The Erratic Path of the Low-Carbon Transition in China: Evolution of Solar PV Policy

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HIGHLIGHTS

The concept of the socio-technical regime is applied to the study.
Four stages of China's solar PV policy are examined.
Factors causing policy shifts in policy priorities and policy instruments are identified
The erratic path of China's solar PV policy is explained.

Abstract

The last twenty years have seen a growth of both solar PV manufacturing capacity and the deployment of solar PV in China, yet this growth has followed a very erratic path. This study applies the concept of socio-technical regime to identify factors which have made this path so erratic. We examine four stages in the development of China's solar PV sector from the mid-1990s to 2013 and show that each is characterized by different combinations of policy program. These changes in government policy and in the resultant trajectory of the solar PV sector are attributed to three main sets of variables. The most important of these are events which shape the wider policy priorities of China's government. Secondary factors include the government's poor management of the policy interaction between the domestic solar PV manufacturing industry and the deployment of solar PV across the country, as

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well as policy learning within government. The general lesson from this study is that the development path of a single element of a national strategy for the low-carbon transition is likely to be erratic, subject as it is to a range of political and economic forces, and to experimentation and learning.

Keywords: Solar PV; China; Socio-technical regime; Low-carbon transition

1. Introduction

The low-carbon transition involves wide ranging changes of technologies and behaviors across many sectors. The adoption of specific low-carbon technologies forms one element of this transition. In a given society or country, the pace and trajectory of the low-carbon transition are likely to be erratic and unpredictable as they are shaped by a variety of political, economic, technological and social forces. These forces will affect not just the low-carbon transition as a whole, but will also play an important role in determining the development and deployment of individual low-carbon technologies.

Since the mid-1990s, particularly since the early 2000s, 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 (World Bank, 1996). By 2012, PV module manufacturing capacity and output in China had reached 37 GW and 22 GW, representing 37% and 54% of the world total respectively (SEMI, 2013). China's output of solar PV cells grew dramatically after 2004. Since 2007, China has become the biggest solar PV cell maker in the world and in 2011 and 2012 accounted for nearly 60% of global output (Fig. 1). But on the other hand, the cumulative installed capacity of solar PV in the country reached just 7 GW in 2012, accounting for 7% of the global total, having grown rapidly only since 2010 (Fig.2).

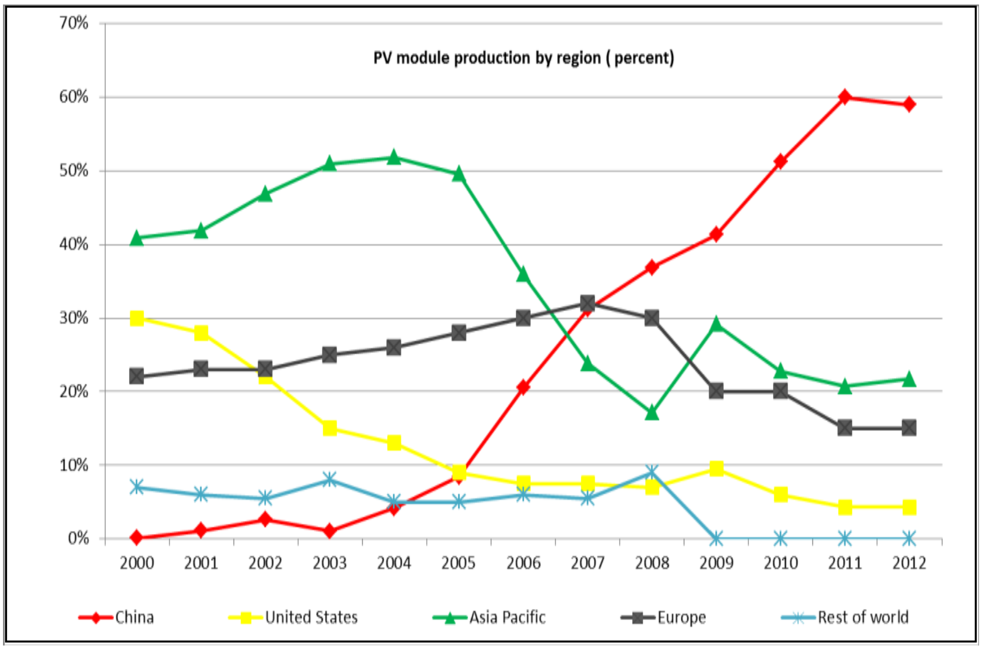

Fig. 1 Solar PV module production by region (%)

Source: EPIA, 2012.

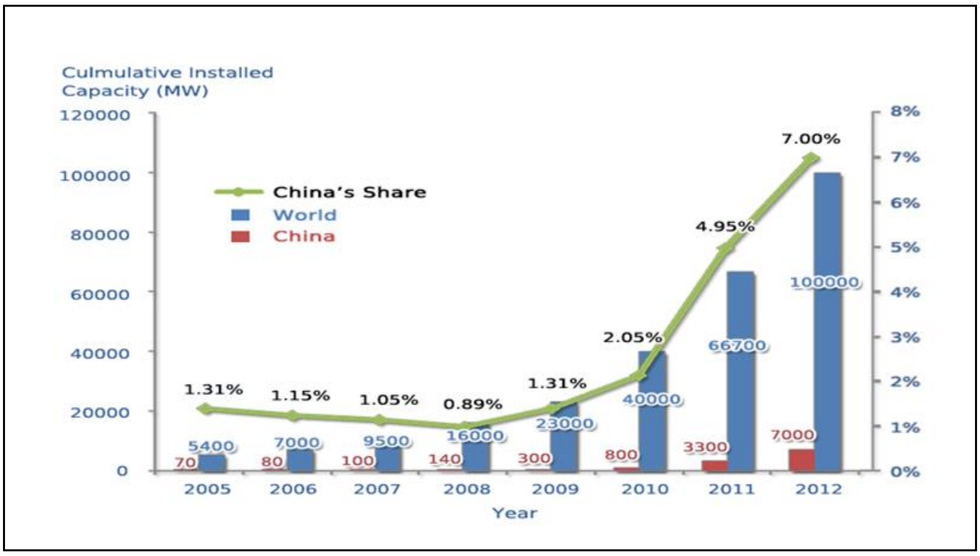

Fig. 2 China's share of cumulative installed capacity of solar PV during 2005-2012.

Source: Compiled by the authors based on SEMI, 2013; IEA, 2013 and REN21, 2013.

The startling achievements in terms of PV manufacturing and relatively modest development in terms of PV power deployment have not arisen from a single coherent policy program. Rather, China's solar PV policy has changed several times since the mid-1990s and these changes have been driven by a number of different forces, both from within and from outside China. Some have been directly related to energy, but many have not. Despite these policy changes, the overall trajectory of China's solar PV sector has been to support the low-carbon transition both within China and elsewhere. This study applies the concept of the socio-technical regime to show how a wide variety of factors have shaped the development and deployment of solar PV technology in China from the mid-1990s to the present day. The overall aim of the paper is to demonstrate how erratic and unpredictable just a single element in the transition to a low-carbon economy can be, due to it being subject to external events and policy priorities from other sectors.

Although a number of studies of China's solar PV policy have been published, most provide only a descriptive account or fail to span the full period from the 1990s to the present day (Zhang and He 2013; Lee, 2011; Li et al, 2013; Liu and Shiroyama, 2013; Liu and Goldstein, 2013; Liu et al., 2010; Liu et al., 2009; Lv et al., 2013; Zhao et al., 2011; Zhao, 2011). Distinct from previous accounts, this paper makes a contribution to the literature on China's solar PV sector from three directions. First, it applies the concept of the socio-technical regime to a specific renewable energy technology in order to illustrate and explain the erratic path of deployment of this technology. Second, it makes a comprehensive study spanning the full period from the 1990s to the present day. Third, it shows how China's latest solar PV policies put in place during 2013 hold the promise of providing an appropriate framework for sustained deployment of solar PV to support the country's low-carbon transition.

In this paper we identify four stages of solar PV policy in China from the mid-1990s to the present day: namely from the mid-1990s to 2003, from 2004 to 2008, from 2009 to 2011 and from 2012 onwards. Section 2 outlines the main features of a socio-technical regime and explains the relevance of the concept to this study. Sections 3-6 examine China's solar PV policy at each stage with the aim of identifying the forces which have shaped the overall policy priority for the sector and the nature of the policy tools deployed, and illustrating their effects on the PV manufacturing industry and on the deployment of solar PV, as well as some unintended consequences. The last section provides concluding remarks.

2. Socio-technical regimes and regime transition

The low carbon transition requires a change of socio-technical regime from a high-carbon energy regime to a low-carbon regime. Technology can determine behavior in society and societies can make choices concerning technology. A socio-technical regime comprises an assemblage of institutions which develop around a particular set of technologies, and which support the development and use of these technologies (Smith et al., 2005).

One important component of a socio-technical regime is the prevailing policy paradigm, which can be seen as a set of shared beliefs, values, ideas and principles relating to the world or to a particular sector. The prevailing paradigm determines the intellectual, political and organizational framework within which policy challenges are identified and addressed. Policy solutions in the form of agencies and instruments are formulated within the framework provided by the paradigm and such solutions are usually consistent with the paradigm (Hall, 1993; Mitchell, 2008; Kuzemko, 2013).

The main drivers of a change of socio-technical regime tend to come from outside the regime itself, from the wider environment or from what has been called the 'socio-technical landscape' (Geels and Schot, 2007). Such drivers may include gradual changes in social structure, in the macro-economy, in the physical environment, or in the price or availability of resources, or the emergence of new beliefs or new policy challenges. External shocks and crises can also trigger or accelerate a transition.

The manner in which a socio-technical regime reacts to these pressures depends not only on the nature and magnitude of the pressures but also on how they combine and on how readily the regime can adapt (Smith et al., 2005; Geels and Schot, 2007). Thus each country facing a broadly similar set of policy challenges, such as energy security and emissions abatement, is likely to take a distinct path in transforming its energy system. Of particular importance is how a government manages the interconnections and relative priorities between energy policy and other sector policies such as social, industrial and macro-economic policies.

Although technological change by itself may not be a primary driver of a socio-technical regime transition, technology plays a critical role in determining the pace and nature of regime change. Of particular relevance is the extent to which technological innovations are already available when the external pressures for regime change arise. If some appropriate new technologies are already available, then the speed of transition can be relatively rapid and the direction will be set by these available technologies. If appropriate technologies are not available when the pressures for change appear, then the duration of the transition is likely to be longer and the direction more uncertain (Geels and Schot, 2007).

All policy changes involve social learning. First order policy changes, such as adjusting the instruments of policy, and second order changes, such as introducing new instruments, require social learning mainly within the state itself. In contrast, third order policy changes, such as adopting of a new paradigm or a totally new set of goals and systems, require social learning across society. The constraining role of the prevailing institutions tend to prevent paradigm changes in the energy sector , and so most policy learning is expressed through first and second order policy changes (Hall, 1993).

As a consequence of these and other forces which shape a regime transition, the path towards a low-carbon economy will necessarily be erratic and unpredictable. Drawing on this understanding of socio-technical regimes and regime change, our analysis is directed at identifying those factors which shaped the erratic path of solar PV policy in China, focusing mainly on long-standing policy paradigms in China, on changing national policy priorities, on the role of external events, and on policy learning within the solar PV sector.

3. The first stage (mid-1990s to 2003): Renewable energy-based rural electrification

Although rural electrification has been a long-term priority for the Chinese government dating back to 1950 (Andrews-Speed, 2012), at the end of 1996 there were still more than 70 million rural people without electricity (CRED, 2000). Several options exist for rural electrification, such as extending existing grids, creating micro-grids, or installing isolated off-grid power generation systems (IEA, 2003).

Until mid-1990s, rural electrification programs in China had been dominated by fossil fuel-based grid extension programs (Pan et al., 2006). But the problem was that most people without electricity lived in northern and western provinces and were far removed from any electricity grids. To extend existing grids was technically challenging and financially unaffordable. However, these remote areas possessed abundant renewable energy resources such as wind and solar energy. As a result, the government decided to provide electricity to these areas by making use of renewable energy. Two programs were launched to support rural electrification during this period, namely the *Brightness Program* in 1996 and the *Township Electrification Program* in 2002.

3.1 The Brightness Program (1996)

The *Brightness Program* was the first national policy formulated by the Chinese government to bring electricity to remote areas of western China by means of renewable energy. This program was also a response to another 'Brightness Program', an international effort designed to bring electricity to rural areas and introduced during the 1996 World Solar Peak Conference in Zimbabwe (NREL, 2004). The Chinese program was formulated under the leadership of the State Development Planning Commission (SDPC), and its overall target was to use renewable energies like wind or solar to provide electricity to 23 million people in remote areas by 2010 (Bhattacharyya, 2012). In line with the *Brightness Program*, since the mid-1990s, electrification with renewable energy[①] in remote rural areas of western China has constituted part of the government's national development plan to promote renewable energy (Pan et al., 2006).

3.2 The Township Electrification Program (2002)

In 2000, the Chinese government adopted a long-term strategy, called the '*Western Development Strategy*', to support the development of western China. Improving electricity access, particularly in remote rural areas of western China, was an integrated part of the strategy. It was in this wider policy context that, in October 2001, rural electrification was specifically emphasized in the government's 10th Five-Year Plan (2001-2005) (Pan et al, 2006). In late 2002 the State Council authorized the *Township Electrification Program* which was part of the Brightness Program and which was fully financed by the Chinese government with 2,600 million CNY for the purpose of scaling up solar PV production and deployment (Shyu, 2010).

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① The term 'renewable energy' first appeared in the Chinese government's 9th Five-Year Plan (1996-2000).

By 2004, the Township Electrification program had been implemented in 1,013 non-electrified townships in remote rural areas of 11 western provinces, providing electricity for 1.3 million people. In the case of solar energy, 670 solar PV power stations and 51 solar PV/wind hybrid power stations with a total capacity of more than 15 MW were constructed in just 20 months in 8 western provinces. The solar PV power stations constructed under the program were all off-national grid, stand-alone and micro-grid systems (Shyu, 2012). A report by World Bank claimed that more than two million people in western China were receiving electricity through PV systems (Bhattacharyya, 2012). By 2002, only 1.2% of the total population lacked electricity access (Pan et al., 2006).

The high electrification rate in China demonstrated that the centralized public sector energy initiatives in China had performed effectively in terms of the production and distribution of electricity (Shyu, 2010). Behind the high electrification rate figure, however, the program at the local level had several implementation problems in terms of financial implications, human resources availability as well as many problems arising from limited experience, poor institutional capacity building, and the use of unsuitable materials. These factors prevented the program from assuring sustainable electricity supply and reliable electricity service (Shyu, 2012; IEA, 2003).

3.3 International cooperation projects

In addition to these domestic policy initiatives, the Chinese government also launched several international cooperation projects with organizations and foreign governments to improve electricity access by means of renewable energy in remote rural areas, which included the China-Japan New Energy and Development Technology Organization (NEDO) project, the China-Germany Financial Cooperation 'Western Solar Energy' Project, the China-Germany Technical Cooperation 'Rural Renewable Energy' Project, the China-World Bank-Global

Environmental Facility 'Rural Renewable Energy' Project, the China- Netherlands 'Lighting the Silk Road' Project, and the China-Canada 'Rural Electrification of Western China through Solar Energy—A Strategy for Eliminating the Global Climate Variation' Project. The total investment of these international cooperation projects was more than 800 million CNY (Shyu, 2010).

3.4 Initial development of China's solar PV industry and market

The national programs and the international cooperation projects stimulated the initial development of China's solar PV industry. The cumulative installed capacity of PV cells in China increased from 6.63 MWp in 1995 to 55 MWp in 2003 (Fig. 3), and domestic demand for PV systems expanded rapidly in the late 1990s (Lee, 2011). A wave of foreign solar cell companies (BP, Shell, Siemens Solar, Sharp, Sayo and SEC) arrived expecting a large volume of sales (Dunford et al., 2013). A new generation of Chinese PV firms such as Trina solar and Yingli were established and developed their experience (Besha et al., 2011). Nonetheless, the quality of Chinese solar PV products such as mono-crystalline solar cell and solar modules fell short of their counterparts in developed countries (Dunford, 2012).

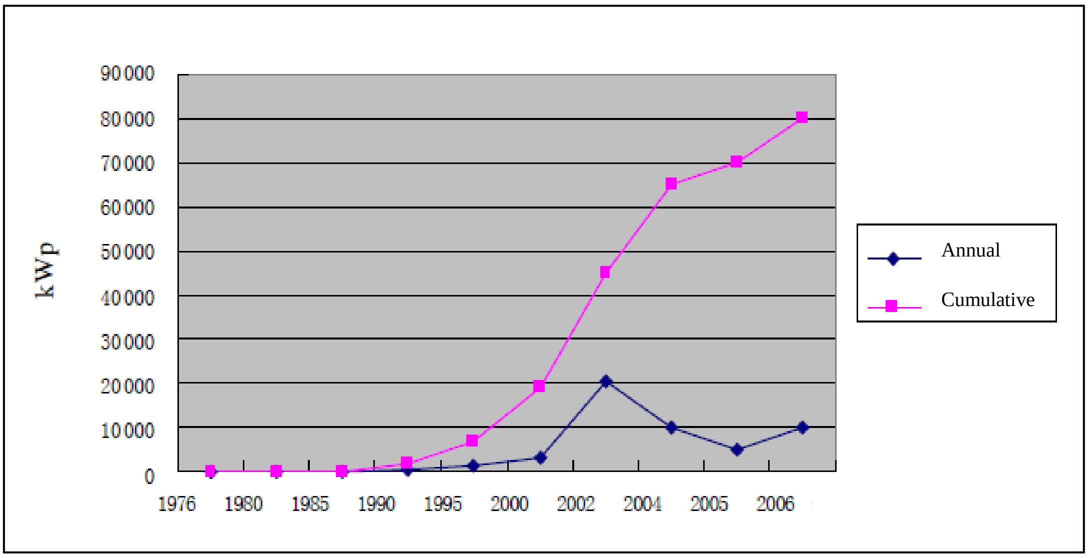

Fig. 3 The cumulative installed capacity of PV cells in China during 1976-2006

Source: Li and Wang, 2008

3.5 Discussion

The late 1990s saw a convergence of forces which could support the deployment of solar PV in China and across the world. Outside China, the most important of these were the steady reduction in cost of solar PV technology and the growing priority being placed on providing access to modern energy to the poor, as exemplified by the Millennium Development Goals.

China’s move to support the deployment of renewable energy at this time was also influenced by multi-lateral organizations such as the World Bank and the UNDP as well as by national government agencies from countries such as Canada, Germany and Japan seeking to promote their own specific technologies. The scale of support given to solar PV deployment by China’s government was greatly enhanced through the Western Development Strategy, a massive economic development program launched to address widening income disparities between coastal and inland provinces.

The policy instruments used to support the deployment of solar PV were consistent with the longstanding energy policy paradigm in China at that time in which the state was seen as playing a central role in the governance of the energy sector (Andrews-Speed, 2012). As a consequence, the deployment of solar PV to support rural electrification was promoted through the direct provision of government funds to state actors for them to implement the program. However, this approach failed to provide incentives for the maintenance of the equipment after it had been installed.

4. The second stage (2004-2008): Export-oriented growth

During the period 2004-2008, China’s solar PV policy shifted to an export-oriented growth stage. This was driven jointly by the explosive growth of global demand for solar PV starting in 2004 as well as by a number of domestic factors including the strong support for solar PV industry resulting from top leaders' recognition of the importance of emerging green technologies, and the poorly incentivized domestic market.

4.1 Explosive global PV demand

After the Kyoto Protocol was signed in 1997, many countries attempted to increase renewable energy generation through various incentive policies, particularly the feed-in tariff (FIT) scheme which guaranteed a relatively long-term fixed price for PV electricity, as applied in Germany for 20 years (Grau et al., 2012). This gave rise to the increase in demand for PV systems. Global PV demand was driven mainly by two countries: Germany and Spain (Fig.4 and Fig.5). In particular in 2004, German demand for PV soared to an annual growth rate of 294%. Due to the explosion of the German market, the global demand in 2004 doubled as it had done in 2003. Moreover, demand in Spain also accelerated due to its adoption of the FIT scheme, with installed capacity growth rates of 461% and 348% in 2007 and 2008 respectively (Lee, 2011).

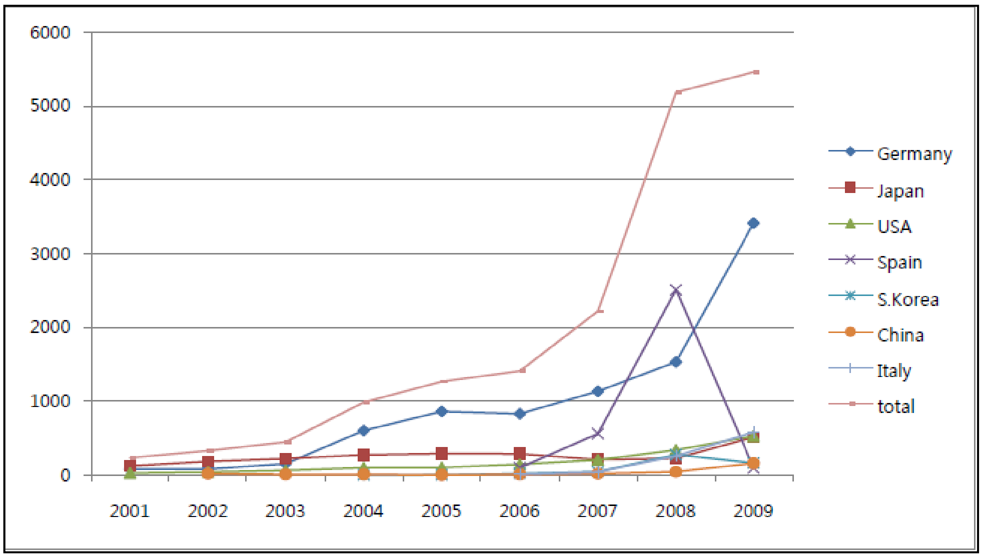

Fig. 4 Annual PV installed capacity of the top 7 countries during 2001-2009 (unit: MWp)
Source: Lee, 2011.

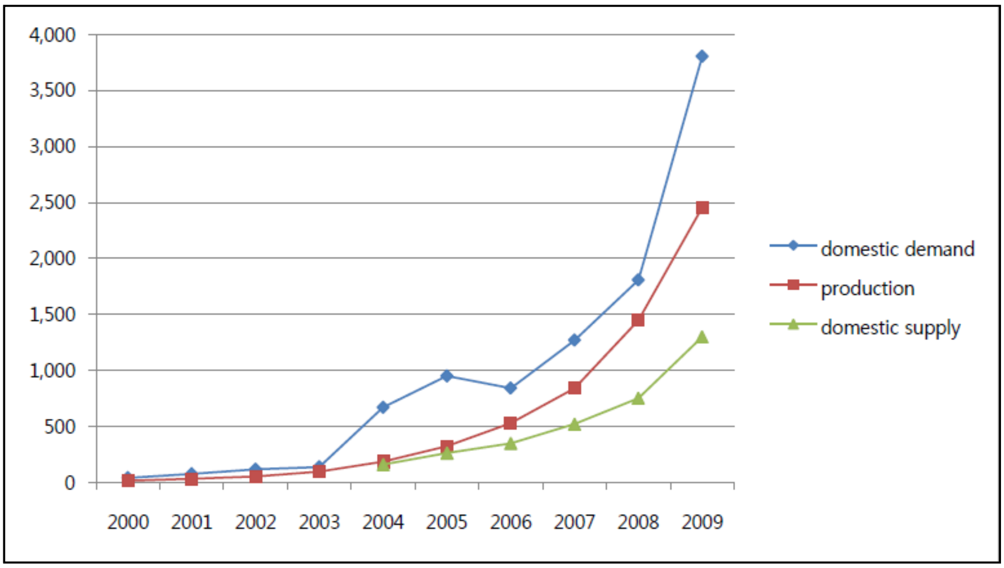

Fig. 5 PV demand and supply in Germany during 2000-2009 (unit: MWp)
Source: Lee, 2011.

4.2 Strong support for solar PV industry

China's central and local governments responded to this growing global demand by providing strong support for the solar PV industry. One of the reasons for the central government's support lay in the belief of China's policy makers since the early 2000's that China had an historic opportunity to position itself as an economic and technological leader in a global transition towards low-carbon energy and that those who moved fastest in the transition to a low carbon economy were likely to gain a significant competitive advantage. By investing in emerging green technologies, China could use its newcomer status in green industries and technologies to leapfrog current capabilities in the advanced countries (Zhang et al., 2013).

As a consequence of the central government prioritizing clean energy development, local governments had a strong incentive to facilitate the growth of local PV industries and granted them greater preferential treatment compared to other industries. Some local officials simply implemented national directives such as directives from the Ministry of Finance calling on local financial bureaus to raise and distribute green energy development funds. Other local governments saw clean energy as a prime growth opportunity and went well beyond national policy requirements in an attempt to turn their provinces into clean energy manufacturing hubs. For example, Jiangsu Province has particularly aggressive solar development policies (reference??).

In response to this governmental support and to the optimistic signals about future markets, many Chinese companies accelerated their investment in the industry. In order to achieve economies of scale[①] rapidly, they sought to raise funds quickly to expand their production. In this respect, China's central and local government provided great assistance. For example, the central government identified the PV industry as one of a number of key industries in the Catalogue of Chinese High-Technology Products for Export updated in 2006. As a result, PV manufacturers were eligible for additional financial support for research and development and received export credits at preferential rates from the Import-Export Bank of China, as well as export guarantees and insurance through the China Export and Credit Insurance Corporation (Solar Server, 2011). Access to such flexible capital has enabled Chinese PV companies to finance raise funds through overseas IPOs.

Suntech led the trend of raising funds through its IPO on the New York Stock Exchange (NYSE) in 2005, and other Chinese PV firms followed Suntech's example. In 2006, Trina Solar and Solarfun were listed on the NYSE and Nasdaq, respectively. In 2007, Yingli followed suit by joining the NYSE, while JA Solar and China Sunergy were listed on Nasdaq. As a consequence, the influx of a substantial amount of capital from foreign stock markets enabled the Chinese PV industry to expand its production capacity at an unprecedented rate. Thus, global financing paved the way for the Chinese PV industry to tap into a huge pool of

① In the National Renewable Energy Laboratory (NREL)'s analysis, raising the capacity of Chinese cell manufacturing plant from 60m MW to a 2,000 MW raises the cost advantage by 7.9%.

foreign capital and the leading PV firms in China were able to greatly expand their production scale (Fig. 6). As a result, China has become the world's largest PV manufacturers after 2008 (Fig.7).

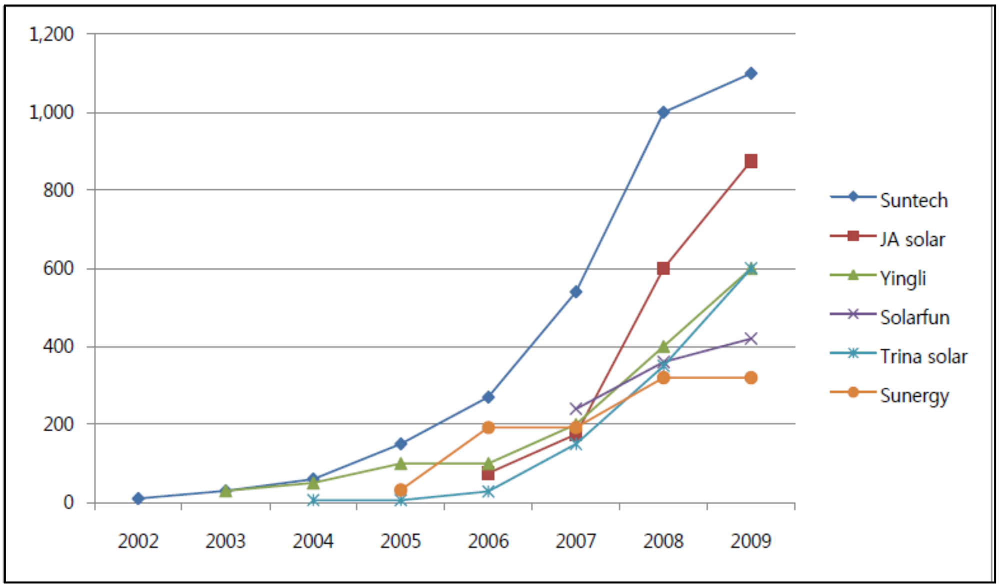

Fig. 6 Production capacity of the top 6 PV firms in China during 2002-2009 (unit: MWp)
Source: Lee, 2011.

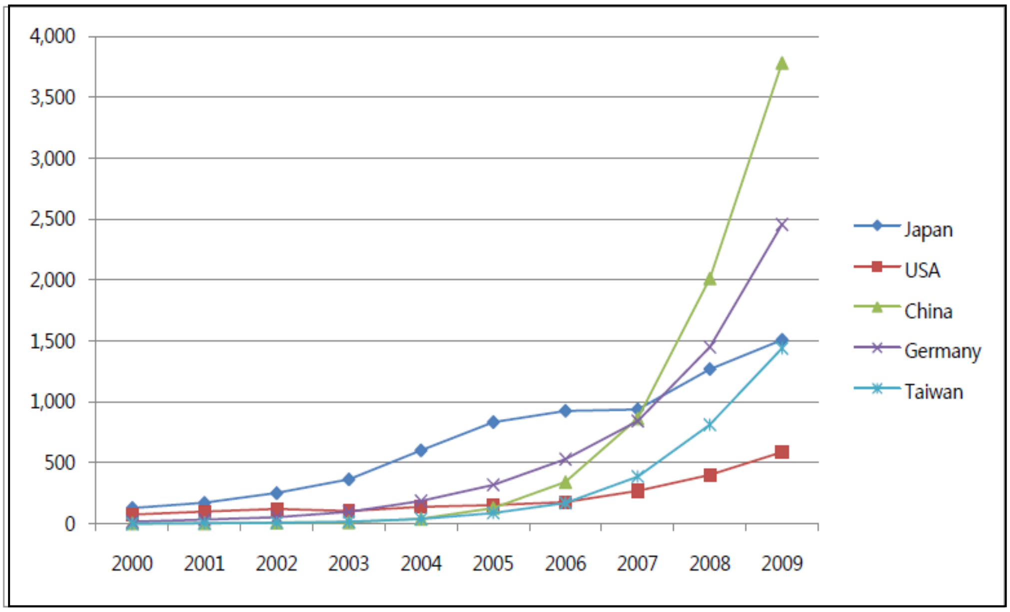

Fig. 7 PV production of the top 5 countries (unit: MWp)
Source: Lee, 2011.

4.3 Poorly incentivized domestic market

Although PV production increased rapidly in China in the 2000s, the domestic PV market still grew slowly due to lack of incentive policies. Since the promulgation of China's Renewable Energy Law in 2005, China had placed priority in the development of wind power rather than solar PV power for two reasons. First, a basic principle set by the Law in developing renewable energy was that the renewable technology should be economically reasonable. Second, the cost of wind power was much lower than solar PV energy.

Over the period of 2004-2008, China's incremental annual installed capacity of solar PV was no more than 40 MW and by 2008, its cumulative installed PV capacity was only 300 MW, accounting for merely 1.31% of the world total (Fig. 2 and Fig. 8). This meant that almost all of China's PV modules were being exported. The country's exports of solar PV components had increased sharply after 2006 (Fig. 9). The European market played a substantial role in the growth of the Chinese industry in the 2000s, accounting for around 80% of PV exports in China at this time (Cao and Groba, 2013).

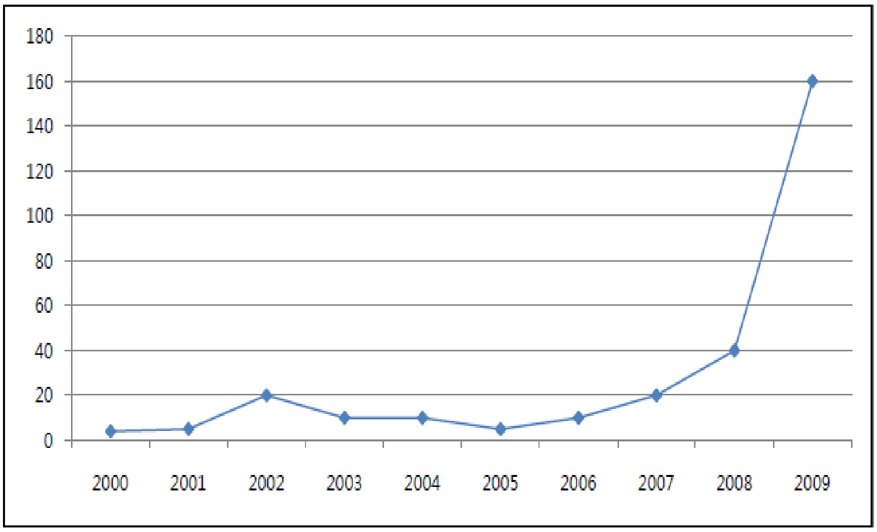

Fig. 8 Annual PV installed in China in the 2000s (unit: MW)
Source: Lee, 2011

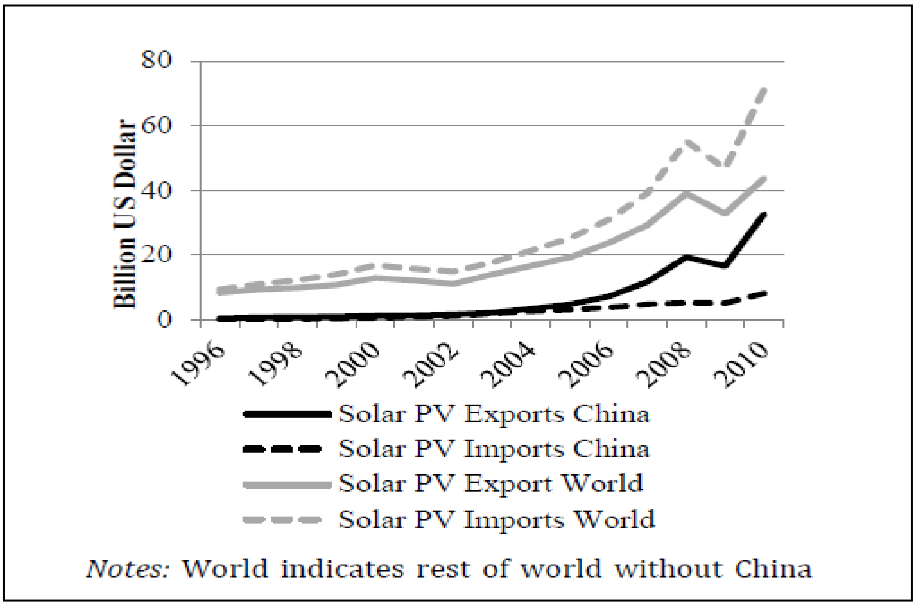

Fig. 9 Exports and imports of solar PV components: China and the World
Source: Dunford et al., 2012.

4.4 Discussion

During the period 2004-2008, a convergence of external trends and Chinese domestic policy priorities assisted the low carbon transition by enhancing the deployment of solar PV in many countries around the world, but not in China itself. One of the priorities of the new government which took power in 2003 was to boost the economy after four years of relatively slow growth following the Asian Financial Crisis. At the same time, there was a realization that China’s long-term economic future depended on developing indigenous high technology industries. The soaring demand for solar PV panels in the West in response to the challenge of climate change provided the country with an opportunity to combine low capital and labor costs with technological skill to build an industry which came to dominate the global market. As in the previous phase, the government provided the solar PV industry with direct support, in line with the prevailing state-led policy paradigm. The export-oriented strategy for the solar PV industry was assisted, as in other sectors, by China’s accession in 2001 to the World Trade Organization (Cao and Groba, 2013). This strategy led to a massive increase in production capacity and output of solar PV products in China, as well as steady improvement in quality, and to a rapid decline of prices. This, in turn, assisted the deployment of solar PV around the world, albeit at the expense of manufactures in developed economies.

The deployment of solar PV within China itself was slow in absolute terms and relative to wind power, despite the passing of the Renewable Energy Law in 2005. The reason for this was that the Law specified that the renewable energy technology must be ‘economically reasonable’. Although financial incentives were provided for wind power as early as 2006, equivalent support was not available for the deployment of solar PV until 2009 as the cost of such support was seen as too high.

5. The third stage (2009-2011): Growing industry support plus market support

When the global financial crisis took place in 2008, both China’s real economy and China’s PV industry were severely and adversely impacted. In early 2009, China’s exports dropped sharply. In response to this, the government announced a mix of macroeconomic and industrial policies. Chinese officials believe that the country’s political stability is highly dependent on continued economic growth. Chinese policy makers were therefore aggressive in stimulating domestic demand as a means to offset the effects of the financial crisis. On the one hand, both China’s central and local government increased the level of direct industry support and, on the other hand, various policies aimed at stimulating domestic demand for PV were put in place.

5.1 Growing industry support

The most important macroeconomic policy response to the financial crisis was the stimulus package of 4 trillion CNY for 2009-2010 announced in November 2008, designed to stimulate domestic demand through enhancing public expenditure. The main industrial policy response was the announcement of seven strategic emerging industries. On 10th October 2010, the government unveiled the *Decision of the State Council on Accelerating the Fostering and Development of Strategic Emerging Industries*. This identified seven industries as strategic emerging sectors: energy saving and environmental protection, new-generation information technology, biotechnology, high-end equipment manufacturing, new energy, new materials, and new-energy vehicles (State Council, 2010). It was logical for the government to make energy saving and environmental protection a top priority as rapid industrialization and urbanization in previous years had consumed a large amount of energy and had had an adverse impact on China's environment.

The China Development Bank (CDB), a policy bank, participated in making the plan for *National Strategic Emerging Industries* in 2009, and was responsible for implementing *The Guide for Developing Solar PV*. In just two years, the CDB gave 250 billion CNY extension credits to the PV industry and opened a line of credit of about US$30 billion for Chinese solar cell and module manufacturers. (Grau et al., 2012).

In 2009, some Chinese local governments issued various refund policies which were supported by their tax revenues to promote new plant investment in PV industry. In Huai'an City, Jiangsu Province, for example, its refund covered refunds of loan interest, of VAT payments, of corporate income tax, of land transfer fees, and of electricity tariffs (Grau et al., 2012).

As a consequence, from 2009 to 2011 the production of PV cell, wafer and polysilicon in China increased 8.3 times, 10 times and 17.89 times respectively (Lv et al., 2013). Over the same period, China's share of PV cell output in the world grew from 31.96% to 60% (Lv et al., 2013). This has led to progressive overcapacity in China's solar PV manufacturing industry. The situation worsened after the USA and the EU filed anti-dumping and countervailing cases against Chinese solar panel producers as will be discussed below.

5.2 Market support

The economic recession following the 2008 financial crisis caused a slump in demand for solar PV cells in OECD countries, which in turn greatly impact China's heavily export-oriented solar PV industry. Recognizing that it was important to address the mismatch between China's solar PV production capacity and domestic use, in early 2009 the government started to shift its solar PV policy toward the domestic market. This was consistent with the principle of economic development that required China to change its economic model from export-led growth toward greater reliance on domestic demand, particularly household consumption.

Between 2009 and 2011, the government launched two national solar subsidy programs: the Rooftop Subsidy Program and the Golden Sun Program, both of which were supported by the Renewable Energy Development Fund, with two rounds of concession program and a nationwide FIT scheme, in order to encourage investment in solar PV power projects to accelerate the demand for domestic PV products.

5.2.1 Two subsidy programs

The first solar subsidy program, the Rooftop Subsidy Program was announced jointly by the Ministry of Finance and the Ministry of Housing and Urban-Rural Development of China (MOHURD) in March 2009. The program provided upfront subsidy of CNY 15/W for rooftop systems and CNY 20/W for building-integrated PV (BIPV) systems, and a subsidy of 50% of the bid price for the supply of critical components. The program required that the scale of a solar PV project be no less than 50 kW.

In July 2009, the second subsidy program, the Golden Sun Demonstration Program was jointly initiated by the Ministry of Finance, the Ministry of Science and Technology (MOST) and the National Energy Administration (NEA) of the National Development and Reform Commission (NDRC). The program provided a 50% upfront subsidy on the investment cost for grid-connected systems and a 70% upfront subsidy for off-grid PV systems over the period of 2009-2011, and set a cap of 20 MW for each province, which also included installations under the BIPV subsidy scheme. The program emphasized the on-site consumption of PV electricity. Excess electricity would be sold to the utility at the local benchmark coal-fired grid price. The program showed that the government wanted to take cautious steps and to gain experience from these demonstration projects. As of 2012, the total installed capacity approved and actually constructed under the Golden Sun Program amounted to 5930.4 MWp and 3044.06 MWp respectively. (Li et al., 2013).

Despite its achievements, the Golden Sun Program came under heavy criticism from China's PV industry for its flaws. This includes the lack of criterion for project approval, the failure of the one-off upfront payment of the subsidies to provide incentives for the companies to build high-performance systems, severe fraud and abuse of subsidy funds arising from the lack of oversight of project implementation①, and delays in the payment of subsidies (Yu, 2013). Due to these deficiencies the government sought to replace the one-time capacity-based subsidies with generation-based subsidies, as will be discussed below.

5.2.2 Two rounds of concession program

In addition to the two subsidy programs, the government also initiated two rounds of solar PV concession programs for large scale PV (LSPV②). This has great potential in China, especially in northwest China, such as Qinghai, Ningxia,

① A report released by China's National Audit Office in June 2013 shows that 7 solar PV projects deceived a total of 207 million CNY (about US$ 34 million) of the Golden Sun subsidy (Yu, 2013). Companies use tactics such as exaggerating the capacity of the projects proposed to varied degrees in order to generate more subsidy than is actually needed, winning subsidies for nonexistent projects conjured up on false contracts and related documents, to swindle Golden Sun subsidies.

② In this paper, LSPV, utility scale PV and ground mounted PV are synonyms and are used interchangeably.

Gansu, Tibet, and Xinjiang, where solar resources are abundant and the annual full running hours of PV plants reach over 1500 hours (Liu and Shiroyama, 2013). The first round of concession program for the 10 MW LSPV station project in Dunhuang city, Gansu Province, was initiated by the NEA during the period March to June 2009. The winning bid for the project was CNY 1.0928/kWh. In June 2010, the second round of the concession program for LSPV station was launched, which included 13 projects with a total capacity of 280 MW. The winning bids were between CNY 0.7288-0.9791/kWh (IEA, 2012), leading to a 'less than CNY 1' era. Under these programs, the successful bidders were required to complete their construction in 24 months and would have an exclusive right to operate the plant for 25 years.

These concession programs were significant in that they not only promoted China's installed capacity of solar PV power but also helped to drive down the on-grid price of solar PV power in the country. In addition, these programs provided the NDRC−China's pricing regulator with some pricing guidance (albeit imperfect given the distortion because of surprisingly low bid of some state-owned companies in order to secure market share in this new industry) in moving forward to tariff setting in other solar projects. Indeed, to some extent these programs contributed to the reduction of on-grid price of solar PV power from CNY 4 per kWh in 2008 to CNY 1 per kWh or less in 2010. This helped the NDRC to determine the nationwide feed-in-tariffs (FITs) in 2011.

5.2.3 First nationwide FIT scheme

In July 2011, the NDRC announced its first nationwide FIT scheme for solar PV power which was warmly received by project developers and project lenders. According to the FIT scheme defined by the *Notice on Perfection of Policy Regarding Feed-in Tariff for Solar PV Generation*: (1) Projects approved prior to July 1, 2011, which have completed construction and have achieved commercial operation prior to December 31, 2011, were entitled to a tariff of CNY 1.15/kWh; (2) Projects approved after July 1, 2011 or approved prior to that date but could not be completed before the end of 2011 were entitled to a tariff of CNY 1/kWh. Exceptions were granted to projects located in Tibet, which, under certain circumstances could still receive a FIT of CNY 1.15; (3) Bid tariffs would continue to apply to grid-connected solar PV projects through the concession bidding procedure. Bid tariffs should not exceed national solar PV benchmark on-grid tariff; (4) Local desulfurized coal-fired benchmark on-grid tariffs would continue to be on-grid tariff of solar PV projects under the two subsidy programs (NDRC, 2011).

However, it is apparent that this FIT scheme failed to take into account the variability of solar resources. Solar energy resources are unevenly distributed in China, with the west having more hours of sunshine than the east of the country. In the nine western provinces, the average quantity of yearly radiation is 5519.46 MJ/m2 while in the 17 eastern provinces, that amount is only 4836.23 MJ/m2 (HIL International Lawyers & Advisers, 2011). As a result, the uniform feed-in tariff led to a severe divergence of profitability between western and eastern regions.

Despite these deficiencies, these government incentive programs have created a surge in China's PV market and have helped to overcome the aftermath of the financial crisis for China's PV manufacturing companies. China's cumulative installed PV capacity grew from 300 MW in 2009 to 33 000 MW in 2011 (SEMI, 2013). Yet, at this time China's PV market remained immature and was still considered by the government to be in an experimental stage, with projects being still for demonstration purposes.

5.3 Discussion

The main trigger for a change in China's solar PV policy was the global financial crisis of 2008. This led to a dramatic decline in the demand for solar PV products around the world which threatened not only the viability of China's manufacturers but also an element of the government's economic strategy. In response to the financial crisis, the government launched a 4 trillion CNY stimulus package which included strong support for emerging strategic industries, of which solar PV was one. The combination of industrial and energy policy achieved short-term success in rescuing the PV manufacturing companies, further enhancing production capacity, and accelerating the deployment of solar PV in China, but it had unfortunate side-effects. The manufacturing industry was soon suffering from massive overcapacity and high levels of debt, despite growing deployment within China and attempts to sustain exports. At the same time the inappropriate design of the Golden Sun Program caused significant distortions in the solar energy market. This short-term 'fix' supported by plentiful government funding created a new set of problems to be addressed during a period of changing government.

6. The fourth stage (2012 onwards): Strong support for distributed solar PV power (DPV) and resources-based categorized FIT

The massive, government-supported investment boom between 2009 and 2011 resulted in even greater overcapacity of solar panel manufacturing by 2012, by which time Chinese production capacity of solar panels had reached 55 GW, representing around 150% of annual global consumption. Excess Chinese production capacity was around 27 GW or some 90% of global demand in 2012 (EC, 2013). The ensuing decline of prices caused some US and EU solar PV manufacturers go bankrupt. This triggered the 'antidumping' and 'anti-subsidy' investigations by the USA and the EU which, in turn, have had an adverse impact on China's solar PV industry. It is in this context that, from September 2012 to August 2013, the Chinese government promulgated intensively a series of policies to provide stronger support for distributed solar PV (DPV) power, adjusted the capacity-based subsidies, and introduced a resource-based FIT scheme.

6.1 Rationale for supporting DPV power?

China's solar PV industry which has seen its profit margins squeezed by significant overcapacity, has suffered greatly following trade disputes with the USA and the EU. In 2012, solar exports to the U.S. and European markets dropped by 35% year-on-year. In late 2012 and through early 2013, there were several signs that the market was still struggling. In March 2013, for example, Suntech Power, China's biggest solar panel manufacturing firm, announced that it had defaulted on its debt, failing to pay USD 541 million worth of bonds that were due. The announcement came after Suntech reported four consecutive quarters of losses in 2012 (China Greentech Initiative, 2013).

This crisis in the solar PV industry persuaded the Chinese government to step up support measures to reshape the oversupplied sector and reorient it towards the under-tapped domestic market. To address this challenge the government introduced two innovative sets of policies. The first was to boost DPV generation and the second was to categorize FITs according to the available solar resource.

Over the past few years of stimulating the domestic market, the government's perception had been that remote large-scale (LSPV) power plants should be the centerpiece of the country's solar energy policy. As such, priority had been placed on the construction of LSPV power plants, particularly in northwest China, the richest region of solar resources in the country, and LSPV power stations accordingly became the dominant role of PV application in China since 2009. In January 2012, however, China's *12th Five-Year Plan for Renewable Energy*

*Developmen*t issued by the State Council stated that the development strategy of solar PV power would shift to 'align the development of LSPV with DPV', meaning to place equal emphasis on LSPV and DPV. This was later reflected in China's *12th Five-Year Plan for Solar Energy Development* (NEA, 2012a) released by the NEA in July 2012, which set the cumulative installed capacity target at 21 GW[①] by 2015, comprising 10 GW of LSPV and DPV and 1 GW of concentrated solar power. This Plan was then supported by the introduction of new instruments to promote DPV and of a resource-based FIT.

This shift in China's development strategy of solar PV showed that the government has learnt lessons from its wind power development experience. China's wind power resources are largely concentrated in China's northern, northwestern and northeastern regions, but the main power demand comes from along the eastern coastal region. Due to their many resource advantages, large-scale wind power installations in China's north have been the main focus of wind power development. However, grid connectivity and curtailment problems have posed the biggest challenges to the development of the wind power sector since 2009. The mismatch between the geographic distribution of wind power resources and power consumption is at the heart of grid connectivity and curtailment problems. It is evident that this provides a very good lesson for China's solar PV development. In addition, the success story of distributed solar PV power in developed countries such as Germany and Denmark also provides useful experience for China.

6.2 Favorable policies for DPV power

Between January 2012 and August 2013, a series of favorable policies for DPV development has been put in place by the State Council, the NDRC, the NEA

[①] This target has been revised upwards to 35 GW by 2015 by the State Council, with annual increase of about 10 GW during 2013-2015 (State Council, 2013).

and the State Grid (Table 1). In September 2012, the NEA released a notice on scaling up demonstration zones for DPV power (NEA, 2012b), which invited each Chinese province to apply for no more than 3 demonstration zones with a maximum installed capacity of 500 MW and stated that priority would be given to the eastern and central regions of the country where local electricity demand is high.

Table 1 Favorable policies for DPV issued between during January 2012 and August 2013

Issuing date	Issuing agency	Document title
January 2012	State Council	12th Five Year Plan for Renewable Energy Development
July 2012	NEA	12th Five Year Plan for Solar Energy Development
September 2012	NEA	Notice on Application for Scaling Up Demonstration Zones for Distributed Solar Power
November 2012	State Grid	Opinions on Providing Good Services to the Grid Connection of Distributed PV Power Generation (Provisional)
July 2013	State Council	Opinions on Promoting the Healthy Development of Photovoltaic Industry
August 2013	NDRC	Notice on Promoting the Healthy Development of Solar PV Industry through Price Leverage
August 2013	NEA	Notice on the Construction of Scaling Up Demonstration Zones for Distributed Solar Power
August 2013	NDRC	Provisional Management Measures for Distributed Power

Ambitions to increase China's solar PV power have long been tempered by onerous grid connection procedures, largely a result of the State Grid's reluctance to assume its due responsibility and simplify the process. But the NEA's move required substantial cooperation from the grid and, in October 2012, the State Grid announced a plan to allow small-scale DPV generators to connect to its power lines. Under the plan, the State Grid would allow solar power generators with less than 6 MW of installed capacity to be connected to the grid. The State Grid would also provide technical assistance and waive some charges associated with connecting to the grid (State Grid, 2012). The NDRC also waived the requirement for DPV power projects to gain approval, regardless of their size. The project developers now only need to notify the NDRC, significantly cutting the time and paperwork for households and small businesses interested in solar PV. These moves contributed to the increase of DPV installed capacity in 2012 when the cumulative installed capacity increased by 608.5 MW to 3775 MW in 2012, of which 2372.49 MW were the cumulative capacity under the Golden Sun Program in 2012, while the installed capacity of LSPV remained at 2 GW (Li et al., 2013).

Since the EU's decision in June 2013 to impose hefty provisional anti-dumping tariffs on solar panel imports from China, the Chinese government has issued a stream of directives and policies to boost the country's solar PV industry. On 14th June 2013, the executive meeting of China's State Council agreed to give support to the then-deeply troubled industry and announced six measures, which included further expansion of DPV, a guarantee of full-price purchase of all PV-generated electricity, the setting of feed-in tariffs based on nationwide zoning, and the expansion of funds for renewable energy development (Xinhua, 2013).

On 24th July 2013, the State Council set the development goal for the development of the industry in its *Opinions on Encouraging the Healthy Development of the Solar Photovoltaic Industry* (State Council, 2013). On 20th August, the NEA announced a plan to build 18 solar PV distributed power generation demonstration zones across the country. These demonstration zones, to be fully completed by 2015, will have a total installed capacity of 1.823 GW, among which 749 MW will be completed in 2013 (NEA, 2013).

On 30th August 2013, the NDRC announced new subsidy policies to boost the country's solar PV industry. According to the NDRC's plan, DPV projects will receive a CNY 0.42/kWh (taxes included) subsidy for all generation, to be provided by China's Renewable Energy Development Fund. DPV generation for self-production and self-consumption is exempted from electricity surcharges, system reserve charges and other grid-connection service charges. For surplus generation connected to the grid, the purchase price paid by the grid enterprises is to be the same as local benchmark on-grid prices of coal-fired units. The subsidy will be pre-appropriated to local grid companies by the state revenue seasonally, and the grid companies will repay the subsidy fund on a monthly basis, making sure that the subsidy is in place in time and at full amount (NDRC, 2013).

6.3 Resources-based categorized FIT scheme

In addition to policies favoring DPV, the government has also adjusted the FIT scheme to support ground-based PV power stations. The NDRC's announcement on 30th August 2013 stated that ground-based PV power stations will receive a FIT of CNY 0.9/kWh, 0.95/kWh, or 1/kWh, depending on the local solar resources. The standards, scheduled to last 20 years, apply to all PV power stations registered after 1st September 2013. Power stations that were registered before the date, but that will only start power generation after 1st January 2014, are also eligible for the subsidies. Excluded from the new subsidies are distributed PV projects that directly receive an investment allowance from the government budget (NDRC, 2013).

6.4 Discussion

This final and current phase of the evolution of the solar PV industry in China reflects a combination of events and policy learning. The main external events were the trade disputes brought by the US and EU in 2012. These just preceded the transition to a new government in China which concluded in March 2013. Structural reform of the economy ranks high on the agenda of the new government and maintaining a massively indebted and over-sized industry was not consistent with this strategy, however technologically advanced it was. Whilst the trade disputes alone would not have triggered the restructuring of China's solar PV industry, they probably acted to provide a sense of urgency to the task of rectifying the solar PV industry. In line with the paradigm of state-led industrial policy, this restructuring is being driven by direct government intervention and is not being left to the market.

The policies to support PV deployment have been revamped in a way which indicates significant policy learning from the deficiencies of earlier schemes. For the first time, the new support framework appears to have been carefully designed to provide a more appropriate range of incentives for distributed as well as grid-connected deployment. As a result, China is soon expected to surpass Germany in terms of scale of deployment of solar PV. Nevertheless, a few policy defects exist. For example, the current DPV policy does not differentiate installation types or consumer types, which is not favorable for encouraging those large roof-top owners who have large electricity demand to install DPV system. In addition, China faces a number of challenges in implementing the DPV policy, such as those relating to legislation and regulation, technology and finance.

7. Concluding remarks

The deployment of renewable energy technology forms an important element of national strategies for the low-carbon transition in many countries. In this paper we have shown that the development path of China's solar PV sector over the last two decades has reflected great advances but has been very erratic.

Through the application of ideas related to the concept of socio-technical regimes, this study has identified some of the key factors that have determined the nature of this development path. First, various forces from both within and outside the energy sector, both internal and external to China, have shaped the development and deployment of solar PV technology in China since the mid-1990s. These forces include national policies to support, successively, rural electrification, the Western Development Strategy, and a clean energy manufacturing industry, as well as external events such as the explosion of global demand for solar PV, the 2008 financial crisis, and trade disputes with the USA and the EU, among others.

Secondly, the poor management of interactions between renewable energy policy and renewable industrial policy has had an important impact on the development of China's PV sector (see also Zhang et al., 2013). The massive overcapacity in the industry has largely been driven by the government's over-zealous pursuit of industrial growth while neglecting to foster domestic PV demand. This is reflected not only in the export-oriented growth stage but also in the earlier stage of supporting both industrial growth and the domestic PV market support stage, when the subsidy for solar PV deployment was based on capital investment rather than on energy generation. These policy approaches reflect the nature of long-standing policy paradigms for industrial and energy policy.

Thirdly, the evolution of China's solar PV sector involved policy learning, which is evidenced by the government's adjustment of the solar PV policy instruments in recent years. When the government became aware of the defects of capacity-based subsidies and of the first FIT policy implemented, it adjusted the policies to generation-based subsidy and resources-based categorized FIT respectively so as to promote the domestic market more effectively. The shift of solar PV policy to boost DPV power in the fourth stage demonstrates that the government has learned lesson from the wind power development in the country and from the experience of other countries.

The general lesson for this study is that the development path of a single element of a national strategy for the low-carbon transition is likely to be erratic, subject as it is to a range of political and economic forces, and to experimentation and policy learning. As a consequence, the long-term outlook for a specific national policy program for low-carbon energy cannot usefully be judged across short time period, for timely intervention can probably be successful at bringing an apparently failing policy program back on track, albeit with some delay.

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