Comparing patterns of innovation in three new energy sectors in China

Xudong Gao, Xuguang Li, Jizhen Li
Tsinghua University

Tariq Durrani
University of Strathclyde

Abstract: In this exploratory paper we are trying to identify the key factors leading to the contrasting patterns of innovation and evolution of three new energy sectors in China: the wind energy industry, the solar thermal industry, and the solar PV industry. Using a case study method and following a historical perspective, we identified four factors affecting the different patterns of evolution of the three industries: cost effectiveness of technology, government support, value chain capability to support the industry, and leading firms' strategies. Cost effectiveness is not independent from but influenced by the other three factors, but it does seem to have played a more important role than the other three factors in starting a new industry. In addition, when cost effectiveness is not high at the beginning, a highly dynamic system could be developed if government support, value chain capability and firm strategy are mutually supportive. These findings have implications for the development of national innovations systems and industry "diamond". We also discussed directions for future research.

Key words: Innovation, Wind energy, Solar thermal, Solar PV, Policy, Strategy

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1. Introduction

In this exploratory paper we are trying to comparing the different patterns of innovation in three new energy sectors in China: the wind industry, the solar PV industry, and solar thermal industry. Although Chinese firms are making rapid progress in all three industries (China is number 1 in all 3 industries measured by production, for example), the three industries have followed different patterns of development.

For example, the wind industry is based on government policy simulated, strong domestic demand; the solar PV industry is an exported oriented industry; and the solar thermal industry is developed through the proactive promotion of a university spin off , including sharing its core technologies with other firms in the industry.

The result of development is also different. In the wind industry, an effective innovation system led by big power companies is being formed; the solar PV industry is struggling to survive; and the solar thermal industry has developed a highly competitive and innovative eco-system, and is moving up to a higher level from the low end market (the base of the pyramid, the rural market).

Because two of the three industries are still evolving rapidly, this paper is exploratory, although we hope we could offer some insights into the key factors leading to the different patterns of evolution of the three industries. Also because of the exploratory nature of the paper, we use a case study method (Eisenhardt 1989;

Glaser and Strauss, 1967; Yin 1989), with a historical perspective in mind (Kieser, 1994).

What emerged from our analysis are four factors affecting the different patterns of evolution of the three industries: cost effectiveness of the technology, government support, value chain capability to support the industry, and leading firms' strategies. These four factors are not totally independent but reflect different dimensions of the same evolution process: cost effectiveness could be regarded as the key element of initial conditions for industry evolution, while the other three factors shape the initial conditions, especially cost effectiveness. An industry's innovation and development evolve because of the interactions of these factors.

The findings of this paper have potential to make contributions in the following directors. First, factors affecting the development of national innovation systems (Freeman, 1988; Lundvall, 1992; Nelson, 1993; Pavitt, 1985) or local "diamond" (Porter, 1990) for new industries. The importance of national innovation systems and local "diamond" is well recognized. However, we still have limited understanding about how an effective national innovation system or local "diamond" is developed. Although this study is still at its early stage, it did find that cost effectiveness is of special importance. When cost is very high, it would be very difficult to build up an effective national innovation system or local "diamond".

Second, the study has policy and strategy implications. For example, the findings of this study suggest that it might be hard to build up an effective national innovation system or local "diamond" when an industry depends heavily on the

international market not only for selling products but also for buying raw materials, key equipment and core production processes.

2. The literature

We used a case study method in this study (Eisenhardt 1989; Glaser and Strauss, 1967; Yin 1989), so it's not necessary to follow any specific theories in the early stage of the study. However, we did draw on several streams of literature to help with our thinking.

The first stream of literature is about national innovation systems (Freeman, 1988; Lundvall, 1992; Nelson, 1993; Pavitt, 1985) and local "diamond" (Porter, 1990). This stream of literature emphasizes the importance of interactions among key players such as firms, universities and research institutes, government agencies, and other organizations. Some authors also point out the importance of firm strategies (Porter, 1990). This stream of literature suggests that we examine how collaborative relationships among major players emerge over time.

The second stream of literature is about factors affecting the emerging of new technologies, new products, and new industries (Christensen, 2000; Christensen and Rosenbloom, 1995; Hargadon and Douglas, 2001; Tushman and Rosenkopf, 1992; Utterback, 1994). For example, according to Tushman and Rosenkopf (1992), dominant designs for simple products mainly emerge based on technical factors, while dominant designs of complex products and systems emerge based on not only technical factors but also social, political and cultural factors. This stream of literature suggests

that we look at not only technological factors but also non- technological factors in examining the evolution of the wind industry and the solar industry.

The third stream of literature is about technological capability development in developing country firms through technology transfer (Amsden, 2001; Kim, 1997; Lall, 1982; Lee and Lim, 2001; Westphal, Kim, and Dahlman, 1985) or internal technology development (Foster, 1986; Hobday, 1987, 1990; Perez and Soete, 1988; Utterback, 1994). According to this stream of literature, the relationship between technology transfer and internal technology development should be examined in understanding the evolution of the wind industry and the solar industry.

3. Research method and data

As mentioned previously, in this study we used a case study method (Eisenhardt 1989; Glaser and Strauss, 1967; Yin 1989) to explore the differences in the three industries' innovation and development. Because we are examining the evolution of the three industries, a historical perspective is helpful (Kieser, 1994).

We collected data through two approaches: conducting interviews and utilizing secondary sources. The firms we interviewed are mainly equipment makers such as Goldwind, Dongfang, and Guodian United Power in the wind industry, solar PV cell makers such as Suntech, Baoding Yingli, CEEG, and power firms, solar thermal firms such as Tsinghua Solar. We also interviewed people from universities, industry associations, and government agencies.

Following data collection we conducted content analysis using the coding techniques suggested by Corbin and Strauss (2008). In this process, following Yin (1989), triangulation of data sources are employed to ensuring validity of the results and limiting the effects of respondent bias.

4. Key findings

We identified four factors affecting the different patterns of evolution of the three industries: cost effectiveness of the technology, government support, value chain capability to support the industry, and leading firms' strategies. In the following we report these factors in detail.

4.1 Cost effectiveness

The direct factor leading to the different paths of evolution of the three industries is differences of cost effectiveness: the low cost in the solar thermal industry made it easy for this industry to be developed without government subsidy, while the much higher cost of solar PV has hindered the development of this industry (Table 1). For example, in the solar thermal industry, China also transferred technology from developed countries such as Germany and Canada to make solar collector tubes and solar water heaters. However, the cost was very high and the market was very small. After Tsinghua Solar, a spin off from the Tsinghua University, came up with new technologies that could make solar collector tubes and solar water heaters at much lower cost, the market began to expand. Even today, the product cost in China is about 1/3 of that in Europe. In 2010, the market of the solar thermal

industry in China was about RMB7.35B (€ 920M). In Europe, the market was about €260M.

The situation for the Solar PV industry is different. Baoding Yingli has become one of the largest Solar PV cell makers in China and in the world. However, when it was established in 1998, its main business was to carry out a government supported 3MW solar PV project, a high tech demonstration project rather than a commercial project. At that time, high cost made it hard for solar to be commercially successful. In fact, Baoding Yingli's 3MW solar PV project got 20 million Yuan RMB subsidy from the government.

Similarly, when Suntech was established in 2001, the initially designed production capacity was only 3MW, although Mr. Shi, Zhengrong was able to improve production capacity to 10MW. Suntech also got financial support from the government. Most of the $8 million initial capital investment came from the Wuxi government. Constrained by the small domestic market, Suntech had to rely on the international market to grow.

In fact, even in 2011, according to our interview in one firm in Beijing, even after it got 50% government subsidy of investment, the firm's solar PV project still could not be profitable. This is common to the whole industry, and firms invest in solar PV because of strategic consideration rather than short term profitability.

However, for the international market, Chinese firms' cost structure was competitive enough. In fact, solar PV cell makers in China, including Baoding Yingli and Suntech were very lucky: they happened to be able to export to the rapidly

growing international market shortly after they went into operation. In 2004, China's solar PV cell production was 50 MW. It increased to 200MW, 400MW, 1088MW, 2600MW, and 4011MW in 2005, 2005, 2007, 2008, and 2009 respectively.

The cost effectiveness of wind industry is in the middle and the evolution of the wind industry also indicates the influence of cost effectiveness. The former Ministry of Electricity started to encourage the development of the wind industry in 1993 in order to change the energy structure and planned to reach an installation capability of 100MW by 2000.

However, the wind industry was developing very slowly and this goal was not reached until 2005. In addition to technological challenges, the basic reason was the high cost of wind. Compared with coal based electricity, the cost of wind power was about two times higher (0.8~1.2 Yuan RMB/kwh). For the power companies, the reform of the electricity industry in 1998 required that they reduce their power generating cost, so they did not have motivation to develop this new energy. For local governments, because the higher cost of wind had to be shared by local users, they also had no motivation to support the development this new energy (Shi, 2010).

In order to speed up the development of the wind industry, the central government implemented new policies and encouraged cost reduction in 2003. One policy is the requirement of localization rate. Before this year, wind equipment supply was dominated by MNEs and the cost was very high. The new policy required that a component localization rate of 50% (later on changed to 70%), measured by cost, be reached. Cost began to drop quickly, and the wind industry began to expand

dramatically. In 2003, the installation capacity was only 98 MW. Annual installation capacity reached 198 MW, 498MW, 1334 MW, 3287 MW, 6246MW, and 13750MW in 2004, 2005, 2006, 2007, 2008, and 2009, respectively. At the same time, local firms' accumulated market share changed from 11% in 2003 to 76% in 2009.

The evolution of the solar PV industry also indicates the influence of cost effectiveness. Since 2009 the development of the solar industry began to speed up. In addition to increased government support, a critical reason is cost reduction: in the first Solar Concession Program in 2009 the lowest bidding price declined to 1.09 Yuan RMB/kwh, and in the second Solar Concession Program in 2010 the lowest bidding price declined to 0.7288 Yuan RMB/kwh. Although the solar price is still much higher than wind, it's believed that the current price is acceptable.

4.2 Government support

When cost effectiveness is low, government policies could play crucial roles in the development of an industry. Except for the solar thermal industry, both the wind industry and the solar PV industry got important support from government policies, although the wind industry has got stronger support (Table 2). For example, according to the Renewable Energy Law, a basic principle in developing renewable energy is that it should be economically reasonable. Reflecting this principle, the government's planned installation capacity for wind has been much larger than that of solar: the planned installation capacity for wind in 2005, 2010, and 2020 are 760MW,

5GW, and 30GW, respectively, while the planned installation capacity for solar are much smaller: 65MW, 300MW, and 1.8GW.

To facilitate the fulfilling of the goals of installation capacity, seven 10GW level wind power bases were planned in Inner Mongolia (with two bases), Xinjiang, Gansu, Hebei, Jilin, and Jiangsu. The base in Shandong was added later on. The planning of the giant bases has attracted investment from both giant state owned power firms and private companies.

Differences in planned installation capacity have affected the realized installation capacity. For example, the annual installation in 2007 for wind was 3287 MW, and the accumulated installation was 5875MW, while the annual installation in 2007 for solar was 20MW, and the accumulated installation was 100MW. By 2009, accumulated installation for wind reached 25853MW, while that for solar was 300MW.

Reflecting the same principle, other favorable policies have been implemented in the wind industry earlier and more proactively than in the solar industry. For example, in August 2008, the Trial Management Measures for the Special Fund of Wind Power Equipment was announced. This is the first regulation dedicated to the support of renewable energy equipment making using central government's budget. According to this regulation, 600 Yuan RMB/kw could be awarded to wind turbine and component makers for the first 50 units of wind turbines (half of the support goes to the component makers). For the solar industry, government subsidy came in 2009 with the Golden Sun program, and 50% or more of the investment could come from

the government. Solar firms have also been able to get favorable bank loan support since 2010.

More importantly, the first Wind Concession Program started in 2003 by the National Development and Reform Commission (NDRC) with a total installation capacity of 200MW. By 2007, the installation capacity of the first 5 Wind Concession Programs had reached 3400MW. In contrast, the first Solar Concession Program began in 2009 with a total installation capacity of 10MW, much smaller and much later than the wind industry, and the second Solar Concession Program was in 2010 with a total installation capacity of 280MW. In December 2010 four Ministries began to proactively promote solar energy.

4.3 Industry value chain capability

In addition to the technology determined cost effectiveness and government support, the capability of the whole industry value chain, including the capability to reduce cost, is a vital factor in explaining the different patterns of evolution of the three industries. The industry value chains of the wind industry and the solar thermal industry have showed stronger capability in supporting industry development than that of the solar PV industry (Table 3).

We first look at factors making the wind industry value chain more effective in supporting industry development. The first factor is that key players in the industry could transfer their existing knowledge and capabilities easily to the new industry. A typical example is Sinovel, now the largest wind turbine maker in China. It entered the

wind industry in 2006, eight years later than Goldwind, the former industry leader measured by market share. However, because Sinovel has a strong mechanical engineering background, it leveraged its strong manufacturing capability and quickly surpassed Goldwind.

Similarly, Dongfang also entered the wind industry in 2004, much later than Goldwind, and has quickly become one of the industry leaders. A key reason is that Dongfang is a leading traditional electricity equipment maker in China and has developed very strong manufacturing capabilities.

The second factor making the wind industry value chain more effective in supporting industry development is related to the capabilities of local components makers. Except for converters and precision bearings, local firms are able to supply most components such as blades, gear boxes, generators, and metal structure parts with good quality. For example, two companies, Nanjing High Accurate Drive Equipment Manufacturing Group Co. Ltd (NGC) and Chongqing Gear box Company, hold a market share of more than 50% (Wang, Ren, Gao, 2010: 53-55).

The third factor making the wind industry value chain more effective in supporting industry development is the dynamics of the industry. Factors such as cost effectiveness, strong government support, and easy transfer of existing knowledge and capabilities have made the wind industry highly dynamic, and players in the industry could benefit from the each other's development.

In the wind industry, an effective "diamond" as described by Porter (1990) is becoming clear. For example, wind farm developers have requested the supply of not

only low cost but also high quality products. This sophisticated demand has forced components suppliers to speed up their localization process and increase their R&D investment. Giant wind farm developers are also working with universities and research institutes to develop new talents and new technologies. They are also working with various government agencies to work out appropriate policies to support the development of this industry.

In the solar thermal industry, the high capability of the industry value chain is closely related to the strategy of Tsinghua Solar: it shared its core technologies with other firms through training these engineers from these firms. Tsinghua Solar believed that it had to help other firms in the industry in order to grow itself, because the industry had to be started from scratch and only Tsinghua Solar had the core technology in the early days.

The second factor for the high capability of the solar thermal industry value chain is closely related to the strong capabilities of the suppliers and related industries (Porter, 1990). For example, a special kind of glass is needed for the development of the solar thermal industry, and a state owned company in Beijing happened to have the capability to supply this kind of glass with both high quality and low cost (Li, 2012).

The situation for the solar industry is very different. Although leading firms such as Baoding Yingli had some experience when they entered this industry, key equipment, key raw materials, and key knowledge and capabilities were new to most firms when they first entered this industry and had to be bought from other countries.

Localization process has also been slow. For example, even today 50% of the key raw material, poly silicon, has to be imported. When expensive imported equipment and process are used in making poly silicon, it has been hard to reduce cost. As a result, the solar industry value chain has not been able to offer cost effective products to support fast development of the industry.

The industry dynamics in the solar PV industry is also different. Without strong demand from local power companies, solar PV cell makers have been relying mainly on the international market. This market focus has made it hard for local firms among the value chain to take intentionally actions to build up the industry "diamond" (Porter, 1990). The whole industry is more fragmented, and firm relationships are more competitive rather than cooperative.

4.4 Leading firms' strategies

The fourth factor affecting the evolution of the three industries is leading firms' strategies (Table 4). In the wind industry, leading power firms such as Guodian have played important roles in shaping the industry development. After the restructuring of the Chinese electricity in 2002, Guodian realized that it could not compete with other giant power firms in traditional energies such as coal based electricity, and new energy, especially wind, was selected as the strategic focus. Guodian has not only made the development of wind a strategic goal but also developed clear strategies to reach this goal.

Guodian also came to the conclusion that reducing cost through increasing the scale of wind turbine and the installed capacity is the key for the development of wind. Directed by this understanding, Guodian has taken concrete measures, including the following, to quickly develop its wind business.

First, proactively build up wind farms by using MW level machines. Guodian realized that the benefits of MW level machines could be several times higher compared with KW level machines. Guided by this understanding, the scale of Guodian's turbines doubled between 2005 and 2009.

Guodian is also far ahead of other firms in building up wind farms. In 2009, the newly added capacity was 2600MW, accounting for 18.8% of the newly added capacity in China (the other top 4 firms' market share was 12.6%、11.9%、8.3% and 6.2%). In 2010, the accumulated installation capacity of Guodian increased to 8941MW (the second largest firm was 6331 MW), and the market share was about 20%.

Second, set up Guodian United Power to make wind turbines. Before 2005, most wind turbines made in China were at KW level, and MW level wind turbines had to be imported with high price. In order to speed up the transition from KW level turbines to MW level turbines and reduce cost, Guodian believed that it could be more effective by setting up its own turbine making unit than relying solely on outsider makers. This is the reason that Guodian United Power was set up in 2006. Now Guodian United Power has become one of the leading wind equipment makers in

China. It is not only the 4th largest wind equipment maker in China but also one of the leaders in technological innovation.

Third, emphasize the development of strong comprehensive internal capabilities. In addition to manufacturing capabilities, Guandian has been very active in building other capabilities internally. For example, it has developed strong wind farm design capability. Compared with outsourcing design to MNEs, Guodian's design team was able to save more than 200 million Yuan RMB in a wind farm project in Jiangsu province.

Guodian has also developed strong capabilities in operating wind farms. Also in Jiangsu, in one of its wind farms wind turbines could run more than 2200 hours, 200 hours more than other firms in the same region. Because of the strong operation capabilities, Guodian's performance is much higher than its competitors. In 2008, its market share measured by installation capacity was about 25%, and its electricity from wind was about 1/3 of the whole industry.

Fourth, proactively collaborate with other organizations, including domestic universities and research institutes. For example, Guodian United Power has formed close collaborations with the Tsinghua University and the Chinese Academy of Sciences in developing grid friendly wind turbines. Guodian is also very active in working with other organizations and the government to address challenges such as over-competition in wind equipment manufacturing in the development of the wind industry.

In the solar thermal industry, the Tsingnua University or more precisely, Tsinghua Solar, a spin off from the university, has been the key driver of the industry. R&D by Professor Yin Zhiqiang's team since the 1970s has been the source of advanced technologies, and the largest solar thermal market in the world has been developed without government subsidy. For this reason, Professor Yin actually got the Achievement Through Action Award in memorial of Christopher A. Weeks in 2005.

It could be argued that Tsinghua Solar has been willing to play the leading role in nurturing the whole industry value chain through several strategies. The first strategy is to develop appropriate technologies to serve the local market. Specifically, the technologies are advanced but the cost must be low. The goal is challenging but the market is real and huge.

The second strategy, as discussed previously, was to share its core technologies with other firms in the early stage of the industry's development. This significantly lowered the entry barriers and created favorable conditions for the industry to realize fast expansion: a lot of players, intense competition, growing "diamond" (Porter, 1990).

The third strategy was to avoid direct competition with other firms. For some time, in order to attract more firms to get involved in the solar thermal industry, Tsinghua Solar chose to focus on making intermediary products only (solar thermal tubes) and did not get involved in making final products (solar thermal water heaters). The signal was clear: final product makers did not have to worry about Tsinghua

Solar's taking advantage of potential synergies between intermediary products and final products.

Compared with the wind industry and the solar thermal industry, the solar PV industry has been focusing mainly on the development of the international market. For this reason, leading firms' value chain collaboration occurred much later in the solar industry. It was stimulated by the first Solar Concession Program in 2009 that leading firms in this industry began to seriously think about industry wide coordination and collaboration in order to reduce cost significantly (to less than 1 Yuan RMB/kwh).

5. Discussion and conclusion

We started with the question of why the wind industry, the solar thermal industry, and the solar PV industry in China have followed different paths of innovation and development. Using a case study method (Eisenhardt 1989; Glaser and Strauss, 1967; Yin 1989) and following a historical perspective (Kieser, 1994), we identified four factors affecting the different patterns of evolution of the three industries: cost effectiveness of the technology, government support, value chain capability to support the industry, and leading firms' strategies.

Because of the exploratory nature of this study, we are reluctant to develop a model or even a framework to explain the three industries' evolution in China. However, the four factors do indicate some patterns. First, although cost effectiveness is not independent from but influenced by the other three factors, it does seem to have

played a more important role than the other three factors in starting a new industry. Lower cost of the wind industry and the solar thermal industry made it much easier for them to be developed than the solar PV industry.

Second, when cost effectiveness is not high at the beginning, a highly dynamic system could be developed if government support, value chain capability and firm strategy are supportive. In the wind industry, these three factors have contributed to the continuous reduction of cost, and thus effectively facilitated the rapid development of the wind industry in China.

In the solar PV industry, the situation is very different. Policies of the central government were not effective before 2009. The required knowledge and capabilities for solar PV are new to most firms in the industry and thus the vale chain capability has been weak. Although leading firms such as Baoding Yingli have been active in reducing cost, they do not face as strong pressure as the wind firms as their market is mainly international. Accordingly, the solar industry has not developed as quickly as the wind industry and the solar thermal industry in China.

The findings of this paper have important theoretical and practical implications. For example, these findings offer some insights into the development of effective national innovation systems (Freeman, 1988; Lundvall, 1992; Nelson, 1993; Pavitt, 1985) or local "diamond" (Porter, 1990) for new industries. Although many technical, social, political and cultural factors are at work (Tushman and Rosenkopf, 1992), some factor or factors such as cost effectiveness are more important. Other

factors affect the building up of effective national innovation systems or local "diamond" mainly through their influence on this dominant factor.

The findings of this study also suggest that both technology transfer (Amsden, 2001; Kim, 1997; Lall, 1982; Lee and Lim, 2001; Westphal, Kim, and Dahlman, 1985) and internal technology development (Foster, 1986; Hobday, 1987, 1990; Perez and Soete, 1988; Utterback, 1994) are important for developing country firms' capability development. However, according to this study, if the transferred technologies are not effectively localized, they could still help with export to developed countries but their contribution to the development of local industry, or more accurately, national innovation systems or local "diamond" would be limited. In this sense, technology transfer must be complemented by internal technology development, and internal technology development must play increasingly important roles in the development of local industry.

This paper raised a lot of questions for future research. For example, from a government policy perspective, what kinds of policies are more appropriate? This study seems to suggest that the policy of supporting strong research that is closely linked to the country's specific context in universities could be most effective. Of course, more research is needed to see if the solar thermal industry model could be generalized to other settings.

Another question is how could firms develop and implement effective strategies in a rapidly developing environment. A rapid changing environment creates a lot of pressure for strategic management. In our research we observed that firms find

it hard to make a balance between developing capabilities and capturing market share. Some have chosen to focus on market share using mature technologies, while other firms have chosen to develop new technologies even if they have to lose market share.

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Table 1 Cost effectiveness of the three industries

	Price for consumer or Power companies' purchasing price of new energy	Profitability
Solar Thermal	● Much lower cost and price than imported products or products based on technology transferred from developed countries. Cost is about 1/3 that of Europe.	Product makers profitable
Wind Energy	● Lowest purchasing price determined through competitive bidding in the first Wind Concession Project in 2003: 0.4365 Yuan RMB /kwh. ● Purchasing price determined by government regulation: 0.5~0.61Yuan RMB /kwh (from 1 August, 2009)	Power firms profitable
Solar PV	● Lowest purchasing price determined through competitive bidding in 2009：1.09 Yuan RMB/kwh. ● Lowest purchasing price determined through competitive bidding in 2010 ： 0.7288 Yuan RMB/kwh.	Power firms not yet profitable

Table 2 Government support

	Wind Energy	**Solar PV**
Renewable Energy Law	Wind was given higher priority for development than solar because of lower cost	Solar was given lower priority for development than wind because of higher cost
Planned installation capacity	Big: 2005/760MW; 2010/5GW; 2020/30GW	Small: 2005/65MW; 2010/300MW; 2020/1.8GW
Timing of Concession Program	First came in 2003	First came in 2009
Special Fund support	600 Yuan RMB/KW for the first 50 Units of turbines (2008)	50% or more of investment could come from government subsidy (2009)
Localization rate requirement	First 50%, than 70%.	No requirement.

Table 3 Value **chain capability**

	Wind Energy	**Solar Thermal**	**Solar PV**
Cost of products	Market price for wind turbines dropped from 6200 Yuan RMB /kw in 2008 to less than 4000 in 2010	Significantly lower than imported products	Market price dropped but still much higher than wind
Support of expansion	Could support fast and large scale domestic expansion	Could support fast and large scale domestic expansion	Constrained by import of expensive raw materials and technology transfer
Local industry system	Effective national innovation system and industry diamond basically formed	Effective national innovation system and industry diamond basically formed	Effective national innovation system and industry diamond not yet formed

Table 4 Leading firms' strategies

	Wind Energy	**Solar Thermal**	**Solar PV**
Nature of leading firms	(Integrated) users (power firms) such as Guodian	Technology leader/Tsinghua Solar	Makers (solar PV cell firms) such as Baoding Yingli and Suntech
Capability development	Balance capturing market share and development of strong internal capabilities, including technology capabilities	Balance capturing market share and development of strong internal capabilities, including technology capabilities	Emphasize technology transfer and capturing market share
Value chain coordination	Active coordination by users	Active coordination by technology leader/Tsinghua Solar	Limited coordination