Interactions between renewable energy policy and renewable energy industrial policy: A critical analysis of China's policy approach to renewable energies

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Abstract

This paper analyzes China's policy approach to renewable energies and assesses how effectively China has met the ideal of appropriate interactions between renewable energy policy and renewable energy industrial policy. First we briefly discuss the interactions between these two policies. Then we outline China's key renewable energy and renewable industrial policies and find that China's government has well recognized the need for this policy interaction. After that, we study the achievements and problems in China's wind and solar PV sector during 2005-2012 and argue that China's policy approach to renewable energies has placed priority first on developing a renewable energy manufacturing industry and only second on renewable energy itself, and it has not effectively met the ideal of appropriate interactions between renewable energy policy and renewable energy industrial policy. Lastly, we make an in-depth analysis of the three ideas underlying this policy approach, that is, the green development idea, the low-carbon leadership idea and indigenous innovation idea. We conclude that Chinas policy approach to renewable energies needs to enhance the interactions between renewable energy policy and renewable energy industrial policy. The paper contributes to a deeper understanding of China's policy strategy towards renewable energies.

Keywords

Renewable energy

China

Policy interaction

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1. Introduction

Along with its rapid economic growth in the past three decades, China has successively become the largest carbon emitter in the world since 2007 and the largest energy consumer since 2009 (Chen, 2013). On the other hand, as a developing country, China has a long way to go in its industrialization, urbanization and modernization. To advance further toward these development objectives, China has been striving for rational growth of energy demand through closures of outdated production facilities and the use of energy efficient equipment and clean energy, among others. However, since China's energy mix is dominated by coal which accounted for 66.2% of its primary energy consumption in 2012 (NREC, 2013) and cannot be substantially changed in the near future, the control of carbon emissions will be rather difficult. As such, how to achieve a trade-off between short term economic growth and long term sustainable development becomes a great challenge to the country.

Since the beginning of this century, China has looked to address the challenge by making greater efforts to develop renewable energies, particularly wind and solar PV energy, and remarkable achievements have been made in these two sectors. To date, China has emerged as the largest wind power market in the world, both in terms of manufacturing and installed capacity. At the end of 2012, the cumulative installed capacity of wind power in the country reached 75,324 MW, representing 26.7% of the world total. At the end of 2011, China hosted four of the global top ten wind turbine manufacturers (GWEC, 2013). Yet China's rapid growth of wind power industry has run far ahead of the power grid development scheme and the mechanism reform suitable for renewable energy deployment, which results in industrial overcapacity, immense grid connection problems and ever-growing amounts of curtailed wind generation in recent years.

Compared to its wind power market, China's domestic solar PV market has been rather small. However, its solar PV manufacturing industry has grown dramatically since 2004, currently taking the first position in the world in terms of production scale, which is due to incentivizing industrial policies provided by the Chinese government as well as to overseas market demand simulated by governments like Germany and other European countries. Yet, in recent years the industry has been facing challenges such as industrial overcapacity and financial losses resulting from shrinking overseas markets.

These lines of evidence show that there are two distinctive development features in China's wind and solar PV power sectors: on the one hand China has emerged as a manufacturing leader in the world in these two sectors, on the other hand industrial overcapacity and under-deployment of wind and solar power have occurred. Our premise is that this stems partially from China's policy approach to renewable energies, which has not led to appropriate interactions between China's renewable energy policy and renewable energy industrial policy. The aim of the paper is to analyze China's policy approach to renewable energies and assess how China's renewable energy policy and renewable energy industrial policy have interacted.

To this end, the rest of the paper proceeds as follows: we first discuss the analytical approach and theoretical groundings upon which the interactions between renewable energy policy and renewable energy industrial policy are built in Section 2; Section 3 outlines the key renewable energy and renewable industrial policies in China; Section 4 examines the major achievements and problems in China's wind and solar PV sector over the period of 2005-2012, to illustrate China's policy approach to renewable energies. In Section 5, we make an in-depth analysis of the ideas underlying China's policy approach to renewable energies. Section 6 provides concluding remarks. This paper contributes to a deeper understanding of China's strategy towards renewable energies.

2. Interactions between renewable energy policy and renewable energy industrial policy

To date, there is no uniform definition of either renewable energy policy or industrial policy for renewable energy in the world. Indeed, these two policies have been more often used interchangeably. In this paper, we define renewable energy policy as policy aimed at promoting the development and deployment of renewable energy, which provides a sustainable and stable domestic renewable energy market, while renewable energy industrial policy is defined as policy aimed at enhancing the competitiveness and capability of renewable manufacturing industry.

Self-evidently there is a natural affinity between these two policies. As depicted in Fig.1, the improved competitiveness and capabilities of the manufacturers of renewable equipment, components and parts result in price reduction for wind turbines that leads in turn to lower costs for the installation and generation of wind power. At the same time, the development, generation and consumption of wind power are conducive to enhancing the manufacturing competitiveness and capability of wind turbines by providing a sustainable and stable domestic renewable energy market. This provides signals to both local manufacturers and to foreign firms that they have the long-term planning horizon necessary to allow them to reasonably invest in the market and may be a pre-requisite to attracting leading foreign manufacturers to establish local manufacturing facilities or to develop local joint venture partnerships (Lewis and Wiser, 2007). Companies facing unstable or small renewable energy markets, on the other hand, will be less willing to spend money on

R&D, product development, and local manufacturing facilities. It is apparent that appropriate interactions between renewable energy and industrial policy for renewable energy enhance both renewable energy manufacturing industry and renewable energy development and deployment.

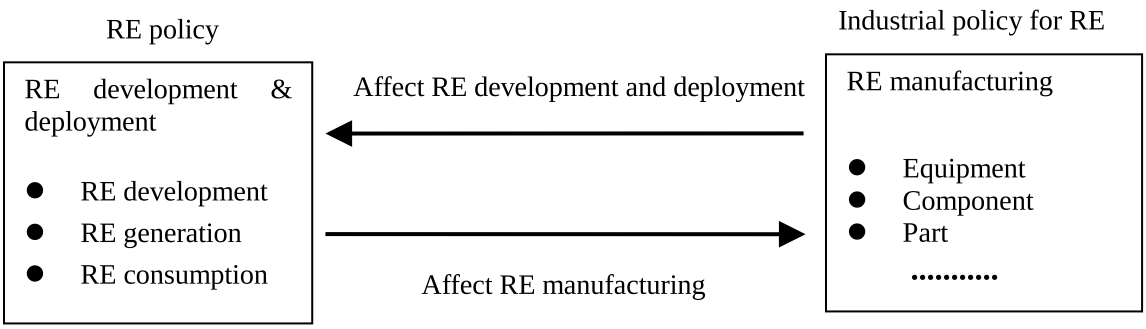


Fig. 1 Diagram of interactions between renewable energy policy and renewable energy industrial policy

Note: RE is the abbreviation of renewable energy.

Source: Authors' own illustration.

The nature and progress of national strategies to promote renewable energy deployment depend, among other factors, on the motivations of key actors and on the national innovation systems. Four categories of national motivations for the development of renewable energy can be identified (Sims Gallagher, 2013):

- the economic drive to develop industrial capacity in the development and manufacturing of renewable energy technology;
- the wish to exploit a generous (per capita) endowment of renewable energy to meet national energy needs;
- political motivations of different types which support the development and implementation of policies to encourage the deployment of renewable energy;
- embedded social values and ideas which support renewable energy strategies.

Although the relative importance of these motivations varies between different countries, economic policy, in other words industrial policy, ranks highly in many cases (Sims Gallagher, 2013). As a consequence, renewable energy policy and renewable energy industrial policy have a general tendency to be intimately linked, at least in those countries that have the potential to develop such industrial capacity. Whilst such complementary policies can be mutually supportive, they can also lead to interactions which undermine the original objectives and lead to the emergence of new problems. Such policy interaction has been especially notable in the arena of climate change and clean energy (Sorrell and Sijm, 2003).

Governments are likely to become directly involved in developing frameworks to support the innovation and to provide the incentives necessary to achieve the twin industrial and energy goals. Such involvement can be justified on the grounds of the need to deliver a public good and to reduce the barriers to entry facing renewable energy (Sims Gallagher et al., 2012). In this way the government becomes an actor in what is known as the national innovation system.

A national innovation system involves a range of public and private actors, from government agencies, universities, national laboratories and banks, to state-owned enterprises and private companies (Nelson, 1992; Lewis, 2013). Whilst the concept of national innovation systems is contentious and has evolved over time, not least due to globalization, key elements such as the need both for research and development and for learning by doing remain relevant today. Globalization has increased opportunities for importing technologies and for cooperating with foreign actors, including in the renewable energy industry (Lundvall, 2005; Ockwell, 2009; Watson et al, 2011; Lewis, 2013). Despite the growing international dimensions of technological innovation and diffusion, systems for innovation still retain strong national characteristics. The sources of these national traits lie in the institutions that govern technological and industrial innovation which include the political and economic systems, the approaches to education, and the nature of social capital (Nelson, 1992; Lundvall, 2005; Bell, 2009; Kash, 2010).

In China, economic policy has clearly been an important motivation for the development of renewable energy (Sims Gallagher, 2013) and has resulted in the government providing substantial policy support to this sector. Ideas have also played a significant role, as will be argued below. The national innovation system, together with its international links, has permitted rapid innovation and growth both of the renewable energy industry and of the deployment of renewable energy capacity in China. However, this success has been marred by the emergence of a number of deficiencies in both the manufacturing industry and in the generation of renewable energy.

3. China's renewable energy policy and renewable energy industrial policy

For the purpose of assessing how effectively China has met the ideal of appropriate interactions between renewable energy policy and renewable energy industrial policy, in this section we will go into these two types of policy in China.

Since 2005, China promulgated a series of renewable energy and renewable energy industrial policies, including the Renewable Energy Law, the 11th Five-Year Plan for National Economic and Social Development (11th FYP), the Medium- to Long-Term Plan for the Development of Science and Technology (MLP for S&T), the 11th Five-Year Plan of Science and Technology Development (11th FYP for S&T), the Medium- and Long-Term Plan for Renewable Energy Development (MLP for RED) and the 11th Five-Year Plan for Renewable Energy Development (11th FYP for RED), among others. This section outlines China's key renewable energy and industrial policy tools for renewable energy over the period of 2005-2011, with particular focus on wind and solar PV sector policies.

3.1. China's renewable energy policy

The major renewable energy policy tools employed by the Chinese government for promoting the development and deployment of renewable energy and pulling the market demand for renewable energy equipment, components and parts include guaranteed grid connection and full purchase, categorized on-grid price setting, mandatory market share, government concession program and government financial support for renewable energy project.

Guaranteed grid connection and full purchase. The Renewable Energy Law which was promulgated in 2005 and took effect as of 1st January 2006 and its 2009 amendments, together with other relevant regulations, obligate power grid companies to provide grid-connection services and related technical support, and to purchase and dispatch the entire amount of electricity generated from the renewable energy projects when entering into interconnection agreements with projects. The original 2005 Law simply requires grid companies to purchase without condition all renewable power available for purchase (NPC, 2005). However, the 2009 amendments limit grid companies' responsibility to purchase renewable power only from those renewable power generators that meet certain technical requirements for connection in order to improve the implementation of mandatory connection and purchase policy (NPC, 2009). In response to China's government's call for supporting distributed solar PV development, the State Grid Corporation of China (SGCC), China's largest state-owned power utility company, in 2012 announced that starting on 1st November 2012 it would provide free connection services for distributed solar PV electricity producers located close to customers and with installed capacities of less than 6 MW each (SGCC, 2012). Subsequent to this, on 27th February 2013 it announced that the free connection services are to expand to all types of distributed electricity sources (SGCC, 2013).

Categorized on-grid price setting. The Chinese government has implemented categorized on-grid price setting for each individual renewable energy generation connected to the grid. This takes into account the techno-economic performance of different renewable energy technologies, their geographic location, and the availability of renewable energy resources. Two primary methods have been adopted —competitive tendering (government-guided pricing) and feed-in tariffs (FITs) (government-fixed pricing) (NPC, 2005; NDRC, 2006). During the period from 2006 to July 2009, the grid-connected power price of wind power projects was determined by a government-guided price set in accordance with the price selected through a public request for tenders. In August 2009, China began to implement a national four-category scheme of FITs for new onshore wind power projects located in regions with different wind abundances, in the range 0.51~0.61 RMB/kWh (equivalent to 3.16~3.79 USD/kWh at current exchange rates). As compared to the 0.385 RMB/kWh on-grid tariff for coal power, these categorized FITs represented a significant premium for wind power generation over coal-fired electricity generators. For the PV power projects, prior to 2009, the government approved all on-grid prices, according to the principle of reasonable production costs plus reasonable profit, which ranged between 4.0 and 9.0 RMB/kWh.

In early 2010, the government set on-grid prices for four newly grid-connected solar power stations at 1.15 RMB/kWh, which was drastically lower than the tariffs approved by the National Development and Reform Commission (NDRC) for earlier approved pilot PV power plants (Ma, 2011). During 2009 and 2010, the government sponsored two rounds of public tender for solar powered projects. The approved FIT based on the bidding result for the first round was 1.09 RMB/kWh and the FITs for the second round ranged from 0.729 RMB/kWh to 0.991 RMB/kWh. As a consequence of these much lower bidding prices for projects and the tough time faced by China's PV industry, in July 2011 the government announced its first nationwide two-category FIT scheme for solar PV projects: Projects approved before July 2011 are to receive 1.15 RMB/kWh for their generated electricity. All projects approved later are to obtain a generation price of 1.10 RMB/kWh with the exception of projects in Tibet, which under some circumstances, can still receive 1.15 RMB/kWh.

Mandatory market share (MMS). China's Renewable Energy Law states that a "mandated market share" of renewable power should be required of the major national generating companies. Each of these companies must generate or purchase specific shares of their total power from renewable sources. In 2007, the exact mandated shares were announced as part of the MLP for RED. According to the plan, the share of non-hydro renewable energy supply should reach 1% of total power generation by 2010 and 3% by 2020 for regions served by centralized power grids. In addition, any power producer with capacity greater than 5 GW must increase its actual ownership of power capacity from non-hydro renewable energy supply to 3% by 2010 and 8% by 2020 (NPC, 2005; NDRC, 2007).

Government concession program. Under the concession program, investors and developers are selected for concession projects through a competitive bidding process and the government confirms coordinating the power grid connection and purchasing all the electricity generated by the concession projects. From 2003 to 2007, the NDRC initiated five rounds of concession biddings for wind power projects. In the wind concession projects, price was the determinant criteria in deciding bid winners.

In almost all cases the company with the lowest bidding price won the bid (Wang, 2010). Following the example of wind, two rounds of concession biddings were implemented for solar PV power projects during 2009-2010.

Government financial support for renewable energy projects. China's government supports renewable energy projects by providing financial subsidies. For example, in 2009 the government initiated two national solar PV subsidy programs to boost its domestic solar industry: the Solar Roofs Program which provides upfront subsidy for building-integrated PV systems and a subsidy of 50% of the bidding price for the supply of critical components (Huo and Zhang, 2012), and the Golden Sun Demonstration Program which provides subsidies for both on-grid and off-grid PV system.

3.2. China's renewable energy industrial policy

The industrial policy tools for renewable energy employed by the Chinese government include financial support for innovation and R&D and manufacturing, local content requirements, among others.

Financial support for innovation and R&D. China's MLP for S&T gives top priority to developing technologies related to energy. Consistent with the MLP for S&T, the 11th FYP for S&T which provides short-term targets and goals for China's R&D and innovation activities from 2006-2010, lists energy technologies as a key area. Specifically, the Plan highlights three key clean technologies, one of which is 2-3 MW wind turbine commercialization. Among various publicly funded S&T programs, the "863" and "973" programs, the two most important national research projects, have provided the most direct funding sources for renewable technologies. During the 11th FYP period, renewable energy was one of the technology priorities in both "863" and "973" programs. For instance, specific research into large-scale wind turbines was undertaken in the context of "863" program. On average each project in the "973" program received funding of 22 million RMB over a span of 5 years (Tan, 2010).

In addition, the Ministry of Finance (MOF) established a special fund to support the R&D of domestically controlled or wholly owned enterprises manufacturing wind power machines and equipment (including spare parts such as blades, gear cases, generators, converters, and bearings) within China. Wind power equipment manufacturers fulfilling the fund’s qualifications are eligible for a 600 RMB/kW grant for the first 50 wind turbines produced (Lovells, 2008). In recent years, China's government has started to strengthen the wind power innovation system by establishing new national-level R&D centers and laboratories for all forms of new energy technologies. The central government has also funded a number of PV R&D projects which faced many technical difficulties and uncertainties, so as to supply elemental technologies for industrial development. For example, polysilicon was in shortage in China until the state-owned Emei Semiconductor Research Institution’s achieved successful R&D of polysilicon technology, and transferred it to polysilicon manufacturers in China (Huo and Zhang, 2012). In 2010, a total of thirty-eight national energy R&D centers were approved and established by the National Energy Administration (NEA)(Yang, 2010).

Financial support for renewable technology manufacturing. For the purpose of promoting self-sufficiency in renewable energy equipment, China offers import tax exemptions for complete sets of foreign-made equipment, and import tax exemptions for key foreign-made parts which are necessary for the development of key equipment to domestic enterprises. China's state-owned banks and local governments have also provided strong financial support for renewable manufacturing industry. In response to the central government's call for supporting strategic emerging industries, China's state-owned banks have given a huge amount of capital support to domestic PV manufacturers. For example, of the USD 41.8 billion invested in the global solar industry in 2010, USD 33.7 billion came from the Chinese government. The China Development Bank (CDB) was the prime source of this capital infusion. In 2010 alone, the bank handed out USD 30 billion in low-cost loans to the top five PV manufacturers in the country. The Chinese government also supports its PV industry as one of a number of key industries identified in the Catalog of Chinese High-Technology Products for Export, updated in 2006. As a result, PV manufacturers are eligible for additional financial support for R&D and provision of 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).

Local content requirements. Local content requirements compel renewable energy developers to source a specified share of equipment from local suppliers. A principal goal of a local content policy is to ensure that the government’s renewable energy policy produces tangible local economic benefits. Wind projects under the China's wind concession program were required to source at least 50% of their content from local manufacturers in 2003, which was increased to 70% in 2004. The local content requirement was discontinued in 2009, as it was criticized as being against WTO rules. However, these local content requirements caused foreign firms interested in selling wind turbines in China to develop a manufacturing strategy that allowed them to meet these requirements. Consequently, many leading international wind turbine manufacturers established either local manufacturing facilities or assembly plants for Chinese-made components (Lewis and Wiser, 2007). Ultimately, for China it may have been worthwhile having these local content requirements as it had many years to develop technological capacity until coming under the scrutiny of the WTO.

3.3. Summary and discussion

The above policies illustrate that the Chinese government has recognized the need for the interactions between renewable energy policy and renewable energy industrial policy. Indeed, the MLP for RED explicitly expressed this recognition, with the language "*For those more newly developed renewable energy sectors with large resource potential and good commercial prospects, such as wind and biomass power, necessary measures should be taken to enlarge market demand, while at the same time increasing the input for technology development. With this two-pronged strategy, sustainable and stable market demand can create conditions beneficial to the development of the renewable energy industry. China should also develop self-dependent innovation abilities as the basis for its renewable energy R&D and industry development system. In this way, it can speed up progress in renewable energy technology development, raise its ability to manufacture equipment, and, through sustained scaling-up of development, raise the market competitiveness of renewable energy. In sum, the measures mentioned above will form a solid basis for the large-scale development of renewable energy*." (NDRC, 2007).

However, the outcomes of China's wind and solar PV power development, as shown in the next section, reveal that the interactions between the renewable energy and industrial policies in China has not been managed effectively.

4. Empirical cases of China's policy approach to renewable energies

Wind and solar PV power are the two renewable energy technologies that have witnessed relatively rapid growth in China. In this section, we examine the major achievements and problems of the two sectors to illustrate China's policy approach to renewable energies.

4.1. Achievements in China's wind and PV power sector

(1) Achievements in China's wind power sector

Wind power market. Before 2005, China's wind power market was very small. By the end of 2004, the total installed wind capacity was only 769 MW, ranking tenth and accounting for 1.43% of the world total (GWEC, 2012). However, thanks to the five rounds of concession bids under the wind concession program as previously noted, a total installed capacity of 3,400 MW (Ni, 2008), 50.8% of the nation's total wind power capacity in 2007, has been achieved. As a consequence, the wind power market has grown tremendously. From 2006 to 2009, China's cumulative total installed capacity kept up an annual growth rate over 100% for three successive years. The previously noted national FIT scheme for wind power in 2009 further stimulated developers' interests in wind farm investment (Kanga, 2012). From 2010 to 2012, China's cumulative installed capacity continued to grow rapidly, ranking the first in the world for three consecutive years, with cumulative capacities reaching in each year 44,733 MW, 44,733 MW and 62 75,324 MW, accounting for 22.7%, 26.2% and 26.7% of the world total respectively (Fig. 2).

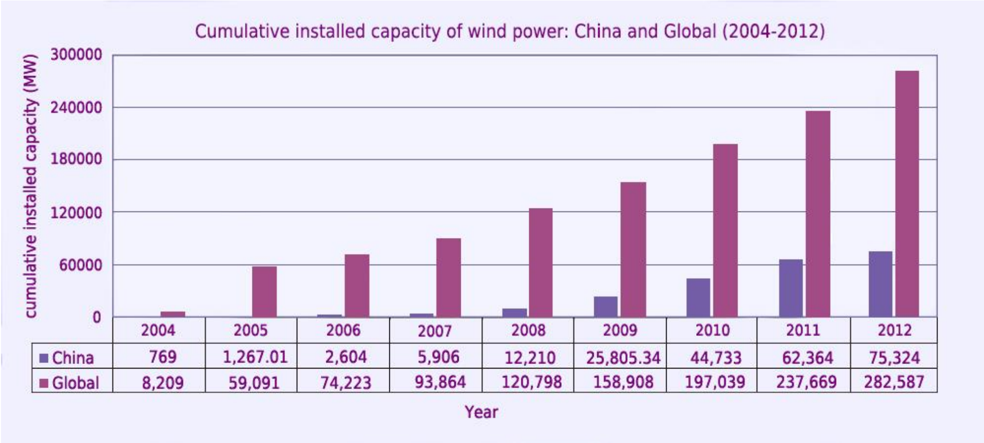


Fig. 2. Cumulative installed capacity of wind power: China and global (2004-2012)
Source: GWEC, 2013.

Wind turbine manufacturing industry. Until 2005, China had only a few small-scale and low-technology wind power manufacturers and most of its wind plant construction had relied on imports. However, thanks to the localization industrial policies compounded with the expansion of aforesaid domestic wind power market, since 2005 Chinese wind turbine manufacturing capacities have increased steadily. In 2011, four Chinese companies, Goldwind, Sinovel, United Power and Mingyang, were among the world's Top 10 wind turbine manufacturers, together representing 26.7% of the world total, and Goldwind became the second largest power equipment supplier in the world, taking a share of 9.4% (REN 21, 2012). Thanks mainly to the local content requirement policy, the foreign share of China's annual new purchases of wind power equipment fell from 75% in 2004 to 24% in 2008, and further to around 12% in 2010 (Jiang, 2011).

Wind power technologies and indigenous innovation. Chinese wind power manufacturers were able to leverage the advantage provided by national wind concession programs, achieved several technological breakthroughs, and gradually caught up with their international competitors. The large wind turbine companies are able to produce not only 1.5 MW, 2 MW and 3 MW wind turbines, but also 5 MW wind turbines and offshore wind turbines. The average scale of wind turbines has also increased from 849.7 kW in 2005 to 1545.4 kW in 2011 (Fig. 3).

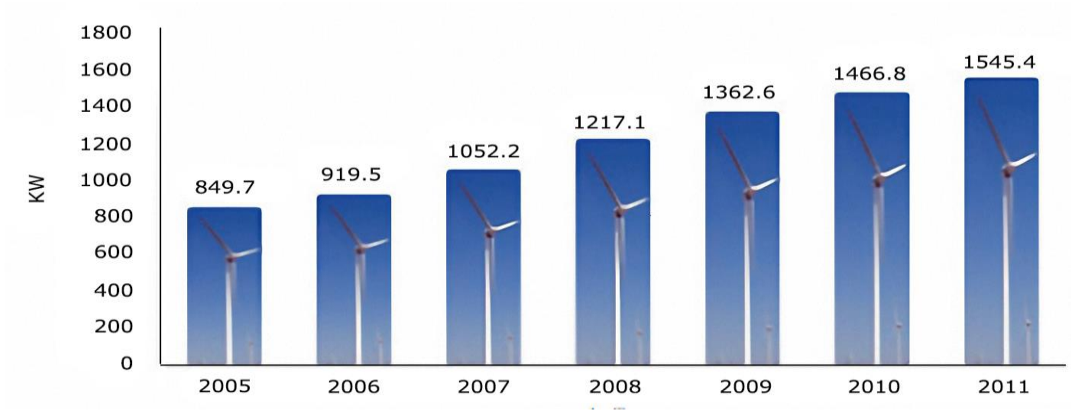


Fig. 3. Average scale of wind turbines in China during 2005-2011
Source: Li, 2012.

(2) Achievements in PV power sector

Solar PV market. Before 2009, few incentives were put in place to spur China's domestic PV market, as the government had given policy priority to wind rather than the PV power market, due mainly to the high cost of PV system. The total installed capacity of PV power in each of the years between 2005 and 2008 was less than 150 MW, with a share of roughly 1% each year in the world market. However, since 2009, in response to the national solar PV subsidy programs and the concession programs, China's domestic PV market has seen a steady growth, with its cumulative installed capacity rising from 300 MW in 2009 to 800 MW in 2010, then surging to 3,300 MW in 2011and 8,300 MW in 2012, representing 4.6% and 8.1% of the world total in 2011 and 2012 respectively (Ren 21, 2012; Wang, 2012; EPIA, 2013). However this is still very small in comparison with China's wind market and the PV markets in leading countries such as Germany and Spain.

Solar PV manufacturing industry. In contrast to the development model of China's wind industry which has been pulled mainly by domestic market, China's solar PV industry has been pulled to a great extent by overseas markets in countries such as Germany and other European countries. China's share of the world market in terms of solar PV production has grown from about 1% in 2001 to more than 50% in 2010. In 2011, China manufactured 21 GW of solar cells, representing 60% of the global total production. The export value of solar cells accounted for 60% of the global market. The production of polysilicon also saw steady growth, ranking first in the world in 2011. Out of the top fifteen solar PV module manufacturers in the world, nine were Chinese companies which took a share of 30% (Xu et al., 2012). In addition to the strong overseas demand, the aforesaid supportive renewable industrial policies offered by the government have also contributed greatly to the rapid growth of China's PV manufacturing industry.

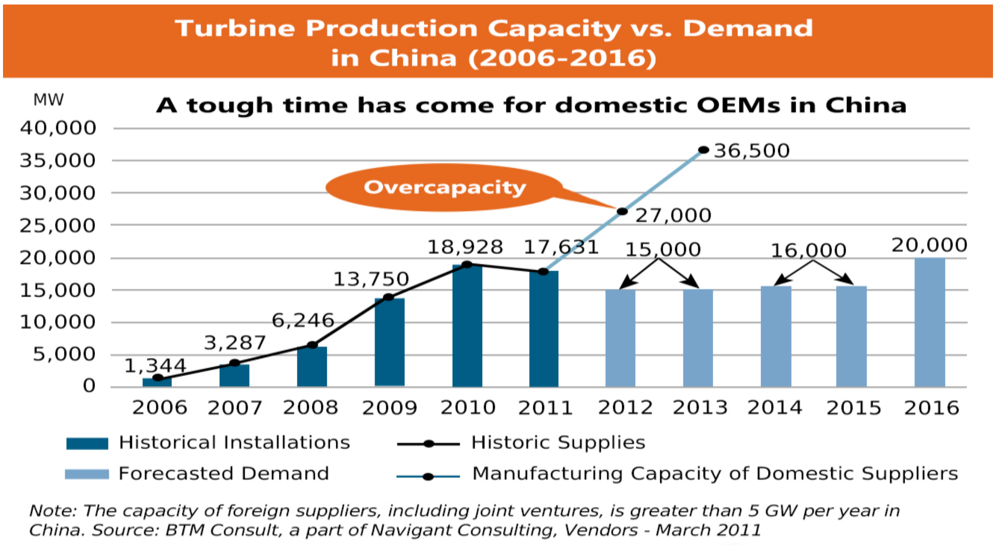
Solar PV technologies and indigenous innovation. China still lags behind international advanced levels of key polysilicon technology, high-end equipment used for manufacturing crystalline silicon cells still needs to be imported, and Chinese enterprises notably lag behind in thin-film cell processes and equipment. Despite these deficiencies, great progress has been made in solar PV technologies in the country. In terms of the quality and technology level of solar cells, China is gradually gaining a leading position in the world. The raw material self-sufficiency rate in China’s PV industry has increased from almost 0% in 2006 to 50% in 2010. Through a combination of indigenous innovation and the introduction of foreign technology, the level of manufacturing of polysilicon, battery modules, and controllers continues to improve. Leading Chinese polycrystalline silicon enterprises have mastered key technologies required by thousand-tonne production capacity through a modified Siemens process. In particular, leading enterprises have made rapid progress in terms of conversion efficiency. The conversion rates for monocrystalline silicon solar cells, polycrystalline silicon, and solar cells thin-film and other new types of cells have reached 17%-19%, 15%-17% and 6%-8% respectively. The localization rate of manufacturing equipment now exceeds 50%. Except for automatic printing machines and cutting equipment, the industry is basically able to manufacture special equipment for crystalline silicon solar cells domestically, and home-grown enterprises are now capable of producing silicon-based thin-film cells (NEA, 2012).

4.2. Problems in China's wind and PV power sector

Along with the rapid development of wind and solar PV manufacturing industry, two types of problems have occurred in these two sectors in recent years, that is, industrial overcapacity and under-deployment of renewable energy.

Industrial overcapacity. By 2011 the production of China's major wind industry has exceeded 30 GW while the domestic market demand was merely less than 18 GW. This had led to more than 40% of China's production capacity standing idle. In 2012, excess production capacity of wind equipment has become even greater, with the total production capacity far exceeding the demands of domestic market (Li, et. al., 2012). BTM Consult estimates that Chinese turbine manufacturers faced 27 GW of overcapacity in 2012, growing to 36.5 GW in 2013 (Fig. 4).

The industrial overcapacity problem is more prominent in China's solar PV sector than in wind sector. It is reported that more than 300 Chinese cities are making efforts to develop the solar PV industry. *"There are more than 2,000 companies in the country's PV industry, half of which are focusing on producing solar products,"* according to Shi Lishan, deputy director of the New Energy and Renewable Energy Department within the NEA. This has led to overcapacity in the sector. Massive subsidies and state intervention have driven China's overcapacity in solar power panels and systems to more than 20 times of the total Chinese national market demand for these panels, and close to two times the total of world demand. Data from the U.S. investment agency, Maxim Group, shows that China's top ten photovoltaic makers have accumulated a combined debt of 111 billion RMB, leading the whole industry to the brink of bankruptcy (Min, 2012).



. **Fig. 4.** Wind turbine production capacity vs. demand in China (2006-2016)

Source: Gardiner, 2012.

Theoretically, an industry at the growing stage of its industrial life cycle is characterized with a continuous growth of market demand, increasing recognition of the products by the consumers and steadily declining costs. Overcapacity generally occurs at the mature stage rather than at the growing stage of an industry (Shi, 2012), as in the cases of many Chinese industries such as steel, TV, and cement, among others, due to a combination of the investment-driven development model, local government protectionism and a general desire to sustain high levels of employment (Kynge, 2006; Peerenboom, 2007; Coase and Wang, 2012). However, China's wind and solar PV industry are emerging industries which are both at the growing stage of their industrial life cycle. This somewhat unique "premature recession" phenomenon is largely due to the excessive investment enthusiasm aroused by the government for the purpose of not simply to obtain clean energy and enhance energy security, but most importantly to restructure upgrade China’s industry, the success of which will determine whether the entire industry will shift in a sustainable and green development direction. Ideas behind this motivation will be discussed in Section 5.

It is in this context that while pledging to encourage mergers and restructuring among manufacturers to phase out outdated capacity, the government sought to rescue the struggling industry. For example, the China Development Bank, a policy bank, has pledged to provide loans to the PV industry. However, the negative consequence of this reluctance to allow firms to go bankrupt is a dampening of pressures on the management of these firms to enhance technical and commercial performance which in turn may constrain their international competitiveness in the long run.

Under-deployment of renewable energy. The other type of problem in China's wind and solar PV sector is that the growth of wind and solar PV manufacturing capacity has not led to a proportionate energy dispatched, demonstrating the problem of under-deployment of both wind and solar PV energy, though the reasons for this in the two sectors are different. While the under-deployment of solar PV power is largely attributable to the small size of the domestic PV market, at least prior to 2009, the under-deployment of wind power has mainly resulted from grid connection constraints and the curtailment of wind power output.

The grid-connected capacity for wind power in China has lagged behind its installed capacity by more than 30%, higher than the 10% gap in developed countries (Zhe, 2011). According to the China Wind Energy Association (CWEA), in 2011 about 15 terawatt-hours of wind power generation were curtailed, representing 16.9% of China's wind generation (CWEA, 2012). As depicted in Fig. 5, in the most recent years the growth of wind power curtailment has surpassed the growth of on-grid installed wind capacity. As a consequence, over the period of 2005-2011, the share of wind generation in China's total has been lagging behind its share of generating capacity in the country’s total (Fig. 6). Prior to 2009, both the installed capacity and the generation of solar PV had grown very slowly. Since 2009 the growth of solar PV generation has overwhelmingly lagged behind the growth of solar PV capacity (Fig. 5). To date, wind generation as a proportion of total electrical power output has been very small and the proportion of PV power generation in China is negligible. As a result, the overall proportion of electricity generation from renewable energy has remained low in China's total electricity generation mix (Figs.7, 8 and 9).

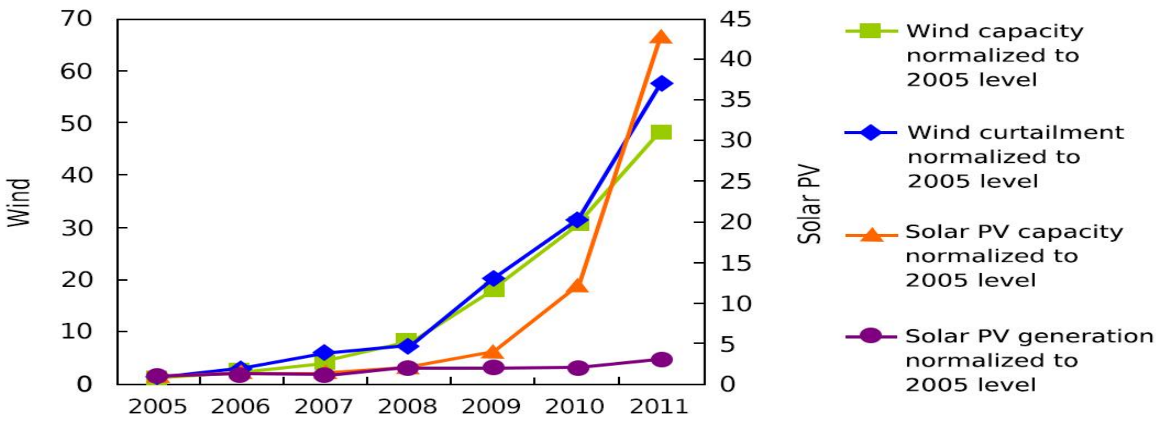


Fig. 5. Wind capacity vs. curtailment and solar PV capacity vs. generation over 2005-2011

Source: Authors' calculation based on the data released by the China Electricity Council.

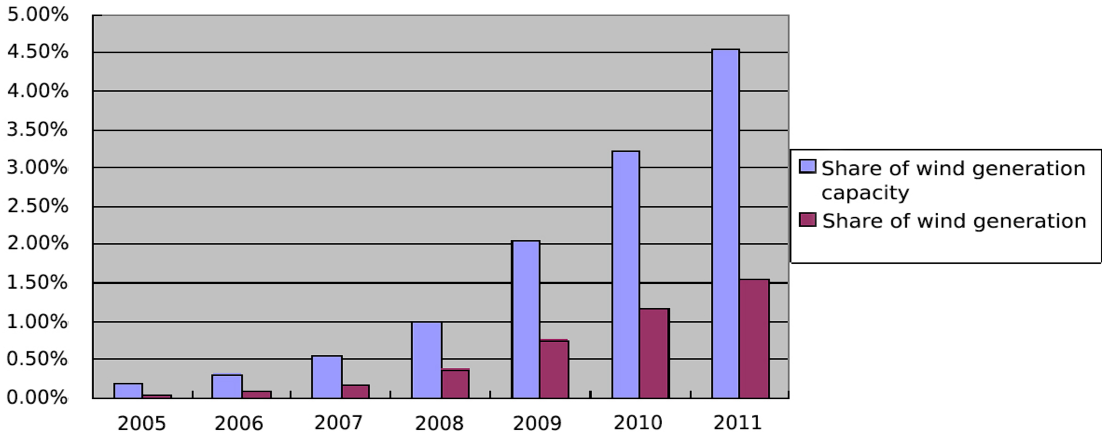


Fig. 6. Shares of wind generation capacity and wind generation in China's total generation capacity and generation respectively during the period 2005-2011

Source: Authors' calculation based on the data released by the China Electricity Council.

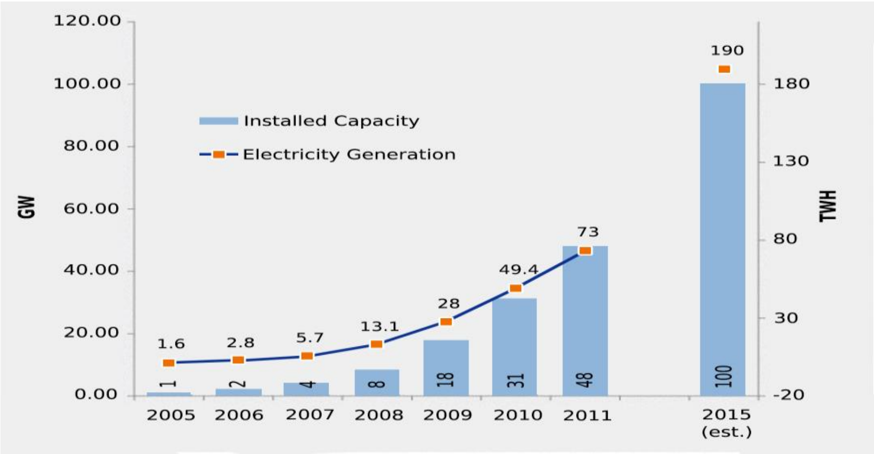


Fig.7 . On-grid wind power installed capacity and electricity generation

Source: NEA and NREC, 2012

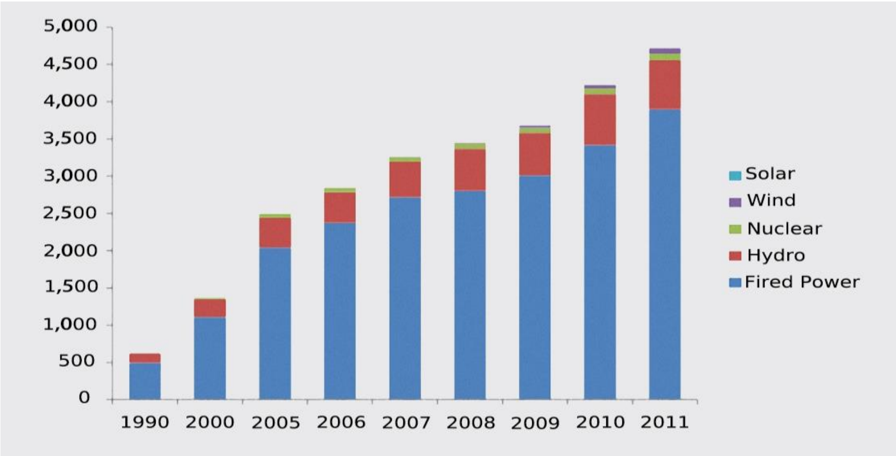


Fig. 8. China's electricity generation mix (TWh)

Source: NEA and NREC, 2012

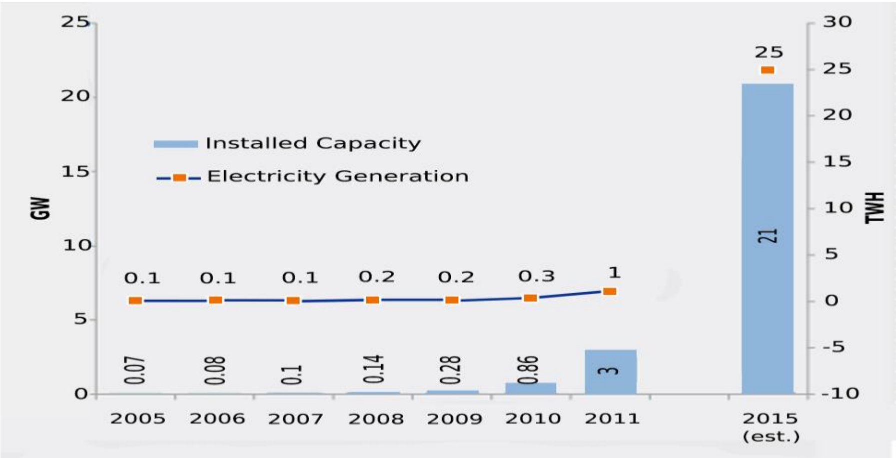


Fig. 9. China's installed capacity and electricity generation of solar PV power

Source: NEA and NREC, 2012.

4.3. Summary and discussion

In sum, the achievements and problems in China's wind and solar PV sectors show that China's policy approach has, on the one hand, driven the dramatic growth of China's wind and PV manufacturing industry, assists Chinese wind and PV manufacturers to rapidly expand and achieve global market leadership in less than a decade, laying a good foundation for renewable energy generation infrastructure in the country. On the other hand, it has led to industrial overcapacity and to under-deployment of wind and solar PV power.

Notwithstanding these deficiencies, it appears that China's policy approach to renewable energies has been to place priority first on developing its renewable manufacturing industry and only second on the generation of renewable energy itself. Indeed, this train of thought can be found in China's government discourses with regard to the development targets set for renewable energy and the implementation measures for developing wind power, It is also revealed in China's prevailing policies for renewable energy.

(1) Development target set for renewable energy. Although China's 11th FYP explicitly states that the objective of developing renewable energy is to *"Encourage the production and consumption of renewable energy and increase its share in total primary energy consumption"* (State Council, 2006), and both the MLP for RED and the 11th FYP for RED specify that the development objective of renewable energy is *"to raise the share of renewable energy in total primary energy consumption to 10% by 2010"* (NDRC, 2007; NDRC, 2008), what is worth noting is that the development target for each individual renewable source is its installed capacity rather than its share in total primary energy consumption. This focus on capacity-based targets led to

the pursuit of capacity growth rather than generation growth of renewable energy over the years 2005-2011;

(2) Implementation measures for developing wind power. In the *Suggestions on the Implementation Measures for the Promotion of Wind Power Development*, a document released jointly by the NDRC and the MOF in 2006, China established a two-pronged wind power development strategy: the first step was to establish relatively comprehensive wind power industrialization system so as to lay a good foundation for large-scale wind power development; the second step was to realize large-scale wind power development and increase the share of wind power in electricity supply (NDRC and MOF, 2006).

(3) The prevailing renewable energy policies. Overall, the prevailing renewable energy policies have provided strong impetus only for scaling up development rather than for the generation and consumption of renewable energy. Taking the guaranteed grid connection and full purchase policy as an example, this policy was imposed from the perspective of stimulating renewable energy investment rather than accommodating renewable energy. It requires grid companies to provide grid connection and full purchase of renewable energy generation but gives little consideration to technological and institutional barriers to grid connection, and few specific policies regarding economic compensations and incentives to grid companies for their accommodating renewable energies have been put in place. With regard to PV sector, it was not until July 2009 that the two renewable energy policies—the solar PV concession program and the nationwide FITs policy—were put in place, mainly triggered by the need to rescue the struggling domestic PV manufacturing industry.

Indeed, there are rationales for this policy approach. The major constraint to the commercialization of renewable energies in China (as in other countries) was their high costs which have resulted in higher on-grid tariffs than those for thermal power. Through developing a local renewable manufacturing industry by virtue of China's size and needs, China could obtain significant reductions in the manufacturing costs of renewable energy technologies and accelerate the commercialization of renewable energies. Once the manufacturing base has been developed, this would result in significant cost advantages. However, this policy approach to renewable energies has, by its nature, been driven by a "growth imperative" rather than by a "green imperative". This has led, in turn, to emphasis on the impact of the competitiveness and capability of renewable energy industry on the development and deployment of renewable energy, while overlooking the impact of generation and consumption of renewable energy on the competitiveness and capability of renewable energy industry. All in all, it turns out that China's policy approach to renewable energies has not met the ideal of appropriate interactions between renewable energy policy and renewable energy industrial policy. As such, adjustments should be made to it so as to maintain the sustainable and healthy development of both the renewable energy industry and the renewable energy itself.

5. Ideas underlying China's policy approach to renewable energies

Ideas can have a profound effect on the course of events, acting like switchmen on a railway line, to direct interest-based actions down one track or another. Ideas can influence policy at a number of levels and at a number of different stages of policy creation and implementation (Boyd, 2012). Sometimes the appearance of a new idea by itself can affect a change in what is considered to be pressing and important (Andrews-Speed, 2010). However, more often it is the perceived failure of old ideas and the policies that flowed from them that make different ideas seem newly important and relevant (Andrews-Speed, 2010). In this section, we attempt to analyze the ideas underlying China's policy approach to renewable energies in order to explain these deficiencies in policy interaction. We find that the following three ideas—green development idea, low-carbon leadership idea and indigenous innovation idea, pursued by the Chinese policy makers, are supportive of its policy approach to renewable energies.

5.1. Green development idea

Throughout the 1980s and for much of the 1990s, the traditional development model "pollution first and control second" and "getting rich first, clearing up later"， characterized by high capital input, low output efficiency, high resource consumption and high pollution, has prevailed in China. Although efforts were made to protect the environment, priority was given to economic development, and environmental pollution and degradation continued. However, as China's environmental degradation has become more severe, the limitations of realizing economic growth by following the traditional model have become increasingly evident. Although economic development and growth remains a primary aim for the Chinese government, there is a growing realization that dangerous climate change poses a clear threat to China's developmental goals. Awareness of this worsening environmental crisis has prompted the rise of "green development" as an important concept in China's official discourse.

In the past, a clean environment has too often been considered as an unaffordable luxury—but green development goes far beyond the trade-off between growth and the environment. Chinese leadership has recognized that the two goals—growth and a clean environment—not only may be realized simultaneously but it is possible to significantly reduce emissions without reducing long-term growth. Gradually and steadily, the idea of a "green development" path has been accepted by the government.

China's 11th FYP reiterated two principles for development—the "concept of scientific development" and constructing a "harmonious socialist society". Both principles were based on the Chinese leaders' call for a shift in direction from the singular pursuit of economic growth to "putting people first", to promoting sustainability in economic development, and to progressing toward an "all-around well-off society". Scientific development is, in essence, a euphemism used by the Chinese leaders for economic growth that takes into consideration the welfare of disadvantaged people and regions as well as environmental concerns (Lam, 2005).

In 2004, the State Environment Protection Administration (SEPA, now Ministry of Environmental Protection) attempted to implement the world's most ambitious exercise in environmental accounting, "Green GDP". SEPA estimated the cost of environmental damage and pollution to be 3.05% of total GDP, or one third of the total GDP growth for that year. SEPA qualified this by stressing that *"this accounting is only a fraction of [the] ultimate green GDP calculation result"* as many important environmental indicators were not included (Boyd, 2012).

5.2. Low-carbon leadership idea

Early 2000s, there was a growing consensus in Chinese policy circles that the world was on the brink of a major energy transformation away from fossil fuels to renewable energy sources, and that China had an historic opportunity to position itself as an economic and technological leader in a global transition towards low-carbon energy. Hu Angang, one of the best-known Chinese economists and a leading policy adviser, puts low-carbon leadership in the context of China's geopolitical rise. Hu

(2006) notes that different waves of industrialization and modernization have been tied to the emergence of important new energy technologies. Historically, the countries that have been able to effectively exploit these new energy technologies before anyone else have succeeded in increasing their influence and changing the balance of power in the international system. He argues that China has consistently failed to position itself at the forefront of these crucial technological breakthroughs, and as a result, has remained politically marginalized for much of its modern history. China must not "make the same mistakes once again", but rather "have a strong sense of crisis" in order to become an economic and political leader in the "next wave" of modernization, which will be defined by low-carbon energy technologies.

China's government has also increasingly recognized that while the transition toward green development will not be easy, it will open the door to new opportunities, and those who are moving fastest in the transition to a low carbon economy are likely to gain a significant competitive advantage. And by investing in emerging green technologies, China can use its newcomer status in green industries and technologies to leapfrog current capabilities in the advanced countries. In addition, the size of its domestic market can support rapid achievement of scale economies. Government documents stress that China must "gain a first-mover advantage" and seize the economic opportunities of this historic transition. These ideas were explicitly expressed in Chinese leaders" speeches such as a speech made by China's Vice Premier Li Keqiang, *"... Green economy, low carbon technology, etc. are emerging, and the global competition to seize the high ground in the future development of these sectors is getting more and more fierce every day. In some of these sectors, the gap between the emerging economies and the developed nations is relatively small. In that environment, all we need to do is to take advantage of these (market) trends; if we* *respond appropriately we can seize this opportunity, gain the upper hand, and push forward a new breakthrough in development. Otherwise, if we miss out on our opportunity, it will be harder to overtake (the developed countries), and we may lose the initiative and even fall behind."* (Hart, 2011).

Government documents have also highlighted the need for China to remain competitive and seize the economic opportunities in emerging low-carbon markets. The MLP for RED expresses an expectation that *"each country will hasten their development of renewable energy"* and goes into great detail in describing the policies, laws, targets, research and development, and market mechanisms that other countries have put in place to expand their renewable energy industry (NDRC, 2007).

5.3. Indigenous innovation idea

Since the advent of reform and opening, China's economic development has been characterized by export-oriented "global factory model". The idea of indigenous innovation was inspired primarily by the concern with this model. While China has benefited greatly from this model, its role in the global production process limits its ability to upgrade. One conceptualization of China's role in global manufacturing is the "smile curve"[1] as shown in Fig. 10. Among other things, the curve shows that the nadir of profitability is the manufacturing process, in which China's production activities lie almost exclusively. China has attained global preeminence in the realm of production that yields the least monetary benefit. While this strategy has helped catapult the country from impoverishment to its current state of relative wealth, it is not one that will ensure future advancement in levels of development. Chinese leaders

[1] There are other views on this point. For instance, the Economist Intelligence Unit has a piece regarding how China is moving up regarding what they are producing and Georgia Tech, using a series of indicators notes that China is moving from being the world's factory to the world's R&D hub.

believe that they cannot continue to rely heavily on these types of exports (O'Brien, 2010).

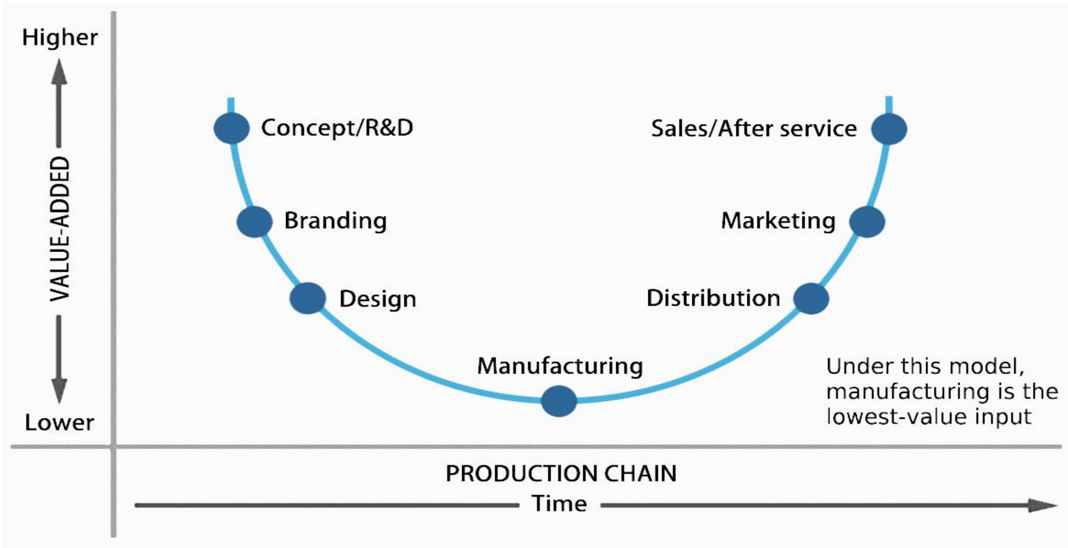


Fig.10. Stan Shih's smile curve

Source: McGill University and the Conference Board of Canada, 2012.

Even if China wished to continue relying heavily on cheap exports to drive economic growth, several factors, most notably rising wages, threaten to wipe away its comparative advantage in production costs. As wages in China rise, the country's long-held comparative advantage in the cost of labor will be jeopardized. Indeed, manufacturing is moving from China to other developing countries, principally those in Southeast Asia and this trend is likely to continue in the years to come. The confluence of these factors renders a continued dependence on low-cost exports untenable (O'Brien, 2010). Strengthening China's domestic innovative capacity is considered to be the key to a sustainable transformation of its economy beyond the export-oriented "global factory" model (Ernst, 2011).

This idea was explicitly expressed in the speech made by China's former President Hu Jintao, "*...building China into a nation of innovation should be adopted as its future-oriented major strategy....The strategy should focus on the central task of* *economic development and the frontiers of the world science and technology. ... China should formulate its strategic goals of independent innovation and step up the establishment of the State innovation mechanism, ... a nation should underscore independent innovation provided it wants to succeed in development and benefiting the world.*" (Yao, 2006).

The Chinese government also reaffirmed its resolution to build up an innovation-oriented country in its documents. For example, in a document issued by the Central Committee of the Communist Party of China (CPC) and the State Council, centered on how to implement China's national MLP for S&T, and thus enhancing its innovation capability, it says *"China will persist in innovation to raise the country's competitiveness comprehensively, in the fields of equipment manufacturing and information industry, the agricultural science, the energy exploration and saving, the recycling economy and environment and etc."* The document calls for the reform of China's present scientific, economic mechanisms and introducing new policies to facilitate and encourage innovation (Zhu, 2006).

5.4. Summary and discussion

In sum, the Chinese government has explicitly recognized that it is imperative for China to transit towards green development, take a leadership in green industries and strengthen domestic innovative capacity. That being said, the priority to develop the renewable energy industry through strengthening domestic innovative capacity has progressively risen to the top of the government's agenda. In essence, both China's low-carbon leadership and indigenous innovation idea embody an industrial development idea which has a higher priority than green development idea, and thus the implementation of renewable energy policy has been shaped by industrial policy. In this way the green development idea has provided a niche for a specific sectoral industrial policy.

6. Concluding remarks

China's policy approach to renewable energies shows that its top policy objective has been to develop the emerging renewable energy industry. This policy approach is particularly powerful because it is pursued as part of a broader Chinese effort to develop a series of industries that are considered strategically important in the longer term. It also coincides with a key policy objective of the Chinese government to shift from a low-cost manufacturing-based economy towards a more high-tech, high-value-added, innovative economy (Fischer, 2012).

However, this study shows that this policy approach has not effectively led to appropriate interactions between renewable energy policy and industrial policy, and this weakness has undermined the sustainable and healthy development of wind and solar PV power sectors to some extent. It is thus imperative for China to make adjustments to its policy approach to renewable energies in light of the long-term development strategy for renewable energy as well as the current problems existed in the process of renewable energy development.

In this respect, it is worth noting that there are a number of new key indicators intended to help China achieve greening initiative, within the time span of the 12th Five-Year Plan (2011-2015) released in March 2011. Among these, emission reduction is emphasized as a key indicator for the first time and there is a restricted target for non-fossil fuels to reach 11.4% of the total energy consumption by 2015, as a step towards achieving 15% of total energy. More importantly, the government will develop several mechanisms to stimulate the overall renewable energy drive, such as looking to the demand-side management rather than just production (State Council, 2011). Further, the *12th Five-Year Plan for Renewable Energy Development* issued by the NDRC in July 2012 specifies support measures for renewable energy deployment. These include the establishment of evaluation system for renewable energy development, the implementation of renewable energy electricity quota system, and the improvement of renewable energy subsidies and fiscal, taxation and financial policy meant to provide more supports for renewable energy generation and consumption (NDRC, 2012).

In spite of this, we must note that China faces many institutional constraints for effectively interacting renewable energy policy and renewable energy industrial policy. This could be a future research direction in the field of China's renewable energy policy study.

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