learn.

II. PV DEVELOPMENT IN CHINA

2.1 Evolution of China's PV industry

In China, policies for solar PV began from 1990s [5]. In the early stage, the China's PV policies triggered increased R&D (research and development) of PV technologies, and product popularization and application stage. The central authority invested in R&D mostly through 863 Programs, 973 Programs and Key Technologies R&D programs [5]. During the 2000, Because of technology transfer from western countries, large European market and low resource costs (labor, land and material resources), China's PV industrial activities began to replace western production capacity. Since 2007 the production of Chinese PV production has been the first place in the world [6]. China's annual output of PV module which provided effective market support to China's PV manufacturing industry.

However, the most PV products are exported to Europe and America, the development of domestic PV market was really slow, only 140 MW of cumulative installation in 2008 [6]. After 2008, the policies were gradually transferring from supply-side policies to demand-side policies to expand domestic market. In 2009, a number of demonstration PV projects were promoted. These demonstrations created an indispensable demand for solar cells and a steady improvement of conversion efficiency of PV. The central authority initiated the Solar Roofs Program and the Golden Sun Demonstration Program and by 2012 these two programs promoted the total capacity to 3423.2 MW [5]. The government 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. In 2011, the National Development and Reform Commission (NDRC) announced a nationwide FIT policy, try in to trigger increased in the development of solar PV market. 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 77.42 GW cumulative installations in 2016 [4]. Today China is a dominant global player in the PV supply chain, including manufacturing of silicon, ingot, wafer, cells and modules [7].

2.2 PV development stage in China

Fig. 1 shows the trend of PV installation in China from 1990 to 2016, from which we could differentiate three phases under the different degrees of development in PV development history:

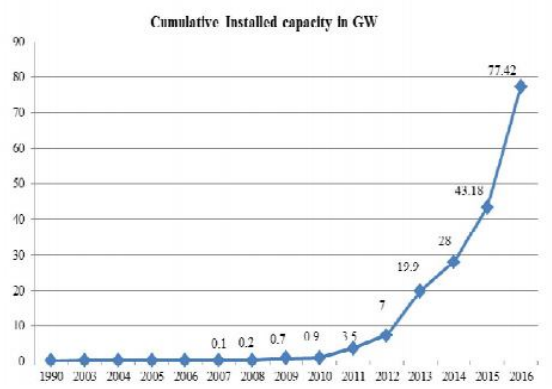


Fig.1 Development of installed capacity of PV in China:

Stage 1(1990-1999): Preliminary development stage

In 1990s, China demand for energy increased further as industrialization and urbanization move ahead. The Chinese government has begun to attach importance to the development of renewable energy sources, and promulgated Outline for New Energy and Renewable Energy Development, focusing on energy saving solar energy buildings, solar water heaters and photovoltaic power generation systems. However, because of the high cost of PV solar generation, Chinese government does not have a policy specifically aimed at PV solar generation. The only policy related to solar energy development is the supply-side policy to promote R&D and follow the development of solar energy technology. On the other hand, the government promoted the PV generation for non-electricity areas. For example, the program of ''the construction of independent PV power stations in 9 counties in Tibet'', but the results does not show that satisfactory.

Stage 2(2000-2009): PV industry rapidly development stage

From 1999, PV installations in Germany increased rapidly under subsidy program of 100,000 roofs and Erneuerbare Energien Gesetz (EEG). The German residential PV installation continuously increased under stable and modified EEG program in form of a Feed-in tariff (FIT). The European PV Market was increased greatly. Under this international background, this huge market stimulated the boom of Chinese PV industry. At the same time, the government issued several national projects to promote the development of the manufacturing industry. In 2003, the Ministry of Science and Technology and Ministry of Commerce issued the Directory of High and New Technology Products Encouraging Foreign Investments, which encouraged foreign investment in manufacturing, such as modules, power generation inverters, controllers and other PV system parts. The Solar PV industry developed swiftly and played a significant role in the global PV market. The annual growth rate more than 100% and the total amount of production ranked first in the world. However, more than 90% of solar PV products were exported to other countries. China issued the ''Tenth Five-Year'' Plan for the

Development of New energy and Renewable Energy Industry, proposing a feed-in policy. In 2005, it issued Renewable Energy Law of the People's Republic of China to accelerate solar energy development. The NDRC issued special projects on the industrialization of solar cell silicon ingots/silicon chips, high efficiency and low cost solar cell modules and system control components. Meanwhile, the government expressed its plan to enhance the policies of R&D, demonstration, fiscal taxation, product price, marketing and sales, import and export tax to promote the development of solar PV products. During this time, the cost of solar PV products has decreased sharply, which was laying the groundwork of the development of domestic PV market.

Stage 3(2009-now): Rapid growth Stage of China PV market

In 2009, China PV industry has experienced a chilling winter largely caused by the anti-dumping actions in the U.S. and Europe, forcing most Chinese manufactures to invest in R&D to reduce cost and to branch out to the developing world. At same time, the National Energy Administration issued the ''Twelfth Five-Year'' Plan for the Development of Renewable Energies. The government has begun to attach importance to the development of the domestic PV market, which have adopted a range of policy to support the development of the domestic PV market, such as special funds for renewable energy, feed-in tariff subsidies and quota transactions, preferential income tax for high and new technology enterprises, financial aid for PV applications, Concession Bidding, government pricing for solar power feed-in tariffs, and demonstration projects.

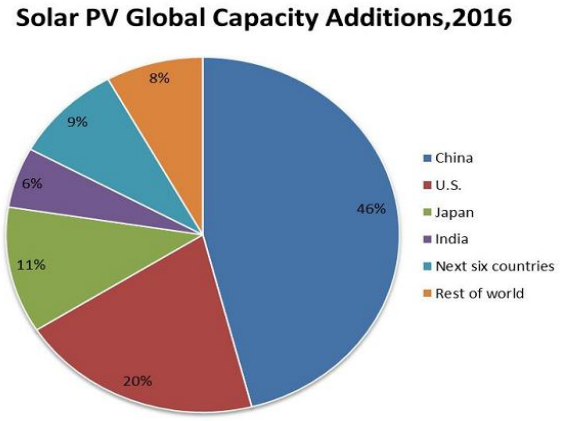


Fig.2 Solar PV Global Capacity Additions, Shares of Top 10 Countries (Next six countries: U.K., Germany, France, Italy, France, Australia) and Rest of World, 2016

In July 2011, the NDRC announced a nationwide FIT policy for the development of solar PV [7]. It stated that (1) non-bidding projects approved before 1-7-2011 and starting with operation before 31-12-2011 will enjoy a tariff of 1.15 CNY/kW h 1 ; and (2) projects approved after 1-7-2011 or approved before 1-7-2011 but starting with operation after 31-12-2011 will get a tariff of 1 CNY/kW h[8]. In Aug.2013, the NDRC issued the ''Notice on the role of price lever in promoting the healthy development of the PV industry". PV power generation was categorized into either distributed or centralized systems. Concerning centralized power generation, the whole country was further divided into three regions, based on solar resource distribution. Particularly, it stated that in principle the feed-in tariffs will be guaranteed for 20 years [7] [9]. In Dec. 2015, the updated policy was issued, the ''Notice on Perfection of Policy Regarding Feed-in Tariff of Power Generated by Off-Shore Wind and Solar PV". The tariffs are actually paid by the industrial and commercial users by adding renewable surcharge into the electricity price. The FiT policy has driven the rapid growth of the PV market in China, which has consistently grown beyond the government targets. The PV cumulative installed capacity increased from 3.5 GW in 2009 to77.42 GW in 2016. In 2016, China added 34.5 GW, the rapid increase in solar PV capacity in China, up 11-fold since the end of 2012, increasing its total solar PV capacity 45% to 77.42 GW, far more than that of any other country (Fig.2).

III. GOVERNMENT POLICY FOR RENEWABLE ENERGY AND THEIR IMPACT ON THE DEVELOPMENT PROCESS OF PV

3.1 Policies in different periods

The table 1 shows the government policies and programs support in different stages of PV development in China from 1990 to 2016.

Table 1: Policies in different periods in China

Policy	Operating principle	Year
Electricity Act	The electricity Act 1996 formulates the fundamental regulatory principles and framework for the electricity industry.	1996
Administrative Regulations on the Power Business Permit	This regulation establishes a market-entry system for electricity companies	2005
Interim Regulation on the On-grid Tariff	Sets the government-approved nation-wide standard on-grid tariff and gives the gradual introduction of a competition-based market price.	2005
Renewable Energy Law	The Renewable Energy Law provides the framework for securing the development of renewable energy in China. Feed-in-tariff: Build feed-in tariff and cost allocation system. Public investment: Build Renewable Energy Development Funding sourced from user side electricity prices	2006
Interim Management Rules for Renewable Energy Development Funding	Use part of user terminal electricity income to develop renewable energy. Levy rate: 0.002 RMB per kWh from 2006; 0.004 RMB per kWh from November 2009; 0.008 RMB per kWh from December 2011;0.015 RMB per kWh from August 2013	2006

Interim Management Rules for Renewable Energy Development Funding	Public investment: Use part of user terminal electricity income to develop renewable energy. Levy rate: 0.002 RMB per kWh from 2006; 0.004 RMB per kWh from November 2009; 0.008 RMB per kWh from December 2011; 0.015 RMB per kWh from August 2013	2006
Notice on Implementation of Golden Sun Demonstration Project	Demonstration project: Installed over 5.8 GW in mainland China	2009
The BIPV subsidy program	Offering upfront RMB20/watt for BIPV systems and RMB15/watt for rooftop systems.	2009
'Twelfth Five-Year'' Plan for the Development of Renewable Energies	Propose development targets of solar power installed capacity up to 21 million kilowatts by 2015 and up to 50 million kilowatts by 2020	2010
Notice of the NDRC on Perfection of Policy Regarding Feed-In Tariff of Solar PV Power Generation	Benchmark Feed-In Tariff nationwide; feed-in tariff for distributed PV power generation projects	2011
Amended: Notice of the NDRC on Perfection of Policy Regarding Feed-In Tariff of Solar PV Power Generation	Benchmark Feed-In Tariff nationwide; feed-in tariff for distributed PV power generation projects	2013
Notice of the NEA on carrying out the Establishment of Demonstration Area of Distributed Solar PV Power Generation	Establishment of Demonstration Area of Distributed Solar PV Power Generation	2013
Top Runner Program	Guide project developers to adopt the latest technology, increase system efficiency and reduce LCOE. Results have been encouraging: by the end of 2016, the average cell efficiency of mono Si produced in Mainland China increased to 20.5%, the LCOE in sun-rich areas was below 0.65 CnY/kWh, and the record auction price reached was as low as 0.45 CnY/kWh	2015
Amended: Notice on Perfecting Feed-In Tariff Policy of Solar PV Power Generation	Benchmark Feed-In Tariff nationwide; feed-in tariff for distributed PV power generation projects	2016

3.2 Important Policies and its impact on PV development in China

Various kinds of government subsidies for Solar PV development in China was implemented by special programs, such as the PV Building Demonstration Program, the Golden Sun program and the solar Feed-in-Tariff (FiT). At present, China is reforming the Solar PV Fit in order to improve the domestic solar market in terms of efficiency and quality. From 2006, those subsidy policies and demonstrate program have greatly affected the development of PV in China. The important PV policies in the last few years will be listed in this section.

3.2.1 The BIPV subsidy program:

In March 2009, China announced its first solar subsidy program, the BIPV (Building-integrated photovoltaics) subsidy program, offering upfront RMB 20/watt for BIPV systems and RMB 15/watt for rooftop systems. China's Ministry of Housing and Urban-Rural Development announced a stimulus plan for BIPV applications in mid-April, offering RMB 20/watt for construction material- and component-based BIPV projects and RMB 15/watt for rooftop- and wall-based projects. On July 2009, the media reported that 111 rooftop-based or BIPV projects nationwide with a combined capacity of 91 MW have been allocated subsidies totaling nearly RMB 1.2 billion [10].

3.2.2 Golden Sun Demonstration Project

In 2009, China's Ministry of Finance, Ministry of Science and Technology and the National Energy Administration of the National Development and Reform Commission, announced the launch of the Golden Sun Demonstration Project, the second national solar subsidy program, on July 21, 2000. The project is to facilitate the growth and expand the scale of the PV power generation industry. The effort will be made through fiscal subsidies, scientific and technological support, and market incentives to accelerate the industrialization of PV technological and enable large scale development of the PV industry [11]. The summary of this project is listed below:

(1) The government will subsidize 50% of investment for solar power projects as well as relevant power transmission and distribution systems that connect to grid networks.

(2) For independent photovoltaic power generating systems in remote regions that have no power supply, the subsidy will rise to 70%, the ministry said in an announcement on its web site.
(3) Grid companies are required to buy all surplus electricity output from solar power projects that generate primarily for the developers' own needs, at similar rates to benchmark on-grid tariffs set for coal-fired power generators.
(4) To qualify for the subsidy, in addition to other requirements, each project must have a generating capacity of at least 300 kilowatt peak, while construction will have to be completed in one year and operations will have to last for at least 20 years.
(5) The government plans to install more than 500 MW of solar power pilot projects in two to three years.
(6) The total generating capacity in such pilot projects in each province in principle should not exceed 20 MW.

3.2.3 Notice of the NDRC on Perfection of Policy Regarding Feed-In Tariff of Solar PV Power Generation

In 2013, the NDRC has set the benchmark on-grid power tariff at RMB 0.9, RMB 0.95 and RMB 1 per kwh according to the solar power resources and construction costs in different resources zones nationwide. Distributed PV power generation projects will be given a standard subsidy of RMB 0.42 per kwh. The feed-in tariff support is granted for period of 20 years. Tariffs for the new PV installations have gradually lowered over the time in order to promote technology development, technology efficiency and competitiveness of the PV sector. And the National FiT rates have two times of change notices by NDRC from 2013 to 2016(Table 2).

Table 2: China national PV FiT rate over the years [RMB/kWh]

Resource region	2011	2012	2013	2014	2015	2016	2017
I	1.15	1	1	0.9	0.9	0.8	0.65
II				0.95	0.95	0.88	0.75
III				1	1	0.98	0.85
Distributed PV				0.42	0.42	0.42	0.42

Source: NEA

Note: Regional solar resource in China is classified as class I, II or III, in descending order of abundance; Resource region I: Ningxia, Haixi of Qinghai, Jiayuguan, Wuwei, Zhangye, Dunhuang and Jinchang of Gansu, Hami, Tacheng, Ataile, and Karamay of the Xinjiang, areas in Inner Mongolia apart from Chifeng, Tongliao, the Hinggan League and HulunBuir; Resource region II: Beijing, Tianjin, Heilongjiang, Jilin, Liaoning, Sichuan, Yunnan, Chifeng, Tongliao, the Xing'an League and HulunBuir of Inner Mongolia, Chengde, Zhangjiakou, Tangshan and Qinhuangdao of Hebei, Datong, Shuozhou and the Xinzhou of Shanxi, Yulin and Yan'an Shaanxi, areas in Qinghai, Gansu and Xinjiang apart from Resource Area I; Resource region III: Other areas excluding Resource Areas I and II.

3.2.4 Top Runner Program

Relatively new to China's PV plan is the PV Top Runner Program, which was introduced in 2015 to give Chinese PV players economic incentives to invest in new and innovative technologies. There are two parts to the Top Runner Program: 1) a policy component where the NEA sets the minimum performance parameters for PV cells, modules and inverters eligible to be a Top Runner component, and 2) a project component where the NEA organizes tenders that utilize exclusively Top Runner components.

The pilot round launched in 2015 consisted of one 1 GW tender of multiple projects in Shandong province, completed by end-June 2016. The second round launched in 2016 expanded to eight tenders (also called "bases") in five provinces, totaling 5.5 GW. All of the equipment used in these projects need to meet minimum requirements of 16.5%/17.0% efficiency for multi-crystalline and monocrystalline silicon modules respectively. A supply crunch resulted, particularly on the multi-crystalline front, as monocrystalline modules of the time could more easily meet the 17.0% efficiency requirement than multi-modules the 16.5% requirement (Table.3). This prompted the 2015–2016 rush towards PERC and monocrystalline silicon capacity expansion, in anticipation of next year's tenders and more stringent requirements to come.

In addition to minimum efficiency requirements, the Top Runner Program is structured such that there are special carve-out projects (min. 50 MW) within individual tenders for "new technologies", which in 2015 was loosely defined to include PERC, IBT, HIT cell technologies. What the program does is provide Chinese PV enterprise with a sizable, assured end-market for technologies that are commercially available but not yet competitive. It encourages Chinese PV enterprise to invest in niche, high-efficiency technologies currently only produced by the likes of SunPower and Panasonic [12].

Table 3: Standard vs. Top Runner Program minimum module performance requirements

		Regular		Top Runner	
	cells	Multi	Mono	Multi	Mono
Efficiency	-	15.50%	16.00%	16.50%	17.00%
Power	60	255 W	260 W	270 W	275 W
(equivalent)	72	305 W	315 W	325 W	330 W

Source: NEA

From Fig.3, we could know that the degree of PV development in China is according to the amendments of polices and the government support programs, each changes of policy always have great impact on PV development.

At the end of 2016, the China PV installed capacity was 77.42 GW, which was on the top of the world.

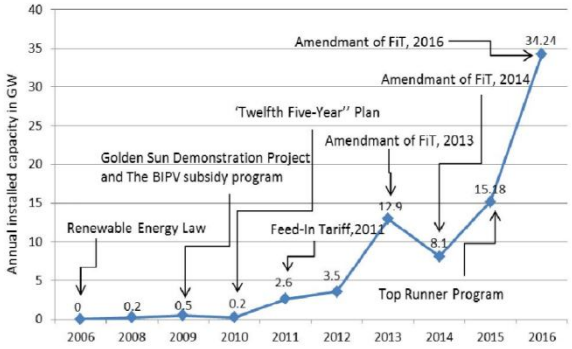


Fig.3 Development of China PV market, 2006–2016

CONCLUSION AND DISCUSSION

This paper examines the development history of China's PV industry policy. The development of PV in China has played an important role in the world. In the beginning, PV development in China was led by the PV products demand in Europe market. In 2009, China PV industry has experienced a chilling winter largely caused by the anti-dumping actions in the U.S. and Europe. Thus the policies were gradually transferring from supply-side policies to demand-side policies to expand domestic market. The government through legislation to compulsory subsidies and used other measures to protect the interests of photovoltaic power generation investor, achieve the goal of promote domestic PV market. With the progress of PV technology, the cost of PV power generation sustained decline, the government though policies amendments to adjust the subsidies in different period, the PV industry in China is gradually to market-oriented development. In this paper, we could know that:

Firstly, in first stage of PV development in China, the market plays a leading role. When the market changed, the guidance of state policy is the key to the rise and fall of an industry. The Chinese government through continuous reform and compilation the Feed-in tariff mechanism, and establish a policy system of Distributed Solar energy promoted the PV development rapidly.

Secondly, because the PV power generation technology was not mature, PV power generation costs is higher than traditional energy. The government should provide subsidy and program to promote the development of the PV industry. At the same time, the policy should support on R&D and gradually switching the emphasis to the market-oriented demand-side. For example, the PV Top Runner Program which was introduced in 2015 to give Chinese PV enterprise economic incentives to invest in new and innovative technologies. In addition, a number of financing schemes and tax rebates have been promoted the PV development. Those polices provides 8 years of feed-in tariff is the most powerful subsidy policy for the PV industry.

Finally, according to the analysis of reality condition of PV development in different period, the China government has been revised and amended the FiT policy in different development years, this policy strategy have ensured the PV development in China healthy and sustaining. For example, the government changed the FiT in 2013 and increased the FiT and made the PV installation scale reduced immediately in 2014.

This study may be could use for as inspiration for a continued research on the diffusion of PV development. Now, many countries in the world committed to increase the amount of renewables and transforming energy system. Achieving this goal in solar PV technology will require an effective, long-term and balanced policy effort in the next decade. Governments will need to provide long-term goals and support policies to build confidence in manufacturing capacity and deployment of investment in PV systems and increase R & D efforts, reduce costs, ensure rapid deployment of photovoltaic ready, but also support long-term technological innovation.

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