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Powerful winds from the east
Explaining the fast development of the Chinese wind turbine industry

Master of Science Thesis in Management and Economics of Innovation

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Cover:
[Snapshot of the two authors' in-between interviews, Xiamen, China, spring 2011.]

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Work has a bitter root but sweet fruit

- Chinese Proverb

Executive summary

With a rising global energy need and a world suffering from pollution and depletion of natural resources, most countries have started to realize that the way we supply energy today will not be sustainable, or perhaps even possible, in the future. Increasing the use of renewable energy sources is necessary and the transformation of the energy system must be accelerated.

Being a country with basically no history of wind power until the beginning of 2000, China's transformation to becoming the world's leading wind power producer in both installed capacity and production of wind turbines is truly one of its kind. Today, China has an installed capacity of 42,3 GW and three domestic companies on the world's top 10 list of wind turbine manufacturers. The Chinese turbine manufacturers are now looking to venture abroad and believe they have the right quality, experience and financial possibilities to start exporting turbines. The questions that we ask and which form the purpose of this master thesis are *"How has China been able to catch up so fast?"* and *"are there any factors hindering further growth of the industry?"*.

These questions were answered by applying the Technological Innovation System framework. The framework comprehends structural components and functions which interact in a technological innovation system and allows us to explain the past and present development in terms of actions within the system. We also look at policy measures, how it has affected the development and is used to address the system weaknesses. The master thesis was conducted during spring of 2011 in China and Sweden. A number of interviews were carried out with key actors and experts throughout the Chinese wind turbine industry.

Our main findings are that the Chinese government played a great role in the development of the Chinese wind turbine industry by setting clear and ambitious goals for an increased use of renewable energy sources and energy efficiency as well as acting as a powerful guiding hand starting early in the history of the industry. The period from the first grid connected wind farm in the 1980's to the adoption of the Renewable Energy Law (REL) in 2005 was characterized by introduction of many supporting mechanisms such as favourable governmental loans, grid connection policy, rules for localization of components in wind turbines and support for setting up of wind farms of domestically produced wind turbines. The regulatory measures led to entry of Chinese wind turbine manufacturers and creation of joint ventures, however the effects were not substantial. Nevertheless, lessons from this periods paved way for improvements and strengthening of the regulatory framework for supporting wind power which were focused in the REL, marking the take off of the Chinese wind turbine industry. Three important parts of the REL was the 70 % localization policy, large concession projects organized by the government and feed in-tariffs. The REL strengthened both demand and supply of wind turbines and ensured reasonable compensation, making the wind power industry attractive for producers and investors. A large and stable domestic market opened up a learning field for Chinese WT manufacturers where networks to international wind power firms and the licensing of WT designs have played an important part. However, the creation of the world's largest wind energy industry and fast expansion has led to a number of growing pains as the industry is lacking experienced talent and sufficient infrastructural components. The rapid development has also led to an overheated industry with fierce competition and dropping prices and margins, as a result putting quality and innovation at risk.

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Best regards,

Maria and Sandra

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1. Introduction

The introductory section includes the background of the project, a discussion of the problem we aim to study and a formulation of a purpose and research questions of the report. Furthermore, the scope and delimitations of the study and the structure of the thesis are outlined.

Background

In 2008, global electricity production was 20 181 TWh and the consumption has been increasing ever since. Fossil fuels, which negatively affect the environment, are currently the dominating energy source in the world and account for 68 % of total electricity production. The remaining production comes from low carbon power sources which include nuclear, hydro, geothermal, solar, wind, combustible renewables, waste and heat (IEA, 2010). As a response to the increasing electricity consumption, and related pollution from carbon fuels, many countries have set goals to increase their share of electricity produced from renewable and low carbon alternatives (Jacobsson and Lauber, 2006). These energy sources have grown steadily since the 1990's and in 2008 they accounted for 32 % of global electricity production (IEA, 2010). However, to be able to reach environmental targets renewable energy sources must grow at a much faster rate than today (Jacobsson and Bergek, 2011).

China has doubled its energy consumption since 2000 and by 2010 it passed the United States (US) and became the largest energy consumer in the world (U.S. EIA, 2011). The driving force behind the increased energy demand is the industrialization of the country and a rapid increase in privately owned cars (Cuiping et al., 2010; Andréasson, 2011 and Liu M., 2011). Energy use per capita is presently less than in industrialized countries, a third of the primary energy use in EU and a sixth of that in the US (Cuiping et al., 2010; People's Daily, 2010) but this is expected to change in the future as China's economy keeps gaining strength and more people are lifted from poverty.

China is currently depending heavily on coal and oil to fulfill its total energy demand (Wang, 2010). Roughly 70 % of the energy consumption comes from coal, 20 % from oil, 3.3 % from natural gas, 0.7 % from nuclear energy and remaining 6 % from Renewable Energy (RE) sources (Cuiping et al. 2010). The country is now the second largest oil consumer in the world after the U.S and second largest net importer of oil (U.S. EIA, 2011). As both coal and oil contribute to already alarming levels of pollution (Cuiping et al., 2010), it is not surprising that China is also the biggest polluter with the highest overall annual emission of greenhouse gases (Rediff, 2009). Today, sixteen of the world's most polluted cities are located in China and health related issues are becoming an increasing problem for China to tackle (Cuiping et al. 2010). Since there is a conflict between fast economic growth leading to an increased energy use versus the need to reduce global CO_2 emissions, China sees RE as an important source of energy for the future. Therefore, policies and regulations have been designed and investments have been made to aid the development of RE (Lema and Ruby, 2007).

In the last two decades wind energy has shifted into a commercial phase. Wind power (WP) is now competitive with conventional hydro and carbon-fuelled electricity in many regions due to continued reduction in generation costs, especially over the last five years (Cuiping et al, 2010). Today the installed capacity in the world is 200 GW and it is expected to reach 1000 GW by 2020 (GWEC, 2011).

The investments in the WP-industry are huge. Only in 2010, 70.4 billion Euro was invested in WP globally and the majority of the investments were made in China. The Asian market is expected to grow continually and overtake Europe as the region with largest total installed capacity by 2013 (GWEC, 2011). The political commitment in China to develop the country's wind resource is strong and has been underpinned by policies in favor of WP development which has lead to exceptional growth in the sector. In 2010, the accumulated installed WP in China was 42.3 GW compared to 40.2 GW in the US and China now stands for one fifth of the total installed capacity in the world (GWEC, 2011). China thereby became number one in accumulated installed capacity and the same year accounted for more than 50 % of the world market for new wind turbines (WWEA, 2011). In their 12th Five-Year Plan the Chinese government has set an official target for WP development to reach 200 GW installed capacity by 2020 (GWEC, 2011).

The Chinese government has also recognized an economic opportunity of creating a strong domestic wind turbine (WT) manufacturing base (GWEC, 2011). Europe and the US have been leaders in the WT industry but during the past ten years, China's WT industry has expanded rapidly. Today, four of the ten largest WT-producers in the world are Chinese[1] (BTM Consult, 2011). What is interesting with the rapid advancement of China's WT-producers is that they started producing WTs in large scale in the beginning of 2000, some as late as 2006, and has now advanced into the top ten-list in the world. This process has not been driven by new technology, instead, the Chinese firms have been catching up with European and US firms.

Purpose

The process of catching up for the Chinese WT producers has been very rapid and we aim to investigate what has been driving this development and whether it is sustainable. Our purpose is, thus, two-fold, with our research questions being;

(1) How has the Chinese WT industry been able to catch up?

(2) Can the speed of the development of the WT industry in China continue or will the industry run into obstacles that will slow down the development?

Scope and Delimitations

This thesis will cover the development of the Chinese WT industry and focus will be on the period from 2000 up until today, which is when the industry has experienced rapid growth. A WT manufacturer is defined as a company which does the final assembly of turbines before delivery to a WT operator or investor. They can produce all or none of the components themselves and do any amount of assembly. Our main focus will be on the largest Chinese WT manufacturers since they represent the absolute majority of installed capacity in China and therefore it is most important and interesting to understand their development.

The Technological Innovation System framework (TIS), later described in the section *Analytical Framework*, is suitable for the study of China's WT industry and will be used to describe the

[1] Sinovel (11,1%), Goldwind (9,5%), Dongfang Electric (6,7%) and United Power (4,2%) (% of installed capacity globally in 2010)

development and to identify system weaknesses. Interviews have been made with Chinese WT manufacturers but also with other actors in the defined WT industry, such as foreign WT manufacturers active in China, suppliers, interest organizations and developers, in order to map the development and the factors behind it. When discussing policy we will look at how it has affected the industry but not assess whether policy as such is preferable or not in a developing an industry.

Structure

The remainder of the thesis is structured in five main parts starting with section two, *Method*. In that section the literature, framework and data collection method used for answering the research questions is described. This is followed by an explanation of China's industrial development in section three. The WT industry is placed in that development to create an understanding of the environment where the WT industry grew from. In the fourth section you will find analysis of the development of the Chinese WT industry and an assessment of how policies, actors and events have shaped the TIS. The fifth section analyses the system weaknesses found in the TIS. The remaining part of the thesis is a concluding discussion of the results from the analysis followed by reflections and suggestions for further research.

2. Method

This section describes the methodology and work process that has been used when conducting the study. The project can be divided into mainly three different phases; literature review, data collection and analysis, in the given order, although some activities overlap. All in all, the project ran over eight months between January and August 2011. Literature review and analysis were carried out in Sweden while data collection was done in China during April and May. This section starts with describing the literature review including an outline of the framework used in the study followed by a description of the data collection.

Literature Review

The literature review was an iterative process carried out continuously during the project but was especially focused upon in the beginning of the project. The main outcome of the review was an analytical framework that was used to guide the analysis of the Chinese WT industry. This framework is further described in the section, *Analytical Framework*. Once the analytical framework had been set we could look into the scope of our analysis, as was previously described in *Scope and Delimitations*, and subsequently evaluate and chose a suitable data collection method and plan the data collection.

Previous Research on Industrial Development

In order to be able to analyze China's WT industry there are two main bodies of literature that need to be consulted; one is on industrial development, especially in a catching-up situation, and the other is on what specific approach to use when analyzing China's WP development. Literature was sourced through searches in databases, newspapers and also at energy, WP and WT organizations' homepages.

There is a broad base of literature covering industrial development. What is commonly emphasized is the different stages an industry must go through (Utterback, 1994 and Tushman et al, 1997), sometimes referred to as nursing, bridging and mass market (Bergek and Jacobsson, 2006). Each step is characterized by different conditions and present different opportunities and difficulties for the industry, especially when it comes to technology and knowledge creation. The role of technological change for industry development is emphasized by Porter (1985), Cusumano et al. (1997), Utterback (1994) and Tushman et al. (1997). When it comes to developing countries' process of catching up with industrialized countries, it has been shown that policy plays a major role (Jacobsson and Bergek, 2006; Jacobsson 1993 and Jacobsson and Alam, 1994). The catching up literature is very relevant for China's WT industry as China has, in a very short time, been able to raise companies that are now among the top ten in the world.

The success or failure of firms in an emerging market is impacted by a large number of actors, networks and institutions[2] (Van de Ven, 1993; Porter, 1998 and Bergek et al., 2008). When analyzing the Chinese WT industry we will therefore use a systems perspective which will allow us to grasp the broader picture and understand system functionality. One framework which is far developed and

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[2] Institutions are regulations, norms and values and regulate interactions between actors. Institutions influence how actors perceive the environment and affect their decisions and behavior.

has been used for this purpose is the Technological Innovation System (TIS) framework. The framework has been applied to analyze European WT-industries as well as other industries (Jacobsson, 2008; Jacobsson and Bergek, 2004; Jacobsson and Lauber, 2006; Johnson and Jacobsson, 2003 and Suurs and Hekkert, 2009).

The framework is centered on a certain technology which forms the basis of a new industry. The TIS consists of structural components; actors, networks, technology and institutions that interact within the boundaries of the TIS. The performance of a TIS can be described in a number of key functions. The functions are either strengthened or weakened by changes in the structural components. The TIS may influence the individual firms by impacting on how e.g. markets and legitimacy are formed as well as how resources are allocated (Bergek et al., 2010) and the functions can also be impacted by factors exogenous to the TIS. By using the TIS framework we will be able to find both inducement and blocking factors acting on the system and affecting the firms and actors in different ways. During our initial literature review we came across a number of studies regarding China's wind energy development, although there were no studies that emphasized the TIS framework in particular. We therefore believe we can greatly benefit from earlier studies while still adding to the previous research by applying a different perspective and up to date information. The literature on catching-up and TIS was used to develop a guiding framework for our analysis. The framework is described in following section.

Analytical Framework

The idea that a firm's success or failure relies only on its own functions and strategy has since long been disproven (Jacobsson and Bergek, 2004). It is suggested that a single firm's strategic options are also shaped by environmental factors surrounding the firm, and which influence how competitiveness of the firm is built and the way innovation occur. When describing an industry with a starting point in a specific technology, referred to as a TIS; collaborations, regulations and customary practices all interact and are subject to change as the political and economic environment or technological opportunities change (Bergek et al. 2010).

In Hellsmark and Jacobsson (2009), a TIS is defined as "…*a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or new product*''. A system is then components interacting in different processes within boundaries (Bergek et al. 2009). These processes can be identified at two levels, a structural and a functional level where the functional level depends on changes in the structural level and exogenous factors. A schematic view of a TIS can be seen in Figure 1 on next page.

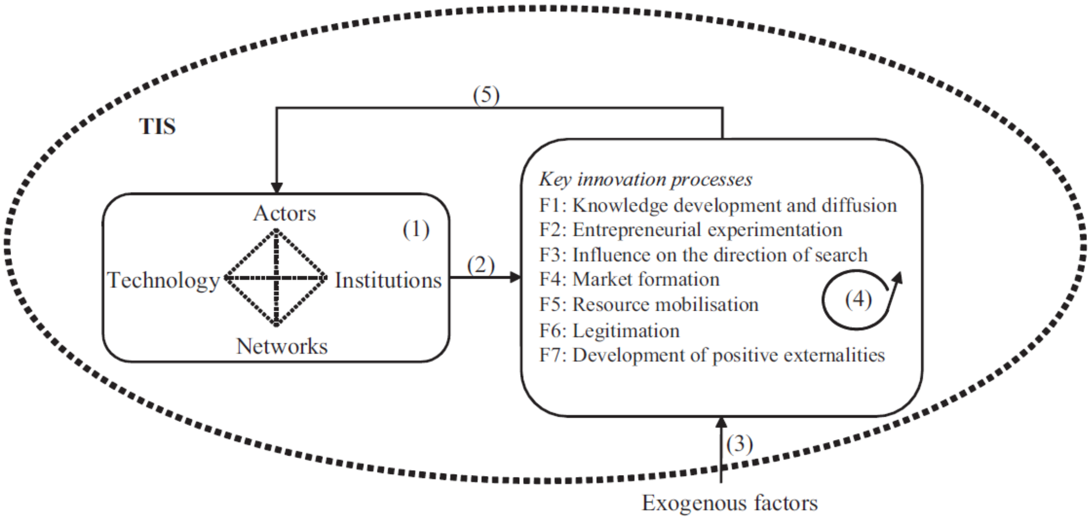

Figure 1. A schematic representation of the dynamics of a Technological Innovation System (Hellsmark and Jacobsson, 2009)

The structural level encompasses the components that make up the TIS, namely actors, networks, institutions and technology. Actors are firms, government bodies and other organizations along the whole value chain. Together with public bodies, universities, influential interest organizations such as industry associations and non-commercial organizations, and also venture capitalists and standard setting organizations, they constitute the important actors who shape the dynamics of a TIS. Networks may come in the form of social, political and learning networks between the actors, the latter consisting of both user-supplier networks and industry-academia networks (Bergek et al 2008). Institutions involve regulations, norms and values and regulate interactions between actors and may also influence the actors' perception of the technology and affect their decisions (North, D.C., 1994; Edquist, C. and Johnson, B., 1997). Finally, technology is the accumulation of knowledge both encoded and in artefacts. It is, thus, both a structural entity and the output of a TIS (Bergek et al., 2008).

The second level refers to what is achieved in the TIS, referred to as *functions* by Bergek et al. (2009). There are seven functions and the first function described is *Knowledge development and diffusion*, which concerns how technology or knowledge is evolved and diffused throughout the TIS, which also can be compared to the term learning. Learning and knowledge creation can happen at firm level, industry level and at a more general social and scientific level. Key actors in this function are firms, universities, government labs, standard setting organizations and research institutes, to mention a few. Another function is that of *Influence on the direction of search and identification of opportunities* which entails how firms perceive and exploit new opportunities. This can be a problem since not all opportunities present themselves in a clear and defined manner. Therefore, identification of opportunities and articulation of demand may be in need of sufficient incentives for firms to search for opportunities and make necessary investments. The activity of searching for new opportunities can be both looking into competing technologies as well as using a known technology in a new application area or industry.

Closely related to this is the function *Entrepreneurial experimentation and management of risk and uncertainty*. As in all novelties there is often a presence of risk and uncertainty in emerging technologies and industries. Risk is defined in the framework as an outcome of an innovation that, although it might be known, can have varying results. Uncertainty is then that the outcome may also be unknown. It is important that both risk and uncertainty is managed by government and policy in order to reduce or diversify it. One way is to encourage entrepreneurial experimentation so that direction of search goes into many different directions and technological solutions and thereby, spreads the risk, instead of putting all eggs in one basket. This can be done with government funding and subsidies or in state owned laboratories for example.

Market formation is the fourth function. It entails articulation of demand by customers and the formation of a market where suppliers and customers can meet. The articulation of demand can be weak in a newly formed TIS due to low price/performance, lacking standards or other uncertainties. In order to strengthen market formation it is important that there are early, so called nursing markets, which allow both customers and suppliers to learn and the technology to develop. These may later turn into bridging markets in the up-scaling phase where more actors enter the TIS and finally the technology may enter a phase of mass market.

Resource mobilization is the fifth function which involves the ability to finance investments, build infrastructure, create production systems and find human resources, necessary to support the development of the new technology.

The sixth function, *legitimation*, involves how the technology is accepted by society. Many factors are involved as legitimacy is a result of whether the new technology is considered to be desirable and in compliance with relevant institutions. Legitimation is strongly related to the other functions as a strong process of legitimation increases the probability of resources being mobilized, affect how markets are formed, experiments undertaken, the direction of search and how knowledge is created. Political networks, strong actors or advocacy coalitions help form legitimacy, although the scale of their success depends on available resources as well as the perception of the anticipated future of the technology.

The final function described by Bergek et al (2009) is the *development of positive externalities* which is more a result of all the other functions as the TIS develops and evolves. As the market takes form and demand increases new actors enter and may further legitimate the technology which in turn may lead to increased mobilization of resources. More actors mean possibility for division of labor and increased specialization and as a result, increased knowledge development and decreasing costs which in turn gives further incentive for more actors to enter the TIS.

The functions are not independent but interact with each other and in turn feed back to the structure. Functional interrelatedness that causes a positive development in one or several functions may spill over to other. The spill over from the functions may then cause positive feedback loops and become virtuous cycles. However they may also cause vicious cycles if the structure is weakened by poorly developed functions (Hellsmark and Jacobsson, 2009).

The functions are dependent on the structural components and so the characteristics of the structure affect the strength of the functions as do influence from external factors. It is then the technology, actors, networks and institutions active in the TIS and exogenous factors which may either block or support the formation of the system. A system is defined as components interacting in within boundaries and so, failing components or connections within a system are known as system weaknesses (Bergek et al., 2009).

The formation and growth of a new TIS, thus, involves four structural processes; accumulation of knowledge and artifacts, entry of firms and other organizations, formation of networks and institutional alignment (Hellsmark and Jacobsson, 2009). Actors form the structure, and their actions, that change it. Networks are formed between actors as the TIS develops, both learning networks such as user-supplier networks or industry-academia networks and political networks (Bergek et al., 2009). The latter may affect institutions when they gain more political strength. As the TIS takes form, institutions need to be aligned to conform to the needs of the new technology (Carlsson and Jacobsson, 1997; Freeman C. and Louca F., 2002). It is important to know that institutional alignment implies that firms in a TIS not only compete amongst each other in the market, but also to gain influence over institutions (Van de Ven and Garud, 1989).

As for all novelties there are many uncertainties involved with innovation and new technologies. In order to reduce these uncertainties and help strengthen the structure and support formation of the TIS it becomes necessary to address failing structure or missing components with policy. This framework can be used as a focusing mechanism to find key weaknesses for guiding policy makers in their efforts to specify key policy issues (Bergek et al., 2008). For this study it has been used as a checklist to find the key functions and structural components which have had impact on the development of the Chinese WT industry, as well as identifying the most important policy measures that were undertaken. It is also used to identify the key system weaknesses in the defined TIS.

Adopting the TIS framework to a catching up situation

The TIS framework is a useful tool for analyzing technological development from a system perspective and identifying system weaknesses. However, the framework may work slightly differently in a developing country context with catching-up processes. From a developing country perspective, industrialization is less focused on developing systems that are new to the world, and more on catching up (Jacobsson and Bergek, 2006). In a catching up situation, it may be easier to imagine future use of capabilities than in leading countries but capabilities may also be used in different ways than in already developed countries. In such an environment the functions of the system may be slightly different which need to be taken into consideration by policy makers. We will therefore describe the above listed functions from a catching-up perspective to convey how they may be different.

For example *Entrepreneurial experimentation* may not be about coming up with a new idea, product or process but realizing that an already existing one is possible to produce in the home country at low cost. However those types of experimentations may not come automatically but need some help on the way. Markets are many times good at signaling profitability of already existing activities but not of those that not yet exist. A second problem is that investments may be smaller than desirable as losses are often tied to the entrepreneurial first movers while gains are shared by many, making investors reluctant to invest early in an industry (Hausmann et al., 2005; Jacobsson and Bergek, 2006).

When *influencing the direction of search* governments may have large impact on what information is available and how opportunities are perceived. They can, for example expand the decision-maker's perceived opportunity set by filling information gaps. *Knowledge development* in catching up countries is often based on imported technology. Therefore, the ability of firms to absorb and learn the technology is very important for *knowledge development* in firms and surrounding infrastructure. One important aspect of *institutions* is that of forming standards. When standards are formed and diffused efficiency is enhanced and barriers to development such as bad reputation due to e.g. poor quality may be reduced. Hence, regulations and standards not only help with *knowledge development* but with the *legitimation* process (Jacobsson and Bergek, 2006).

There might be a need for protected market spaces in order for an industry to take form in a catching-up context. These may be formed by quantitative import restrictions which strengthens the home market and creates room for a nursing or bridging market for domestic suppliers. However, any protective policy measures should be temporary. In Jacobsson and Bergek (2006) we can read that a system weakness was found during the 1980s in the form of poorly developed design capabilities in machinery firms in Korea which was a weakness in *knowledge development*. Policy makers tried to improve the situation by making changes in *institutions* and *actors* and expanding the educational system and R&D programs together with a trade liberalization that forced firms to develop their own design capabilities. But in complex products, trade liberalization is only one phase in a long process of fostering firms and is highly dependent on how previous policy regimes have succeeded in creating a powerful response capacity among firms (Jacobsson and Bergek, 2006).

Resource mobilization, such as human and financial capital, may be difficult in a developing country and is largely affected by a shortage of experienced engineers and scientists. However, this can sometimes be compensated by a larger volume of educated people (Jacobsson and Bergek, 2006). In Jacobsson's study of the machine tool industry in Korea, large funds were given to the industry at low or no interest rate and did not have to be repaid if the projects failed. This meant that the government absorbed the majority of the risk, allowing the industry to catch up and grow quickly (Jacobsson, 1986; Alam and Jacobsson, 1994; Jacobsson and Bergek, 2006).

Finally, in the *development of positive externalities* it has already been pointed out that early experiments are necessary in reducing uncertainties and generating information externalities about new opportunities. In addition to this, advocacy coalitions need to handle any political issues obstructing the process of *legitimation*.

In this study, the framework is applied to data collected in interviews and articles, where events from the past decade, are analyzed from a systems perspective in order to explain the WT industry's development. The purpose, which was outlined in the section *introduction*, had two main questions; "How has the Chinese WT industry been able to catch up?" and "Can the speed of the development of the WT industry in China continue or will the industry run into obstacles that will slow down the development?". The purpose will be achieved by applying the TIS framework to answer the following questions:

- Which are the structural components of the TIS, how have they evolved and interacted with each other?
- How have firms and policy makers influenced industry structure to improve its functions?
- Are there any system weaknesses and what structural components do they relate to?

Data Collection Method

The study is deductive as existing theory is used to structure empirical data in a way that lets us describe how the Chinese WT industry has emerged. Data was mainly collected through interviews which allow in-depth qualitative data collection. The information from interviews was complemented and triangulated with information from reports, articles and relevant homepages.

We developed interview questions based on the TIS framework to capture the structural layers and functions in the TIS, as well as inducement and blocking mechanisms. We started out with broad questions that subsequently were broken down into more specific ones. We chose to use a semi-structured interview guide with open ended questions in order to allow the interviewees to tell their own story. The main strength of the semi-structured interview was the ability to adapt the questions and order of questions according to the different interviewees. The interviewees were also asked to reflect and elaborate on more important issues, if needed. We developed a basic interview guide that served as our starting point for all interviews. The interview guide can be found in Appendix I.

To identify the actors in the industry we primarily used interview data, reports articles and made searches on the internet. During interviews the respondent was asked to identify actors mainly from an input-output perspective. Therefore we might have missed out on actors which are not directly connected to the value chain or that are not directly connected to the interviewed company. Another possibility would have been to use patents and search for technology existing in wind turbines, which was developed and tested by Holmén and Jacobsson (2000). The method identifies actors who might not yet be active in the WP-industry but who possess knowledge applied in wind turbines and may move into the industry later. That would have made it possible to identify more actors than we have. However, as China is in a catching up situation and currently has an abundance of WT-producers, identifying them is more straight-forward compared to in an emerging industry. In newspapers, magazines and academic publications we found large amounts of information regarding the largest actors in the industry.

Sampling

We focused on the largest WT manufacturers for our interviews, as they make up the main part of the Chinese WT industry.[3] We interviewed mainly Chinese manufacturers but also a few international companies with production and sales in China. This enabled us to capture possible differences in how domestic and foreign producers have perceived the development as well as what effects policies have had for their development. For a complete list of interviewees see Appendix II. We started out with a few interviews and used a "snow-balling" method where we asked the respondents to help us with connections and ideas for more interviews as the project proceeded. This method was suitable for the business environment in China, as it turned out to be difficult to arrange interviews without previous connections in companies and organizations. Recommendations therefore enabled many of our interviews.

We spoke to one person from each interviewed company, with a few exceptions. It was therefore important that this person had been in the company for a while to have knowledge regarding the company's development and the industry as a whole. The result of our study might be affected by

[3] The ten largest companies have 90% of the market share (Liu M., 2011).

the persons we interviewed. To avoid this problem we asked the same types of questions in all interviews. This allowed us to compare the answers and identify differences between different types of organizations as well as notice if we got the same answer to a question every time. Many overlaps in the answers suggested that we had captured the right picture and could feel satisfied with the number of interviews.

Chinese culture may have had an impact on our results. It is very important not to lose face in China and to agree on matters. Therefore, there was a risk that respondents might answer questions in a way they thought would make us satisfied and when in doubt perhaps make something up instead of admitting not knowing the answer. We tried, therefore, not to ask leading questions and let the interviewees tell their own story instead. This way we could avoid a situation where the respondent might give us incorrect information.

The interviews were recorded in order for us to go back to them later on in the process. Recording was not an issue and didn't seem to bother the interviewees. We believe the respondents felt they could speak freely even in the presence of a recorder and at some occasions a respondent asked us not to quote certain parts of the conversation which we have respected. A generic problem with interviews is the risk that our interpretation differs from what the interviewees meant. However, recording was a great help for us as in this matter as it allowed us to focus on what the respondent was saying rather than taking notes. We could therefore ask more follow up questions and dig deeper into certain aspects and ask the respondent to clarify and repeat things we were uncertain about. The interviews were transcribed shortly after the interview and key information and take-aways was written down and structured according to the TIS framework. The analysis therefore became a natural part of the process and started early on.

3. Industrial Development and Wind Power in China

In this section we start by making a few remarks on how China as a country has developed and how the country is managing its industrial development. Thereafter we describe China's energy policy with focus on renewable energy and place the wind power industry in its context.

Industrial Development in China

The basis for China's fast economic development in recent years was laid by Deng Xiaoping who came to power in 1978 after the death of Mao Zedong in 1976. Xiaoping introduced a number of reforms and gradually moved China from a planned economy towards a market economy.[4] China's transformation has been called a gradualism approach and Mr. Deng Xiaoping once described the economic reform as a process of "*going across the river by touching stones*", meaning that China "felt" its way forward rather than planned every detail in advance (Xu W., 2010).[5]

The reforms started with the agricultural reform in 1978 which privatized farming and gave the farmers the right to their land. Other reforms included giving State Owned Enterprises (SOE's) more autonomy, foster the development of individual and collective enterprises as supplements to SOEs and reduce the scope of central planning.[6] One of the most important aspects of the reforms was the opening of China to the outside world to expand foreign trade and investment and promote technological exchanges with foreign countries. China encouraged foreign firms to invest in China and set up manufacturing there. Some cities in China were made into special-economic zones with tax reliefs for investors and many cities along the Chinese coast have become extremely large and important production and shipping hubs (Xu W., 2010). Ever since the opening of China to the outside world in late 1970's, the country has had an outstanding economic development (Growth Analysis, February 2011). China quickly became an important trade country and by 1987, the volume of foreign trade increased to 25 %, and by 1988 to 37 % of GDP. In 2001, China joined the World Trade Organization (WTO), which gave another inspiration and pressure for China's further reform from outside. China's gross domestic product (GDP) grew an annual average of 9.67 % from 1978 to 2006 (Xu W., 2010).

China's Economy Today

One of the most important bodies of power in China is the State Council.[7] The State Council is the highest executive organ of State power and State administration and is responsible for China's

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[4] For a brief review of Chinas development and history before 1978, please see Appendix III.

[5] This is very typical for Chinese as they tend to think in an intuitionist way (Xu W., 2010).

[6] Reducing the scope of central planning was achieved by letting prices of more products be determined by the forces of demand and supply rather than central control, develop macroeconomic control mechanisms through the use of taxes, interest rates, and monetary policy and improve the banking and financial system (Xu W., 2010).

[7] The People's Republic of China rests on the following main bodies of power; the National People's Congress, the President of the People's Republic of China, the State Council, the Central Military Commission, the Local People's Congresses and Local People's Governments at various levels, the Organs of Self-Government of National autonomous Regions, the People's Courts and the People's Procuratorates (npc.gov.cn).

internal policies, diplomacy, national defense, finance, economy, culture and education. There are numerous ministries, commissions, organizations and administration bureaus under the State Council (english.gov.cn).

China has Five-Year Plans that act as blueprints, setting the direction of the economy and key targets for the country (MAKE Consulting, 3 Dec 2010). The plan is developed by the State Council and its commissions and the Five-Year Plan is one of the most important and influential political instruments for guiding China's development. The plan creates a political pressure downwards in the decision-making lines and to comply and reach the targets of the plan is very important for the evaluation of all individuals (Growth Analysis, February 2011). Earlier Five-Year Plans focused heavily on economic development and growth in GDP. China has seen a dramatic increase in wealth and welfare during the industrialization phase. However, there is unfortunately also a downside to the industrialization process. In the process of industrialization, China has subsidized goods like petrol, electricity, coal and food to prevent social instability.[8] Such interventions give clear negative environmental effects as China's industries pollute the environment including farmland and waters, more and more people drive cars which emit carbon dioxide, urbanization creates overpopulated cities[9] and big disparities in income between people from different parts of the country (Andréasson U., 2011; Growth Analysis February 2011).

Even though China has among the most modern environmental legislations in the world, the implementation of the law has not been able to keep up. Many of the polluting companies never face restrictions or punishments. This is partly due to lack of knowledge, expensive solutions, overlap and contradictions between national and local standards and widespread corruption. To avoid this problem the use of certification systems is increasing (Growth analysis, February 2011). Also the welfare system and laws concerning intellectual property rights are underdeveloped which create problems in the fast growing economy (Andréasson U., 2011).

The Chinese government has acknowledged many of the above mentioned problems and in the two latest Five-Year Plans there has been a shift away from prioritizing growth of GDP and focus is turned towards environment, innovation and high technology industry (Flash Note, MAKE Dec 2010; Andréasson U., 2011). China wants to get away from being "the factory of the world" and move to "designed and innovated in China" (Andréasson U., 2011).

China's Energy Policy

Energy is in China, as in many other countries, closely monitored and controlled by the government as it is a strategically important area for industrial development and vital for the security and welfare of the country. The Chinese government has a number of ministries and commissions to monitor the functioning of the energy system in the country. The most important is the central development

[8] China is gradually decreasing these subsidies. As an example, the price of electricity has been differentiated between a higher price during daytime and a lower night time price and taxes have been introduced which favor cars with low cylinder volumes (Growth analysis, February 2011).

[9] Every year 1-1.5 % of the Chinese population, that is 13-20 million people, leave the countryside to move into cities (Growth analysis, February 2011).

authority, National Development and Reform Commission (NDRC) under the State Council (Growth analysis, February 2011). The NDRC's functions are to study and formulate policies for economic and social development, maintain the balance of economic development, and to guide restructuring of China's economic system. The NDRC is also responsible for the National Energy Administration (NEA) which has the ultimate responsibility for energy in China (en.ndrc.gov.cn). The government sets targets and laws for industry, controls prices of electricity, controls many actors in the industry, such as power grid companies, and has large ownership shares in power companies and other firms.

The supply of electricity in China struggles to keep up with demand which has been increasing steadily lately. In the first quarter of 2011 the demand increased with 12.7 % and it is expected to continue at that level throughout the first half year of 2011. The increase in demand is largely driven by heavy energy using industries such as chemistry, iron and steel, construction and other similar industries. These industries are very important to China but they have been negatively affected by the shortage of electricity in the country (Growth Analysis, May 2011). One issue that has been important and will continue to be very important for the energy industry in the years to come is to realize a 20 % increased energy efficiency. It has been singled out as the most important environmental target for the coming five-year period (Tukia J., 2011; Growth analysis, February 2011). As mentioned before, reaching the targets in the Five-Year Plan is very important for all decision-makers. As an example many of the heavy energy using companies had to close down their production at the end of 2010 to reach China's energy efficiency goals in the Five-Year Plan. At the beginning of 2011 the production was restarted and many companies invested in even more production facilities which further increased the demand for electricity. Another reason behind the electricity shortage is that NDRC has set a roof for the electricity prices. As the price of coal has increased with more than 80 % lately the large electricity companies find it unprofitable to use all their production capacity for coal. The lack of electricity in combination with increased environmental targets creates a big need for new and environmental friendly electricity production (Growth Analysis, May 2011).

Development of Renewable Energy

In 2010, China became the largest investor in the world in the area of non-fossil energy with a total investment of 354 billion RMB (40 B €). The renewable energy industry in China employed 1,1 million people in 2008 and is expected to increase with 100 000 people per year. The most important driver for the industry is domestic demand (Growth Analysis, May 2011). By the end of 2015 renewable energy is targeted to reach 30 % of the country's energy mix, to be compared with the target of 18 % in 2009 (MAKE Consulting, Dec 2010). The 11th Five-Year Plan pointed out natural resource depletion as a challenge and created a firm base for the country's development of renewable energy. China invested 2 trillion RMB (230 B €) to save energy and reduce emissions and spent almost 40 % of a 4 trillion RMB (460 B €) economic stimulus package on green projects. China's 12th Five-Year Plan puts an increased pressure on the realization of the country's environmental ambitions (Growth Analysis, May 2011).

Renewable energy is seen as an opportunity to create sustainable economic growth and increase employment. The Chinese premier minister Wen Jiaobao has expressed that the accelerated development of a low carbon and green economy will create an advantageous and international competitive position for China. In the 12th Five-Year Plan, China invests 2 trillion RMB (230 B €) per year in seven new strategic industries; renewable energy, biotechnology, new-generation information technology, high-end equipment manufacturing, advanced materials, alternative-fuel cars and energy-saving and environmentally friendly technologies (MAKE Consulting, Dec 2010).

As was the case with the economic reforms, also environmental development is pursued on a gradual basis and the authorities often use demonstration projects to test new approaches. There is a deeply rooted skepticism among Chinese for trying new and unproven solutions. Therefore, pilot projects serve as a great opportunity to provide evidence of the stability and advantage of new solutions (Growth analysis, February 2011).

Wind power is one key area of renewable energy

Wind power offers a great opportunity for diversifying the energy mix, secure the supply of the ever increasing demand for energy as well as finding an alternative solution to expensive fossil fuel import. Environmental factors such as improving air quality and reducing the carbon foot print are also attractive aspects of wind power (GWEC, 2011). China has an abundance of wind resources which makes it a promising area for future development (Liu Y. and Kokko A., 2010).

China started out in late 1990’s producing small turbines and the development of the Chinese wind turbine industry during the past decade has been incredibly fast. The large wind power market in China has encouraged domestic production of wind turbines and components. The development is underpinned by favorable government policies supporting the growth of the domestic industry by making the necessary investments in the transmission needed to supply the electricity produced (GWEC, 2011).Today, China has already started to develop turbines with an effect of up to 5 MW for both land and sea based wind power (Hållén J., 2010). As mentioned before, four of the top ten largest WT manufacturers are Chinese and these are also beginning to expand to overseas markets.

In spite of Chinas large installed WP capacity, WP still only contributes a tiny part to the country’s total energy mix (Cuiping et al., 2010). The Chinese government has increased its support for wind power in the 12th Five-Year Plan through improved financial incentives, increasing renewable portfolio requirements and investments in grid. The Chinese authorities has also set a target of 150 GW installed wind capacity by 2020 and to drive the development seven cities have been selected to develop wind power bases, each having a capacity of at least 10 GW (MAKE Consulting, Dec 2010).

4. The Development of the Chinese Wind Turbine Industry

In this section, we use the TIS framework to analyze the development of the WT industry, using both literature and interview data. The development is described in structural and functional terms and explains the interaction between actors, networks, institutions and technology and the effects on the functionality of the system. We will start by explaining the most important institutional factors followed by a section describing the actors in the industry and the relations between them. Finally, we will describe the development of the technology in terms of sourcing, knowledge development and trends for development.

Institutions

China's dramatic economic development in recent years has created a need for more and greener energy. This is acknowledged in the change of direction in the two most recent Five-Year Plans where an increased focus is on environmentally friendly activities and a reduced focus on economic growth (Andréasson U., 2011). This shift in attitude in the Chinese government has led to an institutional change in recognizing the potential of WP, which in turn has had a great impact on the *legitimation process* necessary in developing a TIS. The government's strong ambition to change towards cleaner and more efficient energy supply to improve the highly polluted environment together with clear objectives towards WP send out powerful signals which consequently affect actors in the TIS (Andréasson U., 2011, Zeng B., 2011, Zhang F., 2011, Tukia J., 2011).

In the case of China, regulatory frameworks have been of outmost importance when it comes to shaping norms, beliefs and expectations of firms in the industry. In many other countries in the world, for example the US, regulations and policies change frequently due to political turbulence resulting in uncertainty of the long term support for WP (Liang X., 2011; Martin B. 2011; Tukia J., 2011). China is in some ways a special case as the country is a one-party state controlled by the CCP. The absence of elections means the government does not need to compromise in any decisions and the firms and individuals can trust that the government will carry through with outlined plans. This reduces the uncertainty of the regulatory framework promoting WP and assures actors in the industry that WP is safe to invest in (Tukia J., 2011). The actions of the Chinese government are therefore incredible important for the WT industry as the political uncertainty is reduced. This strengthens the function *legitimacy* which in turn facilitates *market formation* and *resource mobilization* as more firms dare to enter the industry and make investments. We will now go through the institutional changes that have been important for the development of the Chinese WT industry. The changes can be seen in Figure 2 on the next page.

Institutional Changes Before the Renewable Energy Law

The adoption of WP in China started in the late 1970's. Back then, WTs were not connected to the power grid but supplied electricity to individuals living in remote and rural areas. The first grid connected wind farms were constructed in the late 1980's. They were pilot projects using WTs imported from Denmark. Together with very favorable financial terms from the Chinese government and international mixed-credit loans[10] a demonstration stage of WP started and imported turbines

[10] Mixed credit loans are given to developing countries that are relatively credit worthy. They have low or no interest rates and are aimed at development projects in which they finance supply of equipment and other services.

were set up in many places throughout China. At this stage there were no domestic manufacturers of WTs and all turbines were imported from Europe and the US (Xia C. and Song Z., 2009; Han J. et al., 2009).

Already in 1994 China published the regulation of Management of Grid-Connected Wind Farms which was created to enforce compulsory grid connection, meaning that grid companies were obliged to purchase all energy produced from wind farms, giving incentive to invest more in WP (Cuiping et al., 2010). This secured a market for produced WP, thus strengthening *market formation*. The increased cost was to be shared among all grid companies and added to the sales price of power. The price was to cover the WP producers' material costs, wages, repayment of loans and result in a 15 % profit for the producer. However, the regulation did not have the formal status of a law and grid operators were not keen on bearing the extra costs for buying WP (Liu Y. and Kokko A., 2010).

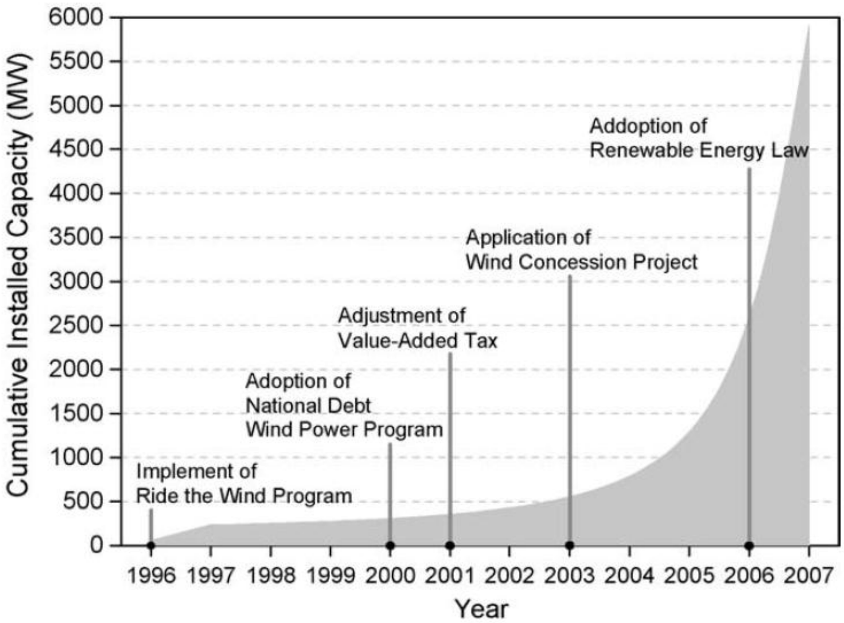

Figure 2. Political milestones for WP development in China (Xia C. and Song Z., 2009).

In 1996 China implemented the Ride the Wind Program which aimed to import WT technology from abroad and create a domestic WT production industry. Between 1996 and 2000 WP projects approved by the State Development and Planning Commission (SDPC) was to have 40 % locally produced components which facilitated the creation of joint ventures between domestic and foreign firms and effectively imported WT technology to China. By 2000, four pilot projects with a total capacity of 73 MW had been completed (Xia C. and Song Z., 2009).

To further drive the development of a domestic WT manufacturing industry the State Economic and Trade Commission (SETC) introduced the National Debt Wind Power Program. Favorable loans were given to domestic WT manufacturers to set up wind farms with locally produced WTs. Another measure to encourage investment in WP was a reduction of the value-added tax (VAT) for WP from 17 % to 8,5 % in 2001 (Xia C. and Song Z., 2009). In the period between 2000 and 2005 domestic WT manufacturers started to emerge (Han J. et al., 2009), showing that the programs helped *legitimize* the industry which had an effect on the *direction of search, entrepreneurial experimentation*, *market* *formation and mobilization of resources*. The institutional changes also had an important effect on the function *knowledge creation* as the Chinese manufacturers learned WT technology and how to produce WTs.

The NDRC initiated concession projects in 2003 to aid the commercialization of WP. This method had earlier been used in China's petroleum and natural gas industries. Relatively large WP projects (100 MW) were chosen to encourage large scale adoption of WP. The government guaranteed access to the grid and a fixed price that was to be decided through a bidding process (Xia C. and Song Z., 2009). These measures reduce market uncertainty for investors and strengthened the function *market formation*. In China, total capacity of concession bidding projects was around 12.15GW in 2011, including the first offshore concession bidding (Zeng B., 2011).

Renewable Energy Law

The regulations was later reaffirmed and strengthened in the Renewable Energy Law (REL) which came into force in February 2005, and that now serves as the central piece in the framework for promoting WP (MAKE Consulting, 4 Mars 2010; Zeng B., 2011). In addition to compulsory grid connection the REL introduced fixed tariffs for renewable energy, a national development and utilization plan and technical standards for renewables (Cuiping et al., 2010). This removed risks for investors and gave incentives for development of WP, which strengthened the functions *market formation*, *entrepreneurial experimentation and management of risk and uncertainty*. The REL contributed in many ways to the take-off of the Chinese WT industry and the installed capacity of WP increased dramatically, as can be seen in Figure 3 below (Liu M., 2011; Liang X., 2011).

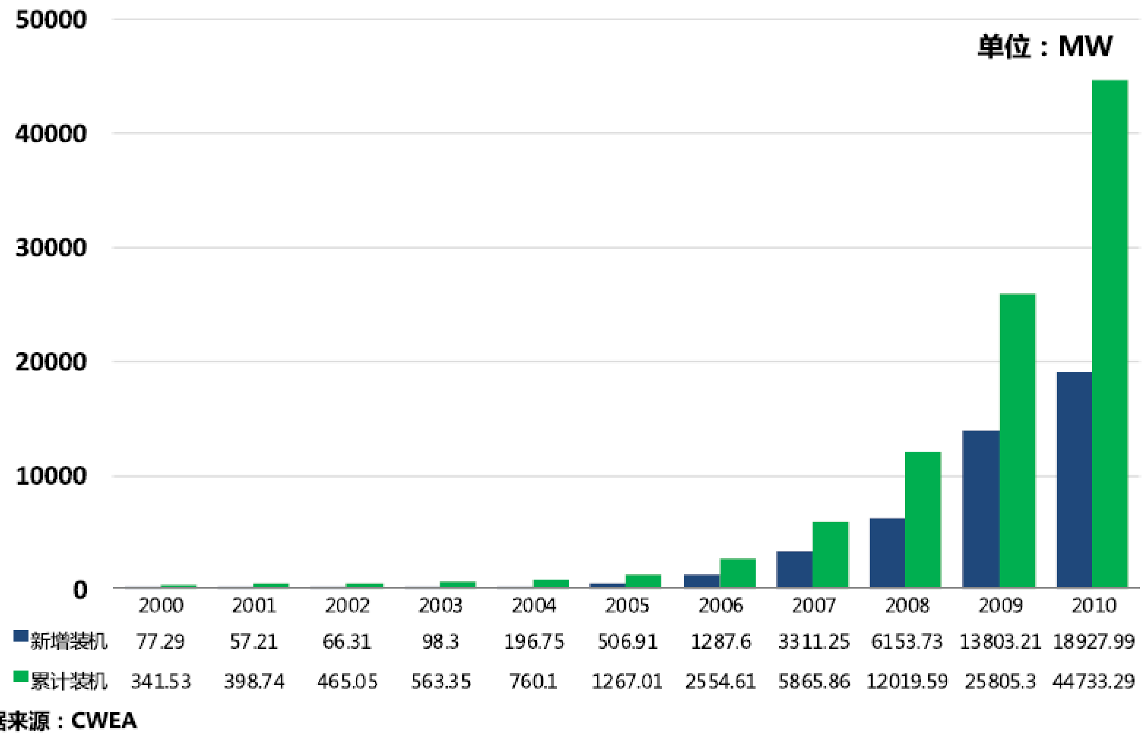

Figure 3. Installed WP capacity in China 2000-2010 (creia.net). Green: Cumulative installed capacity, Blue: New installed capacity

The most important features of the REL for WP are grid connected pricing and cost-sharing principles, concession projects, feed-in tariffs, renewable energy quotas, domestic component policy, public finance policies, preferential tax policies and grid connected WP policy, which will be described in more detail below.

Wind Power Grid Connected Pricing and Cost-Sharing Principles

One of the most important aspects is that prices for grid-connected RE shall be decided by the pricing authorities of the State Council and be adjusted to different types of RE. As mentioned before, power grid enterprises are demanded by law to buy all energy supplied by WP. The costs incurred by the purchase in excess of conventional electricity, including power grid transmission costs, construction investments, operation and maintenance can be recovered by increasing the price of electricity. The added costs are shared equally by all power users in the nation (MAKE Consulting, 4 Mars 2010).

Concession Projects Are Used to Develop a Feed-in Tariff

In 2006 regulations of concession projects was reaffirmed stating that prices for grid-connected WP in large wind power projects announced by the state should be determined by competitive bidding. The idea was for the State Council to observe the bidding process and use the quoted costs as guidance to develop a future feed-in tariff (MAKE Consulting, 4 Mars 2010; Cuiping et al., 2010, Zhang B., 2011).

The feed-in tariff was effective in July 2009 and the country was divided into four different areas with different tariffs depending on wind resources and conditions of construction projects. The better wind resource, the lower is the compensation. The difference between feed-in tariff and coal-based electricity prices varies greatly. In most cases the feed-in tariff is more than three times that of the coal-based electricity price, particularly in the northern parts of China where coal prices are low. In the south-east and coastal areas where coal prices are higher due to long transportation and where wind resources are favorable, the feed-in tariff comes rather close to the coal-based price (Cuiping et al., 2010). The feed-in tariffs creates an incentive for building wind farms as it reduces market uncertainties for investors and ensures profitability upon investment. Thus, increasing *resource mobilization* and *market formation* and further facilitating *influence on the direction of search* and the development of Chinese WT manufacturers.

70 % domestically manufactured components in concession projects

In 2005, the government introduced a restriction stating that participants in concession projects were to have WTs with 70 % domestically manufactured components. This bolstered domestic production of complete turbines and of components but the regulation was heavily criticized by foreign WT manufacturers in China as they became locked out from concession projects. Voices were raised that the restriction was considered to be in conflict with WTO rules of free trade and the regulation was abolished in November 2010 (Bloomberg, 2010). By that time, the restriction had already had great impact on the distribution of market shares in favour of Chinese WT manufacturers and had greatly stimulated the domestic WT industry (Andréasson, U., 2011). An article from 2011 discuss that even though the 70 %-rule was revoked, other protectionist measures are still effective in subtle or non-transparent ways, nonetheless constituting equally successful trade-barriers which promote Chinese domestic manufacturers (Davidson R., 2011).

Renewable energy quotas

Major power companies are required to provide at least 5 % renewable energy of the entire energy mix by 2010 and 15 % by 2020, and large state-owned power companies are to source at least 5 % of their total electricity sales from WP by 2020 (Liu, Y. and Kokko, A., 2010). These targets, in combination with national goals of installed WP of 150 GW by 2020 (MAKE Consulting, 4 Mars 2010), stimulates demand for WP and have a positive effect on *market formation* as well as *influence on the direction of search and identification of opportunities*. The quota forces the power companies to increase the amount of renewable energy provided if they want to increase the amount of energy from coal fired plants, which currently is more profitable for them. However, in this manner the wind energy expansion has become rather forced and the concession projects has led to unhealthy competition as large state-owned utilities have been able to outbid smaller non-utility companies with prices far below reasonable profit levels, simply to fill their RE-quota (Cuiping et al., 2010). This drove down prices of WP and the price pressure was pushed through the value chain and forced WT-producers to lower their prices in order to get the deals. Today, the largest Chinese WT manufacturers are looking to export turbines, hoping to increase profit margins (Zhi W., 2011, Glenn G., 2011, Zeng B., 2011, Liang X., 2011, Zhang X., 2011, Martin B., 2011).

Public Finance Policies

Resource mobilization as well as *management of risk and uncertainty* are strenghtened by public finance funds. WP equipment manufacturers that produce MW-class WP units, key parts or weak link technologies will be given subsidies from funds to support their research and development. One important fund is the RE Development Fund which supports industrial development of technologies through research and development, standard formulation, testing, demonstration and promotion of localization of production equipment. It also functions as a safety net for the grid connected and cost-sharing principles as grid power companies can apply to the fund if they cannot recover their costs of connecting and purchasing renewable energy through additions to the sales price of power. (MAKE Consulting, 4 Mars 2010).

Preferential Tax Policies

The income tax of RE projects listed in the RE industrial development guidance catalogue, issued in November 2005, are reduced by 15-20 %. Both WP generation projects and WP equipment manufacturing projects are included. Value added tax (VAT) percentage for WP generated electricity was reduced by 50 % in January 2001 (MAKE Consulting, 4 Mars 2010) and in 2008 the government cancelled the tariff-free policy for imported WTs below 2,5 MW to encourage the import of larger turbines and simultaneously increase the demand for domestically produced turbines (Cuiping et al., 2010). In 2010, the border was shifted further upwards and import of complete turbines below 3 MW was subject to normal tariff rates at the same time as imported parts and materials in 1.5 MW WP turbines or above was exempt from custom duties and import VAT (MAKE Consulting, 4 Mars 2010). This encouraged domestic assembly and adoption of larger turbines and is a clear example of the government's influential role when it comes to *influence on the direction of search* and *market formation*.

Grid-connected Wind Power Policy

To construct RE power generation projects, an administrative permit has to be obtained from the State Council. If there are several applicants for the same project, the licensee is decided through a tender. Power grid enterprises are obliged to establish and manage the connection of the power plant to the grid and buy all electricity produced by the licensee. Licenses for projects of less than 50 MW are filed at provincial level while larger projects are filed with the NDRC. The licensing process reassures that all RE will be connected to the grid and bought which reduces the risk for investors in RE and WP and thereby strengthens the function *management of risk and uncertainty*. RE power shall have priority scheduling rights to be dispatched to the grid, exceptions are extreme events that jeopardize the stability of the grid. If grid companies fail to connect and dispatch RE without valid reasons they need to compensate the licensee for the economic loss within 15 days (MAKE Consulting, 4 Mars 2010).

Provincial Policies

The role of local governments at provincial and city level is also very important, not only due to the approval process of wind projects under 50 MW. Many local governments have also set up specific policies for WP industry in their region (MAKE Consulting, 4 Mars 2010). There is fierce competition between provinces and the local governments often try to impress the national government as 'successful' provinces to gain trust and recognition which may be useful in future situations (Andréasson U., 2011). Local governments may therefore encourage new startups of WT manufacturers and, as in the case with car brands, prefer to use a local manufacturer over a non-local one (Andréasson U., 2011; Glen G., 2011).

Standards

Being a country still in a catching up phase WT manufacturers have been struggling with quality issues. In order to cope with deficient quality and controls the Chinese government is introducing standards to overcome the barrier of bad reputation of poor quality products. All turbine manufacturers must conform to the IEC standard and be approved by both the China General Certification Center (CGCC) and the government to set up manufacturing in China (Zeng B., 2011). In Europe, turbine manufacturers also strive to achieve IEC certifications but in China it has become a law, thus if you are not certified you cannot sell turbines. It is difficult to achieve the standard goals for smaller WT manufacturers who may be forced to exit. Forcing WT manufacturers to conform to standards is, thus, a way for the government to reduce the number of actors and consolidate the market (Andréasson U., 2011).

Culture

Culture is one important part of institutions as it affects the behavior of firms and other actors in the industry. The *legitimation* and political support of wind power is strong and there does not seem to be any existing opposition groups or resistance from the people in China as can be seen in European countries (e.g. the Association for Protecting the Swedish Landscape). One reason for this is that most wind farms are located far from populated areas and does not create any disturbance (Cuiping et al.; Guo J., 2011; Tukia J., 2011). This may however change as more wind farms will be set up and may come closer to populated areas. Another reason is that Chinese people are less apt to complain and protest against the installation of WTs as groups cannot be formed in China without permission from the government. Low resistance may not be the same as political acceptance but does facilitate the legitimating and implementation process, thus strengthening the *legitimation process*.

Chinese people have a tendency to prefer ‘learning by doing’, which pervades also the industrial development. The Chinese are more willing to deal with uncertainty and face problems as they occur rather than spending time planning for things that may occur. Managing risk is therefore specific in the Chinese case as they rather take the risk and make amends later. An employee of a European turbine manufacturer expressed it as “*…they have a different understanding of what risk is. It’s like they don’t believe you and want to be self-reliant instead.*” (Glenn G., 2011). This may have affected *entrepreneurial experimentation* and be one of the reasons behind why Chinese firms was so quick to jump on the train of WP technology.

To summarize, institutional change has had a very important role in the development of the Chinese WT industry. After a period of demonstration starting in late 1980’s the Chinese government introduced several policies to encourage import and adoption of WT technology from foreign manufacturers. Large numbers of domestic manufacturers started to emerge around 2000 and their development was boosted by the implementation of the REL in 2005 and especially the 70 % localization of equipment rule. This point can be seen as the take-off for the Chinese WT industry after which domestic WT manufacturers has developed and grown rapidly to capture 90 % of the domestic market in 2010 (Tukia J., 2011; Zeng B., 2011). In our interviews with WT manufacturers they all agree on that the most important regulations for the development of their company and the Chinese WT industry was the regulation of 70 % localization of parts, RE and WP quotas for power companies, the feed-in tariff for WP and the strong guidance and support by the government.

Actors and Networks

The Meteorology Science Institute of China conducted investigations of China’s wind resources already in the late 1970’s and found that China had very favorable conditions for developing WP, especially in northern and coastal provinces. The knowledge produced in this first study has later been verified in several Chinese and international investigations and today the total potential of wind power is estimated to be roughly 1000 GW taking offshore into account (Cuiping et al., 2010; Li J. et al, 2007). These studies revealed a great potential for developing wind power in China and, hence, strengthened the function *direction of search and identification of opportunities*.

In China, the most influential actor is by all means the government. It has a very strong influence in the energy industry through its ownership of grid companies, banks, power utilities and WT manufacturers. The influence on the WT industry and its value chain can be seen in Figure 4 on the next page. The government is responsible for planning and control of prices as well as targets for installation of RE and WP. It also sets goals for the country’s energy consumption, pollution reduction and creates rules and regulations for the industry and its related actors to follow (Liu, Y. and Kokko, A., 2010; MAKE Consulting, 4 Mars 2010). The Chinese government acts as a guiding hand for which the other actors are bound to follow every movement, or as several of the manufacturers put it, “*If the government wants something –it will happen!*” (Zhang F., 2011; Liang X., 2011).

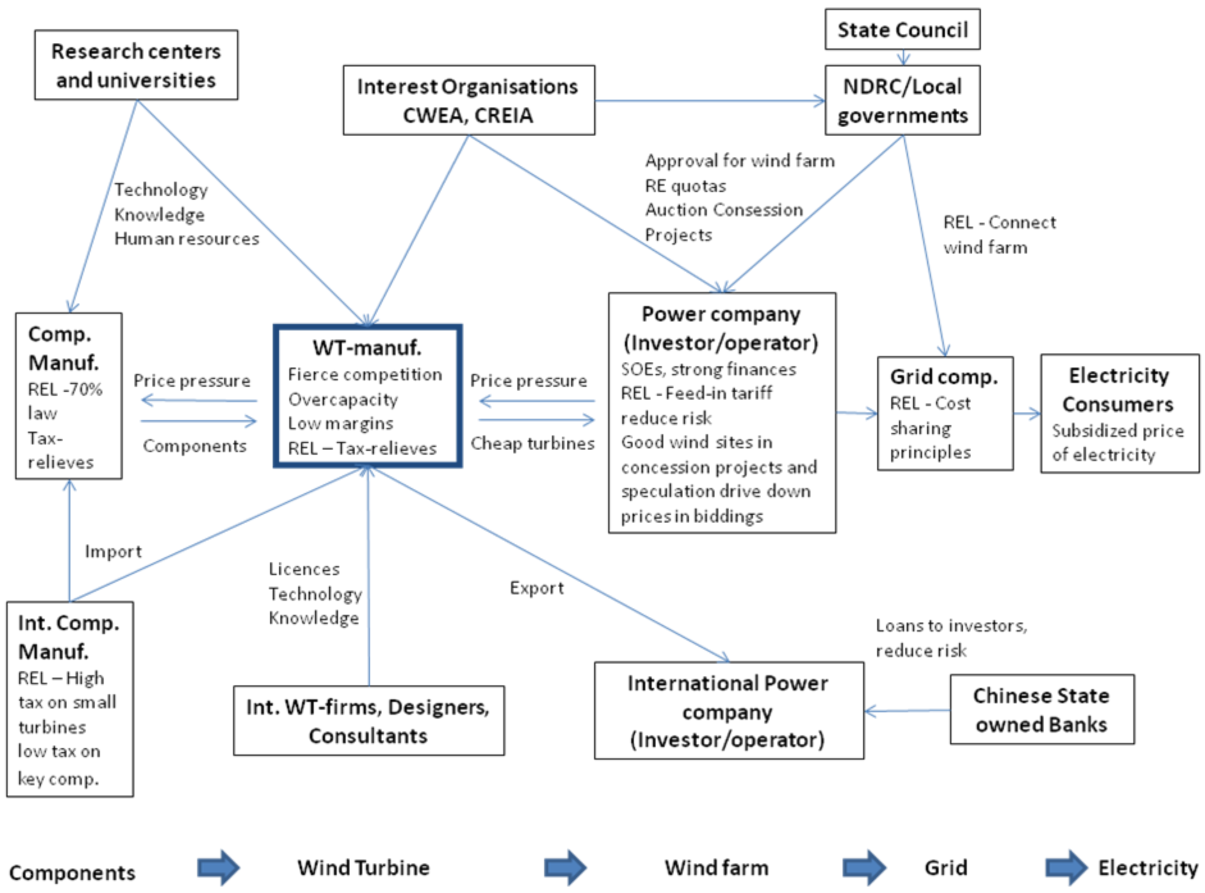

Figure 4. Actors in the Chinese WP industry and the relations between them.

The figure above shows the actors in the Chinese WT industry and important networks between them. The remaining parts of this section will describe the actors and their relations to each other. The role of the government becomes evident as it is involved in all parts of the value chain as buyer, developer and supplier. The government decides to utilize WP and assigns RE quotas to power companies to develop wind farms. The government further subsidizes WP through a feed-in tariff to compensate power companies for increased production costs, as WP is more expensive compared to conventional electricity production. Through the REL, grid companies are enforced to connect and purchase WP from wind farms. The electricity price is then subsidized to the end customer to ensure that consumption can continue in the same rate and not impede the country's industrial development (Rosen D.H. and Houser T., 2007).

The investor and owner of a wind farm is often referred to as a developer. The developers buy wind sites on which they build and operate wind farms. In some cases, local wind energy companies take over the operation of the farm. Developers sometimes have a preferred WT manufacturer to build the turbines (such as their own WT manufacturer) but often there are tenders from many different WT manufacturers for a project (Zeng B., 2011). Many developers of wind energy farms are regional electricity companies and hydropower water management companies (Cuiping et al., 2010). However, the bulk of investment in wind farms comes from the leading state-owned power generation enterprises established in 2002 when the State Council decided to break up the pre-existing monopolized State Power Corporation into seven SOE's; two grid companies (State grid and

Southern Power) and five power generation companies (China Huaneng, China Datang, China Huadian, Guodian Power and China Power) (Liu, Y. and Kokko, A., 2010). The power generation companies are known as the 'Big Five', and together they accounted for 90 % of the installed WP capacity in China in 2008 (Liu, Y. and Kokko, A., 2010). Much of the remainder is generated by independent power producers (IPPs), often in partnership with privately-listed arms of the SOE's.

Grid companies connect the wind farms to the power grid and transport power to end users. Reforms and deregulation has opened the electricity sector to foreign investment, although the effect has so far been limited. While the generation sector has some market competition, the transmission and distribution sectors are heavily state-controlled (U.S. EIA, 2011).

The Chinese Wind Energy Association (CWEA) is an interest organisation that works to promote wind power in China. It works as a communication and learning platform for WT manufacturers and collects data and writes reports on wind power in China and the rest of the world. Every year they release the Global wind report together with the Global Wind Energy Council (GWEC) with updates on the developments in China and prospects for the future. In some cases the CWEA can function as a spokesperson for the WT manufacturers and make recommendations to the NDRC (Liu M., 2011). Another important interest organisation is the Chinese Renewable Energy Industry Association (CREIA). It functions in the same way as CWEA but also include other renewable energy sources.

Entry of Wind Turbine Manufacturers

Many actors started producing turbines in the late 90's and beginning of 2000 on licensing agreements. The process of starting to build WTs was fairly simple as many were able to license the technology, which increased the adoption rate of both utilities and manufacturers as entry barriers were reduced. Most of the manufacturers grew out of power companies or other types of equipment manufacturing firms. Cheap labor costs and acquiring a market share in the fast growing Chinese WP market was the driving factor behind the entry of many of the European manufacturers and design companies.

Market formation and *entrepreneurial experimentation* was strengthened tremendously by the 70 % localized component policy in 2005, which also created a *nursing* or *bridging* market by protecting the Chinese manufacturers and allowing them to grow (Andréasson U., 2011, Zhang F., 2011, Zeng B., 2011, Liang X., 2011, Zhang X., 2011). Many new manufacturers entered the industry at this stage and were able to reach economies of scale as the market for Chinese turbines grew. Wind power was considered to be a 'sexy' industry in which seemingly everyone wanted in (Glenn G., 2011). Therefore *resource mobilization* to the industry has been fairly easy to motivate. As a result of the increased competition prices of turbines was reduced.

The entry of firms helps *legitimate* the TIS as they indicate profitability of the industry for other actors. *Legitimacy* and *influence on the direction of search* was strengthened by large actors and support from the government and more actors began entering the WT industry leading to more *resources being mobilized* and *entrepreneurial experimentation* of different turbine designs. By 2008 there were 67 large scale WT manufacturers and 17 of them were fully or partially owned by foreign companies. Today there are about 80 WT manufacturers in China of which the 10 largest have around 90 % of the market share. As mentioned before, three of these top ten Chinese players are also among the ten largest turbine manufacturers in the world (Liu M., 2011).

The WT manufacturers can be divided into three groups; a few foreign multinational enterprises with local production in China, about 50 relatively new entrants from the SOE sector and established SOEs. The group of established SOEs consists of 17 wind turbine manufacturers that are fully owned by the state and another 10 companies which are listed on the stock market but with controlling state ownership shares (Liu, Y. and Kokko, A., 2010). Some have grown out of power generation companies wishing to have their own turbine manufacturing, while others have started from related industries such as thermal and hydro power or aeronautics and heavy machinery (Liu E., 2011, Zeng B., 2011).

The turbine manufacturers often work closely together with western consulting companies and key component suppliers as they do some of the designs jointly. These *networks* have been of outmost importance for the development of the Chinese WT industry. Component suppliers range from supplying gearboxes, bearings, generators and electrical components to blades and lubricants. There are more than 50 rotor blade manufacturers and around 100 tower manufacturers. As the turbine manufacturers have been moving towards developing larger turbines and offshore turbines, the suppliers have to adapt to these changes in development (Tukia J., 2011, Martin B., 2011).

Financing the Development

Many of the first Chinese wind farms were constructed by loans from the State Economic and Trade Commission and soft loans from foreign governments which have both low interest rates and long payback periods (Cuiping et al., 2010). Such favorable conditions induced investment in the industry, strengthening *resource mobilization,* and increased chances of further development by *influencing the direction of search*. Such types of loans are, however, very limited today which is why, in recent years, many Chinese firms have been listed on foreign stock markets to increase their funds, as local IPO registration is still considered to be difficult as the process is long and bureaucratic. However, China has been making it easier for small- and medium sized technology enterprises to gain access to domestic capital and are easing restrictions and allowing small and medium sized enterprises (SME) to issue bonds (Cuiping et al., 2010).

Today, China has good financing abilities and the Chinese state owned banks play a big role in the growth of the industry. They will be especially important when it comes to exporting turbines as they organize favorable loans and also give loans to developers abroad where other banks would hesitate to take a risk. They can afford to take large risks as the Chinese government absorbs a large part of the risk and promotes investments in wind power. All large Chinese WT manufacturers have agreements with state owned banks to secure loans to aid their export. As an example Sinovel and Goldwind have agreements with China Development Bank of 6.5 and 6 billion USD respectively, to support their international operations (Andréasson U., 2011, Glenn G., 2011, Liang X., 2011, Zeng B., 2011, Zhang X., 2011).

Human Resources and Knowledge Development

As the WT industry grow so does the need for talents, educated people, engineers and skilled workers in all parts of the industry. Many employees have been sourced from related industries such as hydro power and electric industries but universities are starting to become more engaged in wind power development as the need for human resources in the sector is huge. The *Renewable Energy Law* also stated that renewable technologies were to be incorporated into the local curriculum for education (Cuiping et al., 2010). This strengthens the much needed *resource mobilization* as well as *knowledge development*.

According to the Chinese Wind Energy Association, CWEA, much effort is put into training programs where schools and colleges are offering specific career training and hold courses specializing in wind power, for example North China Electric Power University and Tsinghua University in Beijing. This *network* begun as an initiative from the schools, which identified a market opportunity in the form of shortage of human resources (Liu M., 2011). Some of the WT manufacturers have even sponsored college courses and written text books on wind power (Zeng B., 2011, Liang X., 2011 and Liu E., 2011). Some universities and companies also form networks by collaborating in forms of education programs or conducting research together in research centers where they then share the results and technology. China has a state owned national research institute fully dedicated to wind power research which is a cooperation between universities, high level engineers and a number of WT companies. The government has also sponsored an offshore key laboratory, operated by Sinovel, to promote the development of offshore technology (E. Liu, 2011).

WT manufacturers are particularly in need of engineers and have expressed that they are having difficulties finding enough suitable people with experience in WP (Liang X., 2011, Liu E., 2011, Tukia J., 2011, Martin B., 2011). Competition over employees with experience in wind power is fierce which is why many of the WT-producers are looking for talents overseas or offering large bonuses for educated Chinese people abroad to come back (Andréasson U., 2011). Others buy European companies and keep their educated and trained staff. Some WT manufacturers have their own research centers in Europe or have set up R&D labs together with European companies, sharing technologies, which form another type of industry *network* in order to soak up the knowledge where it is created.

To summarize, the Chinese government is a powerful and influential actor which guides nearly all other actors in the industry through rules and regulations. It is also a result of that the government is many times both buyer and supplier and thus controlling large parts of the industry value-chain as well as financing. The entry of firms to the industry was boosted by the 70% localization rule and firms often grew out of existing manufacturing or power companies. Interest organizations, industry-academia, Chinese WTs acquiring or collaborating with foreign companies, and technology-sharing state laboratories were some of the identified networks in the TIS, where the strongest connection is possibly that to foreign technology suppliers through licensing agreements, partnering relationships and consulting. This is of particular importance as know-how and experienced engineers and other talent is difficult to find in China due to the rapid development of the industry.

Technology

As was mentioned earlier in the section *Institutions*, the adoption of WP in China started in the late 1970's with stand alone WTs in remote areas. The first wind farm in China went on line in 1986 as a demonstration project to show that wind could be used as an energy source (Li J. et al., 2007; Wang Q., 2010; Lema, A. and Ruby, K., 2007). The wind farm was operated by Xinjiang Wind Energy Company, established in 1986. The company was later to become Goldwind International Holdings

Limited in 2001 and Goldwind is today on of the top ten WT manufacturers in the world. In the early years of Chinas WP history there were no domestic manufacturers of WTs and all turbines were imported from Europe and the US (Xia C. and Song Z., 2009; Han J. et al., 2009). Chinese WT manufacturers emerged first in the end of the 1990's (Lema A. and Ruby K., 2007; Zeng B., 2011), producing small turbines. Since then the development of turbines in China has followed the international trend towards larger turbines (Martin B., 2011; Zhang F., 2011). Chinese WT manufacturers have also started to develop their own designs to a larger extent (Liu M., 2011; Tukia J., 2011; Liang X., 2011; Zeng B., 2011). The pattern of importing WTs was broken largely due to NDRC's policy of 70 % localized production of parts in WTs and a lower import duty on WT parts compared to WTs (Cuiping et al., 2010; Lema A. and Ruby K., 2007), described under *Institutions*. This strengthened the *legitimacy* and *market formation* of the industry and *influenced the direction of search* and boosted the development of Chinese manufacturers and suppliers.

Sourcing and Ownership of Technology

The main sources of technology for WT manufacturers have historically been licensing and partner agreements with international firms, joint ventures and learning by producing (Zeng B., 2011). The Chinese WT manufacturers built up technical artifacts in the form of manufacturing facilities and started manufacturing WTs from designs licensed from western firms, such as Aerodyn from Germany (Liu E., 2011). The Chinese WT manufacturers learned from producing the turbines and developed both business and technological knowledge as well as formed important networks both domestic and abroad which strengthened *knowledge development and diffusion* of the technology. When buying or licensing the technology they were also able to save on R&D costs which sped up the catching-up process. Chinese WT manufacturers have rapidly built up their technological capabilities while simultaneously kept costs down and some have started to develop and produce turbines themselves at a low cost. The first 1.5 MW turbines produced in China,[11] with completely independent intellectual property rights, cost 20 % less than turbines produced in China by joint ventures (Cuiping et al., 2010).

As the Chinese WT manufacturers grew they usually used one of three strategies for acquiring technology, and sometimes all three in the following order; forming partnerships and co-designing with consultancy firms, acquiring R&D firms in Europe or developing their own designs (Zeng B., 2011). Sinovel Wind Group Co. Ltd. started out licensing technology from Fuhrländer to produce 1.5 MW turbines and later signed development and technology transfer contracts with Windtec for its 3 and 5 MW turbines. Today Sinovel has independent intellectual property rights on its 3 MW, 5 MW and 6 MW turbines (Zeng B., 2011; sinovel.com; windtec.at). For a review of the development and sourcing of technology of Goldwind and Sinovel see Appendix IV.

Driving factors behind reducing the dependency on foreign manufacturers for licensing contracts are to reduce costs and to enable export of turbines to attractive markets, which current licensing agreements are hindering them from (Glenn G., 2011; Liang X., 2011). Several Chinese WT manufacturers have chosen to acquire European technology firms such as REPower, Darwind and Vensys to access the technological rights and patents, manufacturing capabilities as well as full

[11] The turbine, 1.5 MW WEC, is manufactured by Guangdong Mingyang Wind Power Technology Co. Ltd., a subsidiary of Guangdong Mingyang Electric Group Co. Ltd (Lu A., 2007).

competence of the staff (Tukia J., 2011; Zeng B., 2011). In recent years the Chinese government has, as a part of its strategy to move China from being mostly a producing nation to becoming a designing and innovating nation, increased the emphasis of building up technological knowledge in Chinese companies (Andréasson U., 2011; Zeng B., 2011).

Grid Connection and Variety in Wind Turbine Designs

As the installed capacity of WP increases, the strain on the transmission network also increases. WP is an unstable power source as the electricity produce is directly dependent on the wind force. In order to stabilize the grid, the power from a wind turbine needs to be balanced by other power sources (Liu M., 2011). The stabilizing power sources need to be able to respond quickly and therefore hydro power and gas power are suitable. The stability of the grid is always prioritized which means that in case of an emergency, WTs may be disconnected from the grid completely (Guo J., 2011). The opposite situation can also occur. If the grid has a problem, it puts stress on the WP plant to respond to the fault. In order to regulate these conditions regional grid code specifications have been developed which all power plants must meet. WT converters that meet the grid codes therefore become increasingly important in order to obtain operational certifications. One of the requirements in the grid code is a fault ride-though capability. The WT must be able to operate continuously even at reduced voltage and not go off-line in case of variations in voltages (Liu E., 2011; Tukia J., 2011; ABB, 2010). Some WT manufacturers find it difficult to conform to the grid code specifications and therefore they may be locked out of the market. This is also one part of a conscious strategy of the Chinese government to reduce the number of WT manufacturers in China and consolidate the WT manufacturing market.

There are two main types of designs of wind turbines and drive trains; double fed and full converter. The full converter turbine is found in three main types; high-speed, medium-speed and low-speed (also known as direct drive). For a description of the different turbines and their advantages see Appendix V. In China there are companies producing all types of turbines. The full converter turbines are the ones that have been increasing in market share even though the double fed has dominated the market in the past (ABB, 2010; Martin B., 2011; Tukia J., 2011). However, none of the designs seem to become dominant and the industry continues to have different solutions for different conditions of wind sites (Martin B., 2011; Tukia J., 2011; Liang X., 2011). There is therefore a great deal of *experimentation in designs* and some large companies develop several different designs, for example Goldwind which has both double fed and low-speed full converter turbines (Liang X., 2011). Technical development, standards and grid codes all influence the *direction of search.*

The industry sees offshore wind in the coastal area to be the next key development in China. Installed offshore wind capacity may be as high as30 GW by 2020 (MAKE Consulting, 2010). This development is in line with the dynamics in China, with abundant wind resources along the coastal area. These areas are close to major coastal cities, where electricity demand is high. Wind farm development close to load centers minimizes transmission loss and reduces grid related issues. Today much of the technological development is focused on offshore technology and it is still uncertain which type of turbine will dominate this market (Glen G., 2011; Tukia J., 2011; Zhang F., 2011).

Size of Turbines

What is clear is however the trend that the size of turbines is becoming larger. In the early days of wind power in China turbines averaged 30-55 kW but since then the size of turbines has increased continuously and in 2007 the average turbine was 2 MW. This means that wind farms need fewer machines and smaller areas to produce the same amount of energy. Fewer machines need less maintenance and can then keep operational costs down. Profits for the smaller machines barely exist much due to the strong competition from the many turbine manufacturers and overheated market driving most manufacturers towards producing larger machines (Martin B., 2011; Zeng B., 2011).

On top of market forces another driving factor have been generation-based incentives given by the government which has led to an *influence on the direction of search* for larger and more efficient machines (Martin B., 2011; Zhang F., 2011). This development is seen all over the world but it has been hastened by policies and regulations, such as subsidies and tax reliefs previously described in *Institutions*, set by the Chinese government for two reasons. One is to speed up the catching up process for the Chinese WT manufacturers to reach the goal of shifting Chinese WT manufacturers from technological followers to leaders. The second is to exclude smaller manufacturers from the market to reduce the number of actors in the market (Andréasson U., 2011).

In summary, the accumulation of WT technology in China in the form of knowledge and artifacts has been built up for many years and has escalated rapidly during the last five years. Chinese WT manufacturers now claim to have eliminated the technological advantage that international manufacturers once had (Zhang F., 2011; Zhang X., 2011). However, opinions in this matter differ widely. Lack of mature WT technology and related know-how are for example pointed out as impediments to further expansion and commercialization of wind power in China by Cuiping et al (2010) and many key components in Chinese WTs are still sourced from international manufacturers (Liu E., 2011; Martin B., 2011; Tukia J., 2011; Liang X., 2011; Zeng B., 2011; Zhang F., 2011). Chinese WT manufacturers agree that perceptions of their technological capabilities as well as the quality of their turbines remain as large impediments for their international expansion. Therefore, international certifications become very important to achieve to guarantee a certain level of quality (Zeng B., Liu E., 2011; Liang X., 2011). Today Chinese WT manufacturers are focusing on quality both in production in terms of improving components and manufacturing processes as well as investing in testing facilities (Zeng B., 2011). And they are confident that time will prove skeptics wrong as their base of installed capacity and experience of operating their WTs continues to grow (Liang X., 2011).

5. System Weaknesses In the Chinese Wind Turbine Industry

In the past years, the Chinese wind turbine industry has experienced seemingly unhindered growth and is likely to change the wind energy sector on a global level. However, it has not been without experiencing a number of growing pains during this rapid expansion. The following section will discuss a number of system weaknesses related to underperforming structural components in the TIS. These weaknesses, if not dealt with by altering the structural components, may hinder a further expansion of the Chinese wind turbine industry, in China and abroad.

Actor Weaknesses

With a growing industry comes an increasing need of educated and skilled professionals. A weakness that was often pointed out by WT and component manufacturers in China during our interviews was the difficulty of finding enough skilled people to employ (Liang X., 2011, Liu E., 2011, Tukia J., 2011, Martin B., 2011).

Lack of Human Resources

Many of the WT manufacturers see a great challenge in finding experienced people to work in the industry. Even though many universities now are providing educations focusing on wind power, the entire industry is lacking knowledge that can only be gained by long time experience.

The types of turbines that will be used for the offshore technology are larger and far more advanced than the turbines currently used onshore. Turbines that are produced with fully independent IP rights cost less than the ones created in joint ventures, however, the Chinese companies lack long term experience of larger domestically produced turbines (Cuiping et al., 2010). Research and development is needed as well as know-how of more advanced technologies as control techniques and offshore technology. Finding people with sufficient knowledge and experience in developing this type of technology has proven to be extremely difficult and may be one of the next coming bottlenecks for the industry to tackle (Liu M., 2011, Tukia J., 2011, Zeng B., 2011, Liang X., 2011).

The same phenomenon was observed by Jacobsson (1993) in the Korean engineering industry. Studies from the Korean integrated circuit, excavator, machine tool and automotive industry shows that the learning period is often as long as 20 years, during which time the firm builds its competitive advantages. About half of the maturation time is needed to catch up and build up production skills and acquire technical knowledge through absorbing imported foreign technology. The other half of the maturation time is needed to build up R&D skills, design, production engineering, management and marketing capabilities as well as networks, brand names and economies of scale to be able to successfully compete on an international market. Most important of all is to build up technological change skills, to be able to cope with the constantly shifting and developing environment. Catching up and being able to supply products at a similar or lower cost as competitors is therefore not a sustainable business model for firms. To gain a sustainable position in an international market the firm also need to develop technological change skills (Jacobsson, 1993).

The difficulty in developing a broad and competent resource base of skilled individuals must be supported by enforcements in the educational system to ensure continued development of varied and competitive turbines in order to secure the Chinese industry leadership. Building the knowledge domestically will however naturally take substantial time, meanwhile Chinese WT manufacturers are forced to look abroad to find the human resources they need.

From a TIS perspective, lack of human resources reveals that the functions *knowledge development* and *resource mobilization* are underperforming. The problems are caused by a time lag between universities ability to match educations with the knowledge need of companies and the time needed for companies and their employees to learn the new technology. Lack of human resources therefore relate to the structural component *Actors* in Chinese WT industry.

Technological Weaknesses

Chinese WT manufacturers have been relying on license agreements for the main part of their development. This shows that the functions *knowledge development* and *entrepreneurial experimentation* are weak in the TIS. Strengthening those functions are very important if WT manufacturers want to sustain their strong position in the industry.

Moving from made in China to made by China

So far, the WT technology has been brought in from Europe and been produced with European help (through shared R&D or consulting firms for example) or on license from European firms. This reveals a weakness in the functions *knowledge development* and *entrepreneurial experimentation* related to the structural component *Technology*. Some Chinese WT manufacturers have chosen the strategy of acquiring international WT R&D firms to strengthen their R&D capabilities. This is one way of reducing the system weakness related to *Technology*.

However it is important to differ between being able to master the technique and to independently develop the technique behind the turbines. The latter can mean a doubling of the learning period as was observed by Jacobsson (1993) in the Korean Engineering industry. Jacobsson found that the time needed for firms to develop knowledge in order to move from followers with a low cost strategy to establish in a strategic group of technological leaders were substantial, not seldom two decades. The reason for the long learning period is the speed of technological change in the industry. Catching up to a certain level of knowledge and pick up speed in production require a certain type of knowledge and typically took a decade. But by then technology development has often proceeded to new levels and another type of knowledge is needed in order to follow and participate in the technological development, often stretching over another decade (Jacobsson, 1993).

The Chinese WT manufacturers have proven that they can produce turbines, being able to catch up so quickly with the European manufacturers, but can they lead the technological development frontier? According to Gregory Glenn at Siemens Wind, the Chinese are curious about the "hard" technology behind the products and are willing to learn fast, but they are less interested in the innovation process behind reaching that technology breakthrough (Glenn G., 2011). Ulf Andréasson agrees with this view and states that it is originated from traditional Chinese schooling. "*The educational system focus on traditional learning and not on creativity as in Swedish schools, which is why innovation becomes a problem for them*" (Andréasson U., 2011). He believes there is a difference in the way we use creativity. Chinese people are very good at solving known problems that have been solved before in a pragmatic way, but solving a previously unknown problem or preparing for a problem that may not yet exist is a large challenge.

Experts believe that the key for domestic producers is to build up their own innovation capacity. "*Without your own R&D capability, you will not know what technologies you should bring in, and you will not know how to digest them even if you have brought them in, let alone make innovations based on them*," explains He Dexin, president of the Chinese Wind Energy Association. He believes domestic manufacturers should stop trying to obtain core technology from overseas. He contends that "*Core technology can only be generated through self-innovation efforts*" (worldwatch.org). To increase domestic R&D and, hence, *entrepreneurial experimentation* may yet be the toughest barrier for China's WT manufacturers to overcome.

The government has acknowledged the importance of reducing the *knowledge development* and *entrepreneurial experimentation* weakness as can be seen in the 12th Five-Year Plan. China wants to move away from being the factory of the world and become a country with outstanding innovating and design capabilities, able to lead technological development. Consolidating the market, described under institutional weaknesses below, is one measure which is expected to lead to a better focus of R&D capabilities. The government also gives financial support to WT manufacturers' R&D, as was previously described in the section Institutions.

Related to the *technology* and *knowledge development* issue is the on-going discussion about quality. "*Despite the achievements of China's WT industry there are still difficulties in equipment quality control, availability and power generation efficiency*", said Li Junfeng, general secretary at CREIA (china.org.cn). Many of the Chinese WT manufacturers who look to expand to overseas markets as a result of the overcapacity and low margins in China may be facing great challenges in reaching quality standards. As a general manager at Longyuan put it "*China's wind power development will not be sustainable if equipment reliability and quality remain a concern*". According to China Investment Consulting the industry lacks certification and testing procedures (china.org.cn). Currently the operational uptime of Chinese turbines is not long enough to test the quality.

Examples from the Korean studies show that the industries share many similarities with the Chinese WT industry. The Korean firms were also, like the Goldwind and Sinovel, diversified from larger conglomerates or firms, giving them a better start compared to beginning from scratch. Product technology was sourced through licenses and digested by the company under some 10 years which was needed before the firms could begin to expand their R&D capabilities and develop their own designs. During this period they built up their production skills and technology transfer took place in the value chain to suppliers and an increase in domestically sourced components took place. At the point when Korean firms had achieved sizeable volumes, begun to develop their own designs and started to venture abroad they were still technologically immature and lacked reputation abroad.

The Chinese government is working on establishing quality standards and forcing Chinese turbine manufacturers to conform to international standards to reduce any doubts about quality. However, even though the quality of the Chinese turbines is getting better as they move down the learning curve, it may still be difficult to change the perception of Chinese turbines as bad quality/low price products based on a technology that has recently been learnt. The Chinese government is, hence, trying to improve the function *knowledge development* and structural component *Technology* through making changes in *Institutions* and implement more and stricter standards for turbines.

Institutional Weaknesses

Three types of system weaknesses related to *institutions* have been identified and will be described in the following sections. The system weaknesses impact negatively on the functions *entrepreneurial experimentation*, *knowledge development* and *development of positive externalities* and relate to low turbine prices, forced consolidation of the WT market and the power grid. The power grid problems also relate to the structural components *Actors, Networks* and *Technology* but will be described in this section as *Institutions* are the underlying weakness.

Low turbine prices due to unfair competition and overcapacity

The fast growing Chinese WP industry is attracting many new WT manufacturers and the competition over market shares is fierce, thus pushing down prices of turbines to a minimum (Tukia J., 2011, Zeng B., 2011, Liang X., 2011, Zhang X., 2011, Liu E., 2011). This would be considered a normal development pattern in a growing industry and cheaper turbines would also be deemed positive, both for the domestic and international WP market. However, according to the turbine manufacturers, the situation in China is that of unsustainably low prices driven by unjust competition for concession projects and an opaque market with powerful provincial authorities hindering fair competition.

The price war affect the entire value-chain as WT manufacturers has to put pressure on component suppliers to reduce costs to match prices in concession projects. Heavy cost reductions may result in lower quality of turbines and less investment in R&D. Unnaturally low turbine prices may therefore incur problems for *knowledge development* as well as *entrepreneurial experimentation*.

The same functions are also threatened by rules for concession projects which have a negative effect on WT manufacturers and component suppliers. Bidding for concession projects is deemed unfair as large state-owned utilities outbid non-utility competitors with prices below reasonable profit level in order to fulfill their clean energy quota (Cuiping et al., 2010). This excludes smaller and foreign companies from competing and may be harmful for the future development of wind turbines as the feed-in tariffs, which are based on the prices in concession projects, may be lower than the real cost. This system weakness is related to *institutions*.

Unfair competition is also seen on a regional level. The fast growing WP industry has attracted many new regional WT manufacturers as everybody wants a piece of the cake. Provinces prefer to use their own local manufacturers as they provide jobs and development to the region. Competition becomes skewed as local manufacturers are supported by their regional governments and ties to decision makers become very important. As a result of this, an overcapacity has formed on the WT market which further pressure turbine prices downwards and result in the above discussed disadvantages for *knowledge development* as well as *entrepreneurial experimentation*.

Measures to reduce overcapacity may threaten entrepreneurial experimentation, knowledge development and development of positive externalities

To come to terms with the overcapacity, the government is now seeking to consolidate the WT manufacturing industry. In 2011, the National Intellectual-Property Strategy Office issued a directive for the municipal governments to follow. According to the directive, the government wants to reduce the number of actors in the industry to 3-5 competitive turbine manufacturers with R&D capabilities for new product development. This will be done by tightening policy for new entrants

(7economy.com), letting larger WT manufacturers acquire smaller ones and setting up rules and creating standards which effectively excludes many actors from the market.[12]

This is a strategy that has been used before in other industries such as real-estate and the automotive industry (2point6billion.com; autocar.co.uk) as fewer actors will be easier to control than a large number of smaller actors. "*China likes to be able to pick winners early*", says Dr Ulf Andréasson from the Swedish embassy (2011). This strategy is emphasized in a paper examining the learning period in catching up situations in engineering industry in Korea in the 80's by Staffan Jacobsson (1993). Jacobsson argues that large investments are needed in a catching up situation and it may therefore be wise to focus efforts on a few firms. However, he also emphasizes that selecting those few firms is very difficult, if at all possible. Long learning periods must be kept in mind when designing policies to protect a new industry and picking winners early can therefore be difficult (Jacobsson, 1993).

Several sources believe China will succeed in its attempts to consolidate the market. Shen Dechang, at the wind power equipment branch of the China Association of Agricultural Machinery Manufacturers (CAAMM) states that, "*In the next 3 to 5 years, about 80 % of China's wind turbine makers will disappear through mergers and acquisitions*" (7economy.com). MAKE consulting shares the belief that the market will consolidate and smaller actors will disappear within 2-3 years (Zeng B., 2011). But according to Gregory Glenn at Siemens Wind, there are too many local actors for the industry to consolidate into a few actors and many provinces have their own local actors which they prefer to use. The stakes involved for provincial governments in jobs and money invested in projects are high and Glenn believes that keeping job opportunities is higher prioritized by provincial governments than consolidating the WT industry (Glenn G., 2011).

A consolidation of the market can be devastating if it is done too early. When it comes to creating variety and experimentation in designs, choosing only a few companies and their designs might hinder the development of the WT industry, as you put all eggs in one basket when the technology is still developing. If the Chinese government decides to choose a small number of actors as 'winners' it is not certain that these players are the strongest ones or the ones with the best product which may jeopardize the future success of the industry. It may also be in conflict with the goal of moving from a production oriented economy towards an innovating economy as few actors may restrict *entrepreneurial experimentation, knowledge development* and *development of positive externalities* and may make it difficult to maintain diversity.

In sum, by making changes in *Institutions*, the Chinese government is trying to reduce the above mentioned weaknesses related to overcapacity and the functions *knowledge development* and *entrepreneurial experimentation.* However forcing a consolidation of the industry may potentially have adverse effects on the same functions. Perhaps it would be better to tackle the problem of unfair competition and make the market more transparent and thereby let the market mechanisms

[12] Under the Guideline Catalogue for Industrial Structuring published by the National Development and Reform Commission (NDRC) in April 2011, China will not extend the preferential policies to companies that produce wind turbines of less than 2.5 MW effect (7economy.com). Stricter grid standard requirements are also expected to exclude many actors from the market (Tukia J., 2011).

naturally consolidate the market. This view is expressed by several WT manufacturers who want the market to open up and become more transparent (Zhang F., 2011, Liang X., 2011, Liu E., 2011). This would lower some of the risk for the manufacturers by facilitating planning for the future and enable competition on fair grounds with market based rules.

Lack of resource mobilization in infrastructure is causing problems in electricity grid connection of wind power and capacity of transmission grid

The Chinese grid operators are experiencing strains on the electricity grid infrastructure. The grid is struggling to keep up with the rapid diffusion of wind power, and is now acting as one of the main bottlenecks for further development of wind energy. There are two main problems with the grid, the first is to connect the large amount of new installed WP and the second is to transfer the electricity generated in wind rich areas in the north where the bulk of WP is produced to the coastal areas where the electricity is consumed. Both problems relate to lack of *resource mobilization* in the form of infrastructure and financial resources and if not solved they may cause severe problems for further *market formation*.

The first problem is driven by *Institutional* weaknesses in the licensing and approval process of wind farms causing difficulties in the planning process for grid operators to connect new wind farms. The problem is also partly driven by *Technological* weaknesses as there is a physical limit to how large amounts of wind power can be connected to the grid without causing grid instability.

To construct WP generation projects, an administrative permit has to be obtained from the State Council. Grid operators are obliged to establish and manage the connection of the power plant to the grid and buy all electricity produced by the licensee. Licenses for projects of less than 50 MW are filed at provincial level while larger projects are filed with the NDRC. The separation of licensing process for projects at 50 MW has created problems when it comes to grid connection and is one of the largest reasons behind the currently large unconnected wind capacity in China.

Grid companies are not properly informed of projects below 50 MW and therefore they may not be included in the planning of new grid connections (Wu, 2011; MAKE Consulting, 4 Mars 2010; Jiwei G., 2011; Zeng B., 2011). In some cases, wind farms have to wait for several months before being connected to the grid (Global Wind Report, GWEC, 2010). According to Cuiping et al. (2010), only 9 GW of the total 12.2 GW installed wind capacity was connected to the grid. The numbers differ between different sources and calculations but reports have shown that up to 30 % is currently not connected (windturbines.chinawindturbine.com).[13]

The problem is especially large in Inner Mongolia which is the leading province in installed WP capacity but also the province with the largest unconnected capacity. The province has therefore made new regulations stating that no new wind projects can be commenced before all current WT are connected (MAKE Consulting, 4 Mars 2010). The problem has also been acknowledged on a national level and new regulations from the NDRC state that all projects must be filed with the NDRC

[13] This has however much do with the calculation methods used, as only turbines which have completed the commissioning and acceptance procedure are counted even though they are already grid connected and delivering electricity (Global Wind Report, GWEC, 2010). This procedure may take several months and is said to cause the reported time lag.

regardless of size (Wu, 2011; MAKE Consulting, 4 Mars 2010). Putting commissioning of new wind farms on hold until the problems are solved will decrease the domestic demand for turbines and therefore pose a threat to *market formation*.

In the early years of WP diffusion in China, grid operators were reluctant to connect wind farms to the grid as it incurred increased costs. The law of mandatory grid connection, previously described in the section *Institutions*, addressed this problem. Power grid operators were demanded by law to buy all energy produced by WP. The costs incurred by the purchase in excess of conventional electricity, including power grid transmission costs, construction investments, operation and maintenance could be recovered by increasing the price of electricity. However, the law of mandatory grid connection is not sufficient to address the problems today as it is *Technology* that is setting the limits on how much WP can be connected.

As was discussed earlier in the section Technology, WP is an unreliable and unstable power source which cause tension and strain on the electricity grid and may result in breakdowns leading to costly power shortages. In order to stabilize the grid, the power from a wind turbine needs to be balanced by other power sources (Liu M., 2011). Even though the REL give priority scheduling rights to WP, the stability of the grid is always prioritized, and in case of an emergency, WTs may be disconnected from the grid completely (Guo J., 2011).

Due to the above mentioned problems, grid companies have been reluctant to accept large amount of WP to the grid network. The government has however set a target of 80 GW installed wind power by 2015 and 200 GW by 2020 (Global Wind Report, GWEC, 2010). This may become a difficult target to reach if grid problems are not solved and thereby pose a threat to *market formation*.

The second problem, transmission capacity, is partly a consequence of the first problem as difficulties to plan the amount of connected WP has led to insufficient investments in transmission lines. But the problem is also driven by *Actor* and *Network* weaknesses as the coordination between wind farm operators, NDRC and grid operators is lacking.

Many of the richest wind resources are situated in the north far from more densely populated areas, for example Inner Mongolia (Liu M., 2011). As power consumption does not match generation it leads to problem of transporting the generated electricity to the populated areas in need of energy. Transporting electricity such long distances puts a lot of pressure on the transmission lines and large energy losses. New transmission lines have not kept pace with the installment of WP which can be explained both by coordination problems between wind farm operators, NDRC and grid operators as well as insufficient investments in new transmission lines. Almost 60 % of the investments in the power sector go into power generation, leaving only 40 % to developing the power grid (Li X. et al., 2011). However, the Chinese government is starting to invest in high speed transmission lines (Zhang F., 2011, Jiwei G., 2011). According to figures provided by State Grid, 40 billion RMB had been invested into the grid at the end of 2010 in order to facilitate the diffusion of wind power (Global Wind Report, GWEC, 2010).

As can be seen from the discussions above, the Chinese WT industry has a number of difficult system weaknesses in *Institutions, Actors*, *Networks* and *Technology* to overcome to be able to sustain the current growth of the industry and secure a strong industry in the future. The most important challenges are connected to *knowledge development*, *resource mobilization* and *entrepreneurial experimentation*. Building a strong resource and knowledge base takes time and considering the extreme pace of growth that the Chinese WT industry has experienced in the past few years this will probably be one of the largest obstacles to overcome. Mastering technology and building innovation capabilities is a key issue for future development of the industry and for Chinese WT manufacturers to be credible on an international market. Both grid connection and transmission problems reflect a weakness in the function *resource mobilization* and may incur problems for *market formation*. The problems are quite complex as they involve all four structural components; *Institutions, Actors, Networks* and *Technology*, and therefore grid problems might be one of the most difficult issues for the Chinese WT industry to tackle.

6. Conclusions and Discussion

The purpose of this study was to understand how the Chinese WT manufacturers were able to develop as fast as they did by answering the two questions;

(1) How has the Chinese WT industry been able to catch up?

(2) Can the speed of the development of the WT industry in China continue or will the industry run into obstacles that will slow down the development?

Explaining the fast development

The fast economic development in China has boosted growth in many sectors, causing an inevitable increase of energy use. A rising need for environmental friendly energy in combination with strong wind resources seems to have been the factors which sparked the development of the Chinese WT industry.

The Chinese government has been an important driving force behind the development of the WT industry by setting up clear goals and implementation strategies in the Five-Year Plans. The government's firm support for the industry has reduced the uncertainty inherent in a new industry. By acting as a powerful guiding hand the Chinese government has helped the domestic WT manufacturers to become among the largest producers in the world in less than 15 years.

Wind power has been available in China for many years with the first wind farm constructed already in the 1980's. In the early stages turbines was imported from Europe and the US. The development has been supported by numerous regulatory frameworks starting with favorable loans from the Chinese government and international mixed-credit loans. Following came a demonstration period supported by compulsory grid connection rules in 1994 and 40 % localization rule in 1996. The aim was to create a domestic manufacturing base and create joint ventures with international WT manufacturers to import WT technology to China. Chinese WT manufacturers were also given favorable loans to set up wind farms with locally produced WTs. The measures helped *legitimize* the industry and *form a market* for WP which had an effect on the *direction of search, entrepreneurial experimentation*, *mobilization of resources and knowledge development*. Thus, the Chinese government used legislations and policies to set the stage for entry of Chinese firms. However, it was not until the government made an effort to focus its frameworks for the industry and initiated the renewable energy law (REL) that the industry really took off.

The enforcement of the REL in 2005 created a strong demand for WTs but also supported the supply side of the industry. On the demand side the REL forced grid companies to connect all the produced electricity from WP, set RE-quotas for power producers and introduced a feed-in tariff to assure investors a fixed return on investment and hence reduce the risk of investing. On the supply side the industry has been supported by tax-reliefs and the favorable 70 %-rule for domestic component and WT manufacturers which attracted many actors to the industry. Large scale concession projects administrated by the government have acted as a learning field for many Chinese manufacturers, allowing them to increase production volume and reap economies of scale.

The government has above all affected *Institutions* which has strengthened the functions *legitimation*, *market formation*, *influence on the direction of search*, *resource mobilization* and *entrepreneurial experimentation* of the TIS. In the Chinese case the structural component *Institutions* can almost be equaled to the government's actions and intentions as they have such a profound influence on the legislation and norms and beliefs of actors in the WT industry.

The most influential factors and events enhancing and hindering the development of the WT industry and their effects on structural components and factors can be seen in Figure 5 below.

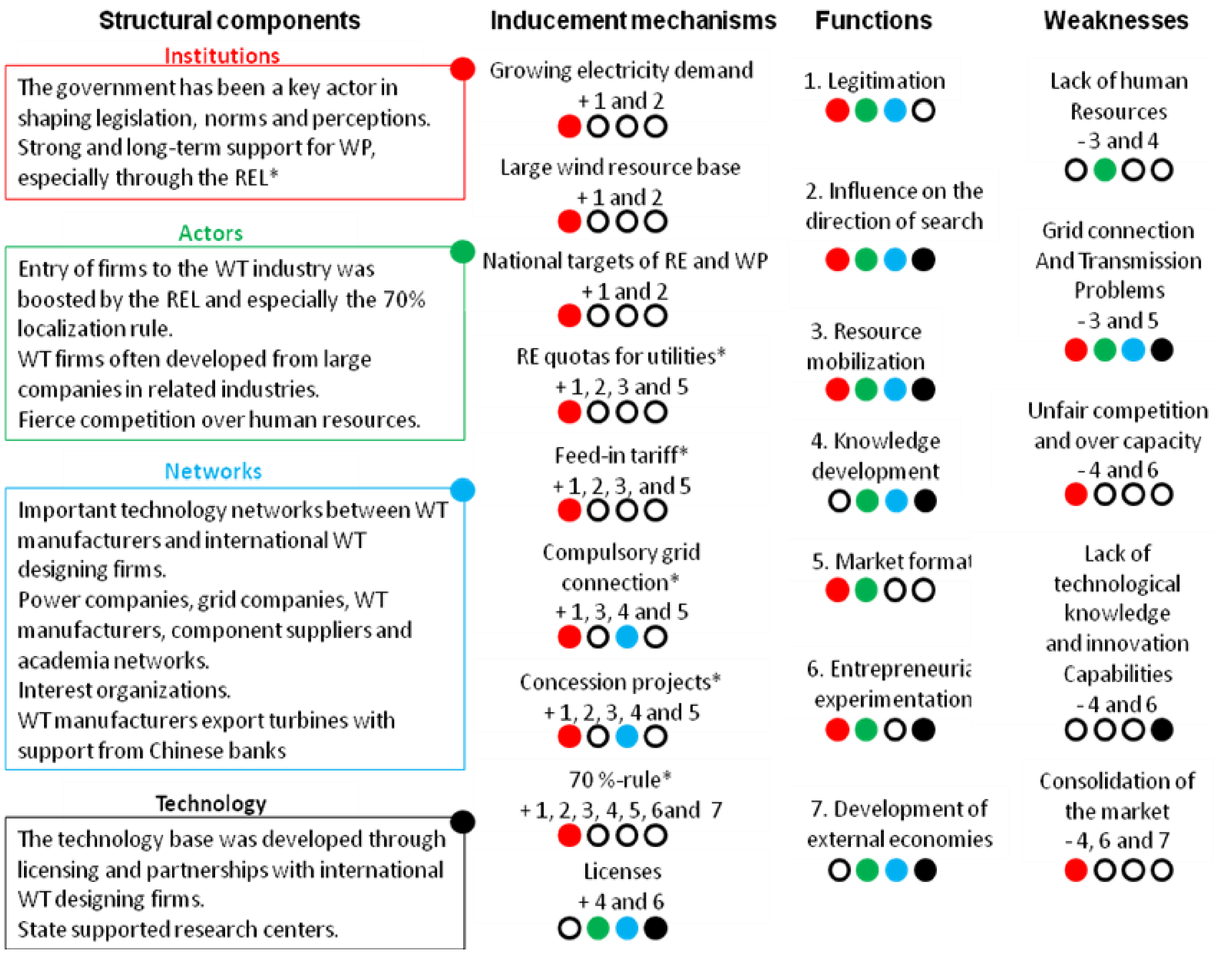

Figure 5. The development of the Chinese WT industry

The technology sourcing networks between Chinese WT manufacturers and international companies has been of outmost importance for the development of the industry. Technology and know-how was initially sourced from the U.S and Europe. Chinese WT manufacturers continued on the licensed designs together with design companies and consulting firms. Many of the Chinese WT manufacturers started from a diversification from large companies in related industries. They therefore had an advantage when it comes to management and production capabilities, which enabled them to catch-up quickly and consequently take over domestic market shares.

Chinese WT manufacturers seem to be confident that they have now eliminated the technological lag between Chinese and European WTs and are focusing on securing quality in components, manufacturing processes and control systems by, for example, adapting to western standards and certification systems. However, the *perception* of Chinese manufactured turbines may still act as a barrier when entering the international market.

Identified system weaknesses

Even though the development of the Chinese WT industry can be seen as a success story, there are still many challenges to meet, particularly when entering the international market. The main system weaknesses were connected to the structural element *Institutions* but weaknesses are also related to *Actors*, *Technology* and *Networks.*

System weaknesses related to *Actors* are found in *knowledge development* and *resource mobilization.* Academia struggles to keep up with the rapid development of wind power. The entire system is affected as an imbalanced demand for educated and experienced talent develops. Skilled human resources is needed to drive the industry forward but is not met by the supply, creating an industry screaming for talent. The situation typically occur if the learning period is very short, as the knowledge base of people and firms can only be gained by long time experience.

Strong supply of WTs has created an overcapacity in the industry with decreased prices and diminishing returns for producers. As a result, Chinese WT manufacturers have started to build up their exporting capabilities. As a result of problems and incidents due to low quality of turbines Chinese WT manufacturers' credibility has been hurt which has led to problems to find investors abroad. Chinese banks are stepping in to solve financing problems and offer loans to foreign investors. Another obstacle connected to exporting turbines is the weakness in *Technology.* The growth of Chinese WT manufacturers has hitherto been based on licensing the technology from international actors and building WTs based on innovations made by others. Licensing agreements are hindering Chinese manufacturers from exporting and it will be necessary to develop technology independently. This will be a challenge for *knowledge development* and *entrepreneurial experimentation* as the Chinese WT manufacturers will have to become strong innovators and not only excellent producers in order to continue to take the lead. There is has also an aspect of culture mixed in to the problem, which can be a difficult obstacle to overcome.

The structural element *Institutions* has many weaknesses on several levels of the functions where strong governmental power first provided protection and growth abilities for the industry, now constitute a threat for the continued growth of the Chinese WT manufacturers. Today the industry is characterized by overcapacity and unfair competition, resulting in unsustainably low prices. This affects both future *knowledge development* and *entrepreneurial experimentation* as less profit may lead to underinvestment in R&D and innovation. In order to master this development the government is trying to control the overheated industry by making efforts to consolidate it. However, this may in turn constitute a threat to the same functions if only a few actors are allowed to continue and the future of the industry depends on only a variety of few.

In the final part of system weaknesses identified in *Institutions* we find infrastructural problems where the grid is struggling to keep up with the rapid rollout of wind farms leading to a gap between wind energy generated and wind energy connected and supplied to consumers. This has an effect on both *resource mobilization* and *market formation* and is, as many of the identified weaknesses, a result of experienced growing pains from an industry which has developed extremely fast. The Chinese domestic demand for WTs is predicted to level out in the coming years due to grid connection problems and stricter regulations for licenses and WT-certificates. This will further strengthen the pressure for WT manufacturers to export.

What can be learnt from how China has developed its WP industry?

It is evident that it is beneficial to have one strong actor as the Chinese government, with resources, capacity and power to decide what, how and when technological change is going to occur. In order to succeed with a development of this kind, the goals and mission has to be clear enough for all the involved actors to understand and unite resources. What differs most in the situation in China from Europe is perhaps the sense of urgent need to explore new energy sources to secure the country's increasing needs of power and improve environmental conditions.

From what we can identify from underlying system weaknesses, it is good to have a strong actor pushing for change in one direction and organizing the resources through plans and policy in an initial stage on technological development. However, to create a sustainable industry, it may be equally important to know when to step back and let market mechanisms select what technology and which actors to favor. This way the actors are forced to compete on quality and innovation to continue to exist and the ones with the best solutions will drive the development.

Looking at the success of the catching up in onshore wind turbine technology (on a protected home market), it will be very interesting to see if China can maintain its strong position in an unprotected global market.[14]

Comparing with the development of Korean firms described by Jacobsson (1993), our study suggests that Chinese WT manufacturers have come halfway to maturity and that another decade is needed before they have gained a sustainable position in the global market. However, China being a very large home market may have provided Chinese firms with the economies of scale that is needed for successful global competition and therefore the time to maturity may be shorter than for other firms in smaller countries. However, they still lack the network and brand recognition abroad which is also a crucial part to becoming successful internationally.

Jacobsson (1993) argue that the length of the learning period depends on the strategy chosen. Moving from having caught up to carve out a firm position in the international market requires that the firm have capabilities matching the firms in the strategic group they want to enter and compete in the international market. It would be interesting to look into what strategies the Chinese firms aim for in the international market and to compare the capabilities to the competitors in this strategic group. Thereby an understanding of how far the Chinese WT manufacturers have to maturity could be gained. This would also provide an answer to if the Chinese WT industry have developed faster than what has been observed in other industries.

The TIS framework that was used for the study proved to be well suited for the purpose as it is designed to find weaknesses within a defined technological innovation system. We suggest that research should be made to identify how policy can address these issues in order to continue the development of wind power technology for both onshore and offshore in the future. We hope that this study may be used as a starting point for realizing the importance of policy for decision-makers in a developing TIS.

[14] Another interesting area to look into is what learnings China takes from the development of the onshore wind turbine industry into the offshore industry, which is currently taking form.

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Appendix I - Interview Guide

Introduction

The framework we will be using is known as the Technology Innovation Systems framework (TIS). It suggests that the success or failure of a company is not completely determined by its own strategy but is largely influenced by other actors in the system. The performance of the TIS can be analyzed through seven different functions, listed below. The focal point of the TIS we are examining are the Chinese wind turbine manufacturers. We are interested in knowing how the Chinese wind turbine industry has developed historically and also of describing the situation today.

We focus on the development of the wind turbine producers in China but will also look at the industry as a whole. To understand this we need to study the perspectives of many different actors in the industry. We therefore plan to interview various actors in the value chain, NGO's, researchers and policy makers.

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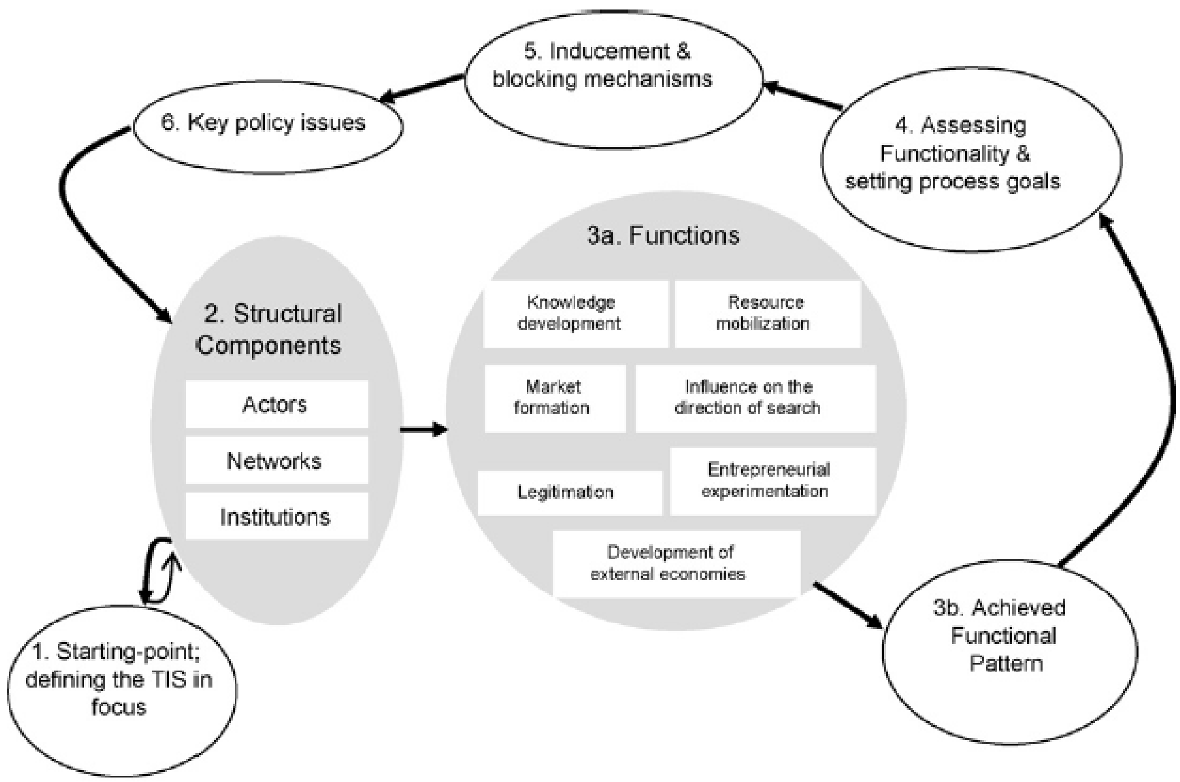

Fig. 1. The scheme of analysis (adapted from Oltander and Perez Vico, 2005).

The interview will take approximately 60 minutes and we wish to record it if possible. If you want to you can choose not to have your own or your company's name in our report. We will transcribe the interview afterwards and can send you a copy of the transcript, for you to verify. We will start with some background questions about yourself and your company followed by more specific questions, derived from the TIS framework.

Q1. Can you please tell us a little about yourself?

Q2. Can you please tell us a little about your company?

Q3. How has your company acquired and built up your technological know-how and skills?

Q4. What types of standards does you wind turbines conform to?

Q5. How has the development been financed?

Q6. Can you please describe the impact that policy has had on the development of your company over time?

Q7. How would you describe your company's role in the value chain?

Q8. What has been the strategy behind the location of your company?

Q9. How does your business model differ from your competitors?

Q10. Does the industry lack any kind of resources or know-how?

Q11. What opportunities do you currently see in the wind energy industry?

Q12. What areas are developing and in what directions are you developing?

Q.13. What opportunities or threats do you encounter today and how do you manage them?

Q14. Are current policies addressing the right issues?

Q15. Who is advocating wind power and who is opposing it?

What do you think has been most important for the development of Chinas wind turbine producers in the past 10 years?

How do you expect the wind energy industry to develop in the next 10-20 years?

Is there anything else you would like to add?

Appendix II - Complete list of interviews

ABB China Ltd.

Beijing, 2011-05-17, 10.00-12.00.

Jari Tukia, Wind Power Manager, NAS and China.

Center for Environmental Technology (CENTEC), Embassy of Sweden

Beijing, 2011-04-05, 14.00-16.00.

Yufeng Xu, Project Officer, Center for Environmental Technology

Chinese Wind Energy Association

Beijing, 2011-05-04, 09.30-11.30.

Wang Yan, International cooperation and events.

Liu Mingliang, Policy department.

Alfred Zhao, Business analyst.

Envision Energy Ltd.

Shanghai, 2011-04-15, 10.30-13.30.

Felix Zhang, Executive Director and founder.

Bo Ben, International Business Department.

Tina Liu, International Business Department.

Goldwind International Holdings Limited

Beijing, 2011-05-11, 12.00-13.45.

Liang Xuan, Business Development Manager, MENA markets.

Growth Analysis, Embassy of Sweden

Beijing, 2011-05-24, 15.00-17.00.

Dr. Ulf Andréasson, Counsellor Science and Technology, Embassy of Sweden Science Office

Guodian United Power Technology Company Ltd

Beijing, 2011-05-12, 16.30-17.00.

Eric Liu, Senior Account Manager, Overseas team

MAKE Consulting

Tianjin, 2011-05-23, 10.30-12.00.

Belle Zeng, Business analyst.

Siemens Ltd., China, Energy Sector, Renewable Division.

Beijing, 2011-05-26, 18.00-20.00.

Gregory Glen, Head of Commercial Sales, Wind Power Offshore, Asia Pacific.

Sinovel Wind Group Co., Ltd

Beijing, 2011-05-06, 09.30-11.00.

Zhang Xin Cynthia, Project Manager, International Business Department (America)

SKF (China) Sales Co., Ltd

Shanghai, 2011-04-28, 10.30-14.30.

Blanca Martin, Business development, Renewable Energy, Industrial Marketing & Product Development.

Kjell Bogvad, General Manager, Industrial OEM Sales.

Shanghai, 2011-04-29, 08.30-09.30.

Blanca Martin, Business development, Renewable Energy, Industrial Marketing & Product Development.

SKF (China) Sales Co., Ltd and Bloomberg New Energy Finance

Shanghai 2011-04-29, 10.00-13.45.

Bloomberg New Energy Finance:

Anthony Bailey , Jonas Karberg and Justin Wu, head of wind energy China.

SKF (China) Sales Co., Ltd:

Blanca Martin, Business development, Renewable Energy, Industrial Marketing & Product Development.

Kjell Bogvad, General Manager, Industrial OEM Sales.

Alexis, Engineering consultancy.

Freddy Ban, Service and monitoring.

State Grid Energy Research Institute

Beijing, 2011-05-21, 10.00-12.00.

Guo Jiwei, New energy department.

Swedish Wind Power Network, Swedish Energy Agency

Shanghai, 2011-04-12, 13.00-15.00.

Wang Zhi, Industrial and business development.

Tsinghua University, Institute for Science, Technology and Society, School of Humanities and Social Sciences

Beijing, 2011-03-30, 11.00-14.00. (And several other occasions)

Liu Li, Ph.D., Associate Professor, Executive Director, Research Unit for Science,Technology, Innovation and Policy

Appendix III - Chinese History and Culture

China has a long and rich history of dynasties that have ruled the country and was as early as 3000 BC a highly developed country with a written language. Throughout its history, China has had different degrees of openness to the outside world depending on the prevailing emperor. In many periods China has had a tendency to be self-sufficient with closed borders to the outside world, protecting China from all harm (Xu W., 2010).

Chinese culture and morals have their roots in work written by the Duke of Zhou and Confucius to mention a few. The Confucius moral standard is still part of the Chinese mindset and affects Chinese way of living and doing business in a number of ways. Confucius' teachings to uphold a high moral standard and to honor one's commitments are helpful in business transactions as they provide a social order under which a market economy can function. They encourage family ties and trustworthiness among friends, which may form the basis for loyalty in a business enterprise. However, the moral standards can also hinder progress by promoting too much respect for tradition. The use of personal honor as a safeguard for business commitments might be a poor alternative to a modern legal system – for ethics is considered more important than law under the Confucius tradition. The negative side of respect for social order and family values is the sacrifice of individual freedom and self-interest. Individualism is taken for granted in many Western societies, but is not necessarily considered a virtue in China, where social responsibility for the common good is more highly prized (Xu W., 2010).

The last dynasty, Qing, fell 1911 when the revolutionaries overthrow the emperor and the Republic of China was established. The following period was turbulent with an unstable parliamentary system and the presidency of China changed hands several times between 1916 and 1927. After that the Sino-Japanese War, 1937-1945, caused further disruption in China. And it was first in 1949 that the Chinese Communist Party (CCP) and Mao Zedong rose to power, took control over and united China. National unity has always been a very important goal for China and nationalism is an important force behind China's economic and political policies even today. When the CCP came to power, China became more closed to the outside world than ever. The planning authority of the Communist Party took control over all physical productive resources, covering land, buildings, machinery and other capital goods and introduced a planning economy with Five-Year Plans for everything that was to be produced, from infrastructure, houses to food. Directly or indirectly, it controlled all enterprises, farms, and factories and sources of supply of inputs. It assigned production targets, controlled prices and set quotas for how much people could buy. It assigned workers to different factories and could direct a person from a city to work in a particular farm, or vice versa (Xu W., 2010).

The planning economy had many disadvantages stemming from the difficulty to have enough information to plan the need of goods and prices in advance and incentives for people and firms to undertake suitable actions. The planning economy, commune system, and failed political reforms such as "the great leap forward" and "the cultural revolution" left China in a very bad shape. Food production was greatly reduced and from 1958 to 1962 it was estimated that over 25 million people died of famine, the most severe in Chinese history (Xu W., 2010).

Appendix IV – Development and Technology sourcing

WTM	**Goldwind** (9,5 % of world market, No.4 in the world)	**Sinovel** (11,1 % of world market, No.2 in the world)
Established	1986 - Xinjiang Wind Energy Company. 1998 - Xinjiang New Wind. 2001 - Xinjiang New Wind is restructured into Goldwind Science and Technology Co., Ltd.	Sinovel was formed in February 2006 by DHA Dali Hai Industry, SOE.
Ownership	Dec 2007, listed on the Shenzhen Stock Exchange. Oct 2010, listed on the Main Board of Hong Kong Stock Exchange	January 2011 Sinovel officially listed as a public company, IPO Shanghai China. Main shareholder is still DHA Dali Hai Industry.
Technology and turbines	Gearbox and Permanent Magnet Direct Drive (PMDD) turbines. 1988 operated wind farm of turbines imported from Denmark. 1989 - Imported 13 BONUS 150 kW WTs from Denmark. 1999 - 600kW (Jacobs Energie --> 750 KW REPower). 2005 - 1.2 MW (License from VENSYS). 2006, Goldwind Energy GmbH is incorporated in Germany. 2007 - 1,5 MW (on and offshore VENSYS). 2008, acquires majority ownership of German VENSYS Energy. In November 2010, The Company signed an agreement with Infineon Technologies AG to introduce core module technology. 2009 - 3 MW (independently developed), 2.5 MW PMDD. 2010 - 1,5 MW PMDD passed low-voltage-ride-through. Research centers in Xinjiang, Beijing and Neunkirchen (Germany).	Gearbox turbines. 2004 - before they officially established, they imported 1,5MW turbines from the German firm Fuhrländer. After that developed on their own with development contract and technology transfer for its 3MW and 5MW turbines from Windtec. 2006 - 1,5MW independently developed (only on-shore). 2008 - 3MW (on/off-shore, technology from Windtec). 2010 June - 34 3MW offshore WTs in Shanghai Donghai Bridge 102MW Offshore Wind Farm, the first national offshore wind demonstration project in China. 2010 October - 5MW (on/off-shore, technology from Windtec), 6MW (on/off-shore) fully independent IP-rights on both turbines. Building the "National Energy Offshore Wind Power Technology and Equipment R&D Center", supported by the government.
Export	Nov 2008 delivers turbines to Cuba. Dec 2009, 3 * 1.5 MW PMDD turbines installed at Uilk Wind Farm in Pipestone, Minnesota, USA. May 2010, signed a strategic cooperation agreement with China Development Bank. Included a credit line of US$6 Billion. Etiopia, 34*1,5MW. Australia 13*1,5MW.	India since 2008. Partnership with China development bank, 6.5 billion USD only to support Sinovel's international operations.
Sources	BTM, goldwind.com, Liang X., 2011.	BTM, sinovel.com, Zeng B., 2011, windtec.at, nyteknik.se

Appendix V – Wind Turbine Designs

There are two main types of designs of wind turbines and drive trains; double fed and full converter.

A double fed turbine feed 2/3 of the power into the stator and 1/3 into the converter allowing a wider speed range as well as the ability to feed reactive power to support the grid. The advantages of this type of turbine are that it may use a smaller converter and is a more economical.

The full converter turbine decouples the generator and the mechanical drive train from the grid and all the generated power flows through the converter to the grid. The advantages of decoupling are that it reduces mechanical shocks on the turbine during grid faults, which are very common in China. It therefore increases grid compliance and allows full control over the power generated (ABB, 2010; Tukia J., 2011).

There are three main types of full converter concepts; high-speed, medium-speed and low-speed (also known as direct drive) which all use different gearbox and generator solutions.

High-speed and medium-speed turbines have the disadvantage that the gearbox are large and heavy which increases the allowed turbine size and therefore makes replacements and maintenance more expensive. The direct drive turbine does not have a gearbox which allows a smaller turbine which makes it lighter and easier to transport and install, and also minimizes maintenance costs (ABB, 2010; Martin B., 2011; Tukia J., 2011; Liang X., 2011

Appendix VI - List of abbreviations

CREIA – Chinese Renewable Energy Industries Association

CWEA – Chinese Wind Energy Association

GW – Giga Watt

MW – Mega Watt

NDRC – National Development and Reform Commission

NEA – National Energy Administration

RE – Renewable Energy

SDPC – State Development and Planning Commission

SETC – State Economic and Trade Commission

TIS – Technological Innovation System

WP – Wind Power

WT – Wind Turbine