The Growth of a Green Industry

Wind Turbines and Innovation in China

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Marius Korsnes,

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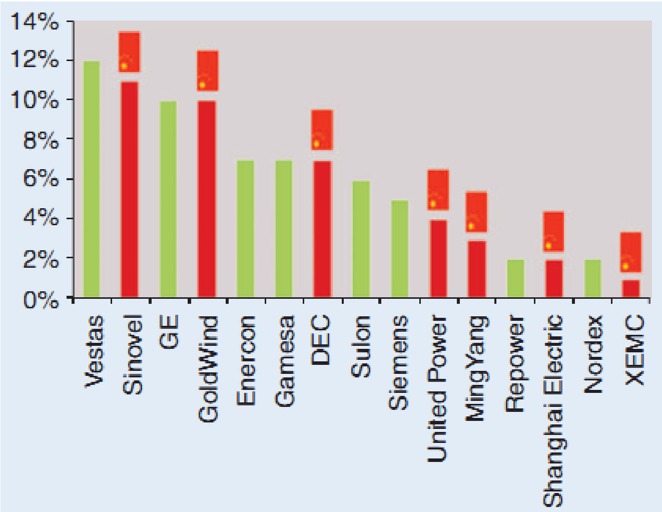
Abbreviations and glossary

BNEF	Bloomberg New Energy Finance
CCP	Chinese Communist Party
CDM	Clean Development Mechanism
CEO	Chief Executive Officer
CREIA	Chinese Renewable Energy Industries Association
CRESP	Chinese Renewable Energy Scale-Up Program
CWPO	China Wind Power Outlook
CWEA	Chinese Wind Energy Association
DNV	Det Norske Veritas
ERI	Energy Research Institute
FIT	Feed-in tariff
GW	Gigawatt = 1000 MW
GWEC	Global Wind Energy Council
IEA	International Energy Agency
IPR	Intellectual Property Rights
kW	Kilowatt
kWh	Kilowatt hour: the rate of energy per unit time
LCOE	Levelised cost of electricity: the price at which electricity must be generated from a specific source to equal market prices.
M&A	Merger and Acquisition: A corporate strategy which involves buying, selling, dividing and combining of different companies.
MW	Megawatt = 1000 kW
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
ReLaw	the Renewable Energy Law
SOE	State Owned Enterprise
TIS	Technological Innovation System
UNFCCC	United Nations Framework Convention on Climate Change
U.S.	The United States of America
WEO	World Energy Outlook
WWF	World Wildlife Fund
XEMC	Xiangtan Electric Manufacturing Co., Ltd

1. Introduction

Ten years ago the Chinese wind turbine industry was virtually non-existent; it was unknown to most people both in and outside of the People's Republic of China, and insignificant in comparison with the cutting-edge countries such as Denmark, the U.S. and Germany. Today the Chinese wind industry is producing more wind turbines than any other country, Chinese companies dominate the list of the world's largest wind turbine manufacturers (Figure 1), and China is the country which invests the most resources in renewable energy globally (CGTI 2011, REN21 2011). What enabled such unprecedented, rapid industry development?

Figure 1: The top 15 wind turbine manufacturers, and global market shares, 2010

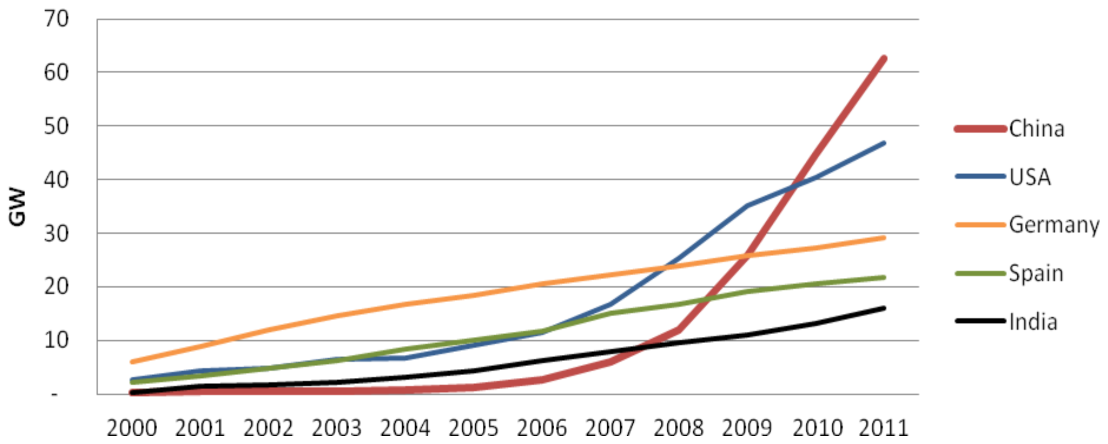


Source: Jiang et al. (2011: 40)

As a result of staggering developments over the last 30 years in China, the country is now facing multiple and mutually influencing crises ranging from environmental and climatic (Economy 2010), to social, political and economic (Fewsmith 2010, Saich 2011). China's scale makes any Chinese problem a global problem, and fortunately, it seems the Chinese government is starting to take these concerns seriously. Thus far, however, the quest for economic growth has received higher priority than any other consideration by the Chinese leadership (Naughton 2010), especially environmental considerations. Yet, not all economic activity is necessarily harmful for the environment, and the wind turbine manufacturing industry is one example. Understanding how the industry has emerged, and how it is performing is the main undertaking of this study. Furthermore, understanding the growth and performance of the industry can help us understand better the more important question of what role a “green” industry—e.g. the wind turbine industry—can play in China’s future electricity mix.

China’s total wind resource potential is estimated at a capacity of 2,580 GW, of which around 200 GW is offshore (Jiang et al. 2011: 36).[1] Measured in annual electricity generation, this resource potential equals 17 per cent more than China’s total annual electricity production today (end of 2011) (IPCC 2011: 17, businessweek.com 2012). As we observe from Figure 2 below, the installed wind electricity capacity in the People’s Republic has developed at a break-neck speed which exceeds that of any other country. Such a rapid development, starting around 2004, can truly be called a great leap forward. The five countries mapped in the figure account for almost three quarters of the total installed wind capacity, that is, about 176.4 GW, out of a total 238.5 GW globally (GWEC 2012).

Figure 2: Installed wind capacity of the top five countries, 2000-2011



Sources: gwec.net (2012) is used for all numbers except for Germany, and for 2010 and 2011, where the latest report from GWEC (2012) was used. For Germany, the latest figures were retrieved from the BMU (2012).

Given this rapid growth of installed wind power in China, one can assume that China is doing everything right. Taking into consideration that Chinese manufacturers captured a domestic market share of 87 per cent in 2010, as opposed to only 25 per cent in 2004 (CWPO 2010: 37), it becomes evident that the domestic

[1] This is according to the latest official assessment. Another frequently referred to figure is a resource potential of least 250 GW onshore and 750 GW offshore (Martinot 2010).

manufacturing industry has increased tremendously. Obviously, such a rapid expansion has carried with it several problems, including grid connection, turbine quality, and other issues. The scope of this thesis is not necessarily to highlight these problems, but rather to understand how they surface as a consequence of the rapid growth—how these issues emerge within a systemic context. In a sense, therefore, answering how the industry has flourished also involves looking at what the dynamics of the industry are today.

Progressive government policies and renewable energy development goals are the basis of the rapid development of wind energy in China. For example, the last five year plan issued by the government had a target of providing 11.4 per cent non-fossil primary energy by 2015 (Jiang et al. 2011). By 2020 non-fossil fuels are planned to account for a 15 per cent share of *final* energy (Martinot 2010: 290).[2] Out of this 15 per cent share, it is estimated that wind power will contribute to around 10 per cent of the total, if the goal of 150GW installed wind power in 2020 is reached (Jiang et al. 2011: 46). Yet, it is simplistic to assume that government goals and policies alone explain how the industry has grown. Throughout this thesis, a point has been made to include factors which on the one hand illuminate how the government is inducing industry growth, and on the other, how many instances are outside government influence.

1.1 A transforming electricity sector

China's electric power sector is dominated by two sources of fuel, coal and hydro power. Even though wind electricity generation has grown quickly, it is still far below the total amount of coal power production in China. In fact, coal alone fuelled about 81 per cent of China's annual electricity generation in 2008 (Cunningham 2010: 236), whilst wind electricity generation represented as little

[2] In comparison, the EU target for 2020 is for renewables to account for 20 per cent of the *final* energy (Martinot 2010: 290). For the Chinese target, note that non-fossil here includes nuclear power (ibid.), and that *final* energy means a larger absolute quantity of electricity than *primary* energy (Martinot et al. 2007).

as 0.75 per cent of the total in 2009 (Yang et al. 2012: 145), and 1.2 per cent in 2010 (CWEA 2011: 36).[3] The rest of the electricity is largely supplied by hydro power (ibid.). In terms of CO_2 emissions, the use of coal is the source of as much as 70 per cent of total emissions in China (Lewis 2010a: 259). Thus, coal electricity is polluting the country, making China the world's largest emitter of CO_2 (although by far not, if calculated per capita) (Economy 2010).

Table 1: Comparison between investments and government subsidies for renewable energy and fossil fuels in 2010, million US$

	Investments		Subsidies	
	Fossil fuel	Renewable energy	Fossil fuel	Renewable energy
Global	157,000	187,000	409,000	66,000
China	?	49,000	21,000	ca. 500*

*This is an estimate made by the author and is not based on official sources

Sources: WEO (2011), BNEF (2011) and Morales (2011). Renewable energy here does not count large-scale (more than 50 MW) hydro power. The basis for the estimate on renewable energy subsidies in China is explained further in Section 6.1.1. To avoid confusion in conventions, I will refer to one billion as 1,000 million throughout the thesis.

As we see from Table 1, though more money is currently being *invested* in the renewable energy industry, the fossil fuel sector is still receiving far more *subsidies*, both globally and within China. As long as the fossil fuel industry is heavily supported by the Chinese government, one can assume that the renewable energy industries taken together will still face difficulties in the future. Finding concrete data on the amounts China today *invests* in fossil fuels has proved thorny. We can nevertheless safely assume that Chinese investments in fossil fuels are larger than in renewable energy (Eisen 2011).[4] On a global basis the International Energy Agency (IEA) has calculated that if fossil fuel subsidies were to be removed, the subsequent emission reductions would correspond to "half the emissions reductions needed to limit global warming to 2°C" (Clark 2012). Thus, such a seem-

[3] According to preliminary statistics, this percentage has increased to roughly 1.5 per cent by the end of 2011, that is, almost 70 TWh of wind electricity generation annually (chinadaily.com.cn 2012) out of a total production of 4600TWh in 2011(businessweek.com 2012).

[4] As one report puts it: "China's investment in renewable energy and other green technologies is miniscule compared to the resources devoted to its continued building of coal-fired power plants and efforts to secure dirty oil shale supplies in Canada and elsewhere" (Quoted in Eisen 2011: 38).

ingly simple measure engenders effective and beneficial climate results. Why is it so hard to carry out?

Transition, technological regimes and lock-in

A point of departure for this study is that emerging technologies very seldom are competitive. Since old technologies have had much more time to establish themselves, mutual benefits have developed between the established technology and its surrounding institutions—such as in infrastructure, financing and political support (Smith 2011). This is what scholars refer to as a technology "lock-in", or "path dependency", and is the reason why state support is crucial in the nursing phase of a new technology's development (Kemp 1994, Jacobsson 2011). An example from the U.S. is illustrative, where nuclear and fossil energy technologies have received larger subsidies historically than renewable energy technologies: "(...) the federal commitment to [oil and gas] was five times greater than the federal commitment to renewables during the first 15 years of each subsidies' life, and it was more than 10 times greater for nuclear" (Pfund & Healey 2011: 6). Moreover, renewal of energy technologies happens especially slowly because capital expenses are large and investments are long term, ranging from 30 to 40 years for an average coal power station (Jørgensen & Münster 2010: 15). Hence, these established technology systems undergo only incremental change—whilst a rapid change is what we need given the grave consequences caused by climate change. How can such a transition happen?

The fact that, for the first time in 2010, renewable energy investments globally were larger than fossil fuel investments (Morales 2011) is a clear indication of the prospects for this industry. Nevertheless, the electricity sector contains some of the most relentlessly "locked-in" technologies, and the sector has had no real precedent for change (Unruh 2000). Given the high CO_2 emissions in the electricity sector in China, one can speak of a "carbon lock-in" of the sector (Unruh & Carrillo-Hermosilla 2006). Carbon lock-in can best be understood as "embedded in a powerful conditioning social context", arising from a "combination of systematic forces" (Unruh 2000: 817, 818). Therefore, to recognise what leads to lock-in of technologies, it is necessary to study their historical development and the system surrounding the technologies—often referred to as a *technological regime* (Smith 2011). In general, a technological regime encompasses all factors that influence, support and constrain the development of a technology—including production and thought processes, routines, knowledge and learning (Dosi & Nelson 1994).

One process of altering a regime is often referred to as *disruptive innovation,* which disturbs or replaces a technological function of an existing industry (Smith 2011). Disruptive innovations lead to changes in established infrastructures or institutions, so that regime characteristics are altered. Although perhaps not immediately evident, the consequences of such a change are that emerging technologies eventually will replace the established technologies. For instance, electricity generated from wind turbines demands very different management and electricity transmission capacities than from thermal electricity, coercing changes in routines and practises of energy incumbents. In the longer term, therefore, wind power induces a disruptive change, and contributes—together with other renewable energy technologies—to the replacement of energy incumbents. Therefore, as we seek to understand how the wind industry has grown and what the industry dynamics are today, a more important insight emerges, namely how China is doing in transforming from a coal-fuelled "grey" to a renewable "green" electricity regime.

1.2 Understanding the growth of an industry

A technological regime may consist of many *innovation systems* (Smith 2011). In order to understand the growth of the Chinese wind turbine industry, this study looks at the growth of technologies and formation of industries through a systems lens—a lens honed by innovation system theorists. This framework takes as a starting point that technology develops in a web of interactions between actors, networks, and institutions. Innovation is seen as resulting from a broad spectrum of factors, and not only, as is commonly perceived, through market forces or research and development. When a new technology emerges, it does so within the frames of an established regime. In fact, in all known transitions from one technological regime to another, the new technology has emerged and developed within the existing regime (Kemp 1994). In order for the new technology to grow, it is therefore dependent on making a new "path"—it needs to build a surrounding system which supports the technology when facing the incumbent technologies (Jacobsson 2011). The technological innovation system (TIS) framework, a subsection of the innovation system theory, looks at how emerging technologies evolve within such a context. The approach is particularly relevant for understanding the Chinese wind turbine industry, because it takes *technology* as a point of departure for analysis (Bergek 2002, Bergek et al. 2008, Hekkert & Negro 2009). The wind turbine is the technology in question here, and the TIS framework allows us to simultaneously study what the industry consists of and what the industry dynamics look like over time. Ideally, to understand which factors have been essential to the growth of an industry, we would wait 10 to 20 years in order to see how the industry develops. However, if we want to understand today what the industry dynamics are, we need to make an early assessment, which "identifies processes that are precursors to manifest market and industry growth" (Sandén et al. 2008: 2). The TIS framework captures such processes (ibid.). By studying how an emerging technology evolves within a "fossil" technology regime, we can simultaneously understand better how the electricity sector can become "unlocked".

Technology transfer

It is clear that China's engagement in renewable energy has already had a globally beneficial effect, not only with respect to clean electricity production *per se*, but also in terms of price reduction, which has increased the willingness to *invest* in renewable energy. Chinese wind and solar manufacturers have induced a significant price-reduction globally, particularly due to increased competition and economies of scale (RETCR 2011: 12, 24, bnef.com 2012). This means that the Chinese contribution makes it easier and cheaper to harvest the higher-hanging fruits that renewable energy sources are. It means that the subsidy ladder can be shortened substantially, and possibly be removed more quickly so that wind electricity can compete with fossil electricity generation. Understanding how the Chinese wind industry has emerged is important if only because of the impact it has on renewable energy globally.

The same way the Chinese wind industry has had a global impact, the industry is also highly influenced by technology and knowledge from other countries. Technology transfer can take many shapes, some of which include foreign direct investment, technology licensing, or joint ventures (Binz et al. 2012). As will be elaborated further in Chapter 2, the Chinese wind turbine industry is based predominately on licensing technology from abroad. The innovation system analysis regards innovation as a complex phenomenon, implying that technology cannot simply be transferred as a "gift" from one country to another. Therefore, an important insight into innovation processes lies in understanding what role technology transfer may take. As highlighted by two innovation theorists, Gu and Lundvall (2006: 27), "borrowing technology and domestic development of technology are both important; they actually are complementary in most real innovation processes". Technology transfer can be understood as a natural *diffusion* process in a global context which is crucial when building up any industry. These territorial conditions as a determinant for successful innovation become highly explicit in emerging countries such as China because, as export-oriented economies, they are involved in an interdependent nexus of actors, networks, and institutions from all over the world (Binz et al. 2012). Research and development activities are also increasingly taking place within China, whether from foreign or domestic initiatives (Steinfeld 2010: 148). Such activities are not isolated from their surroundings: instead, they must be viewed as part and parcel of a Chinese and an international system. Given this international interconnectedness, it becomes clear that a transition can best be studied by simultaneously looking at global and local innovation processes (Coenen et al. 2012). One reason the TIS framework is useful is that understanding the growth of a specific industry is the prime issue of concern—irrespective of the "origin" of a technology. Part of the scope will therefore be to understand how the wind turbine industry draws upon international flows in knowledge, technologies and investment.

1.3 Research questions

To oversimplify somewhat, we can say that we have a global problem; climate change, we have a Chinese problem; coal fuelled electricity supply and CO_2 emissions, and we have an alternative solution; an emerging electricity technology which does not emit CO_2—wind power. Starting from the assumption that technology and society have developed interdependently, understanding how new TISs emerge and what their industry dynamics are helps to understand how technological regimes can change—in this case, understanding how the Chinese electricity sector can transform from a "grey" to a "green" power supply.

The overarching research questions for this thesis are:

- How has the Chinese wind industry grown, and what are the dynamics of the industry today?

Consequently, two more sets of questions emerge as particularly interesting to pursue in detail, namely:

- What is the role of the Chinese government in the development of the industry, and what does this role mean for the wind turbine TIS dynamics?
- How has the global wind industry affected the Chinese wind TIS development?

1.4 Structure of the thesis

Chapter 2 will give a short introduction to China's energy sector, and the historical development of the wind turbine in and outside of China. The chapter will also briefly touch upon the question of *why* China pursues to develop a wind turbine industry. Chapter 3 will further outline the theoretical framework chosen for this study, followed by methods in Chapter 4, which justifies the choice of a case study approach and how it was deployed to answer my research questions. Chapters 5 and 6 delve into the specifics of the Chinese wind industry. Chapter 5 first makes clear the delimitation for the wind industry, and then maps the actors, networks, and institutions accordingly. In Chapter 6 the functional aspects are examined point by point, and an assessment is made on the performance of the industry in light of key processes in the industry. In Section 6.8, the dynamics between these processes are highlighted, after determining a relevant overall industry goal. Chapter 7 then looks at what potential blocking and inducement mechanisms might have influenced the development. These external mechanisms illuminate what impact the established electricity regime has on the Chinese wind turbine TIS. Finally, in Chapter 8, some final conclusions for this thesis are made.

2. The Chinese energy sector and the wind industry

From the beginning of China's reform period, starting in 1978, until today it has been possible to distinguish key concerns amongst decision makers in China as to which direction the energy sector should move in. Meidan et al. (2009) note two important concerns to be energy efficiency and conservation. Also, renewable energy has been for some time now, and will likely continue to be, at the forefront of China's energy policies (Huang et al. 2011). In the following, I will give a brief introduction to China's energy sector, before the history of wind turbines in China is further outlined. Lastly, we shall briefly look at the question why China seeks to build up a wind industry.

2.1 Energy in China

The energy sector is sometimes referred to as the last "fortress" of the planned economy in China (e.g. M. Wang 2007: 248), meaning that the sector is highly centralised and not very flexible or open to change. This picture is increasingly challenged, as a conception prevails that marshalling resources to meet China's considerable energy needs is based on more than central planning (Cunningham 2010). Although central leadership is important for energy decisions, it is only one of several influential factors. As a matter of fact, energy decisions are highly politicised in China because they involve many different actors with diverging interests and objectives. This has lead to a state of affairs where there is

> a 'leadership vacuum' in China over energy policy and many decisions are driven by projects promoted by localities or industries rather than being guided by a coherent national energy policy (Kong 2009: 791).

Therefore, a change in energy policy amongst the top-level leadership does not necessarily equal smooth implementation throughout the system. This is because decisions face strong institutional constraints, ranging from "the vague and contradictory nature of the relevant laws and regulations; the nature of economic incentives for local government officials to prioritize economic growth at the expense of energy efficiency and the environment", to the expectations and beliefs amongst the Chinese people (Meidan et al. 2009: 615). As we shall see in this paper, a burgeoning wind industry has to deal with these institutional constraints.

Perhaps one cause for the troubles in implementing energy decisions is the relatively small staff of the central government energy management. According to Cunningham (2010: 253), only 112 people are employed in the National Energy Administration, which is divided into nine departments. In comparison, the U.S. Department of Energy employs almost 15,000 individuals working with energy policy (ibid: 254). Such a striking difference in employee numbers is remarkable, especially given the size of China's energy sector. In fact, in 2009 China surpassed the U.S. as the world's largest primary energy producer. At the same time, China provided over 94 per cent of this energy domestically (ibid: 223). It is therefore understandable that energy decisions are allocated downwards in the system.

Also, even though energy management can be perceived as more decentralised in China, most analysts agree that state-owned enterprises (SOEs) still have a large impact on energy decision making (Downs 2008, Meidan et al. 2009). We shall come back to their impact in the wind industry later on, but for now it is important to clarify that "state-owned" does not necessarily equate to "state-controlled" (Cunningham 2007: 2). Instead, these powerful enterprises are relatively autonomous actors, and sometimes advance corporate ahead of national interests (Downs 2008: 42). Cunningham (2007: 1) stresses that, following the state-owned enterprise reform by the central government, the SOEs became "newly empowered corporate actors whose operations are largely obscured from official view, and who selectively tap state resources as they see fit". This seriously challenges any perceptions that China—with an authoritarian government—"knows what it wants" and easily "gets what it wants" (Kong 2009: 810). This recognition shall be kept in mind when analysing the Chinese wind industry.

Hence, viewing the energy sector as centrally governed and inert is misleading. Rather, the sector is highly innovative, and absorbs and develops technologies quickly. Indeed, Steinfeld (2010: 164) claims that "whether they are multinational or indigenous firms doing the work, it is in the China market that numerous new-to-the-world energy technologies are being developed and deployed for the first time." Nuclear and thermal electric power generation technologies are cases in point (ibid.), and in a few years wind turbine technologies might well be added to that list. On the one hand, this shows that energy technology can be innovative in China, something which gives hope for the wind industry. On the other hand, this may imply that a transition from a grey to a green electricity sector might take a long time, given that the energy incumbents are so innovative. Even though the incumbents develop energy technologies, they are still firmly placed within the established carbon lock-in, because they are based on fossil-fuels (except nuclear power).

The electric power sector

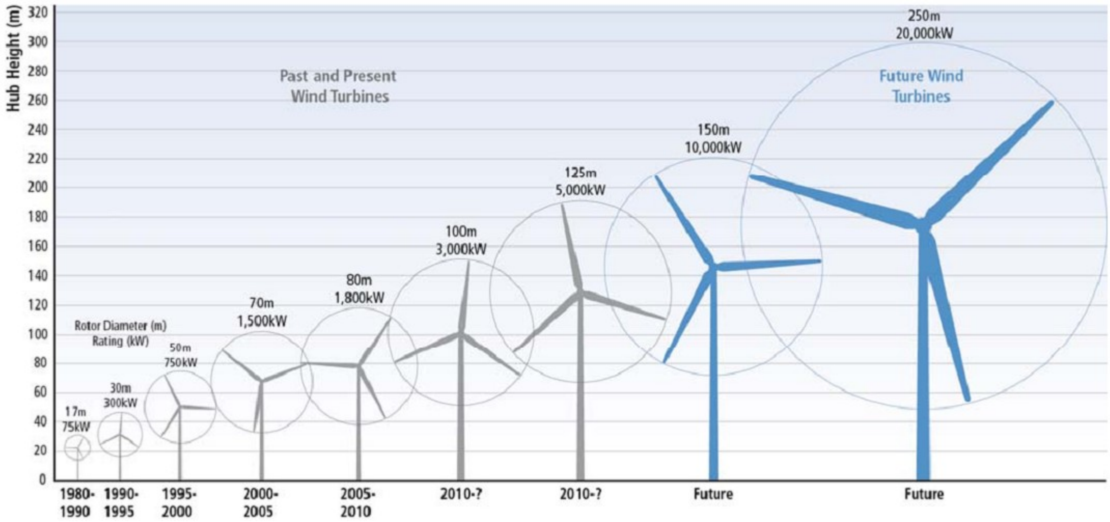
Table 1 above groups fossil fuels together, but it should be pointed out there is a distinction between the subsidies given in China to oil and gas, and those given to coal. Historically, coal has been subsidised, and thermal electricity utilities have benefitted from this. Even though all coal prices were officially deregulated in 1994, thermal coal prices were still subsidised in the early 2000s because of backsliding in implementation, and it was not until 2006 that the last province abolished state-subsidised thermal coal pricing for power plants (Cunningham 2010: 240). This means that most of the subsidies mentioned above are in fact given to the oil and gas industry, which is not as heavily engaged in the *electric power sector*. Therefore, the role the coal-fuelled power industry has in respect to the wind turbine industry is particularly elusive, not only because it is the major electric power "competitor" to wind power, but also because the largest wind farm investors are large, central-government-owned coal-power utilities. As we shall see, these large electricity generation companies without doubt have a large impact on the wind industry. Yet they only own around 40 per cent of total electricity generation, whilst local governments own more than half of China's power generation capacity (ibid.: 243). It is therefore not adequate to measure support to energy incumbents in terms of direct subsidies alone. To comprehend the growth of the Chinese wind industry we need a holistic approach which highlights all potentially influential aspects.

2.2 Modern wind turbines and China

2.2.1 A short introduction to modern wind turbines

Modern wind turbines have slowly developed since the 1950s and 60s, becoming larger in size and more efficient in electricity production (Figure 3). The turbines that are mainstream today spread slowly from countries which led in implementing wind-supportive policies, such as the U.S., Germany and Denmark, but are now found in more than 75 countries worldwide (Manwell et al. 2009: 2, gwec.net 2012). A modern wind turbine distinguishes itself from traditional turbines, or windmills, by converting the wind into electricity. The most common wind turbine capacities installed today are around 1.5 MW, although this varies from region to region: for instance, the preferred turbine sizes are 2.5 MW in the U.K., and 1.4 MW in China (REN21 2011: 40). The largest commercial turbine launched thus far is a 7 MW offshore turbine from Vestas (ibid.), although design capacities can range as high as 10 MW (10,000 kW in Figure 3) or more.

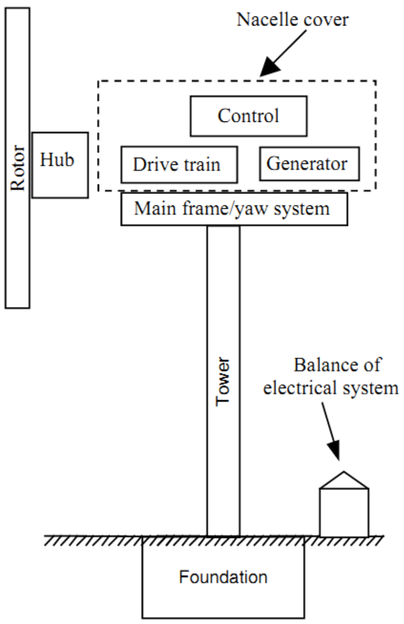
Figure 3: The relative sizes of commercial wind turbines since the 1980s



Source: IPCC (2011)

As displayed in Figure 4, the principal components of a wind turbine are the rotor (the blades), the drive train (the gearbox, if any), the generator, the main frame (e.g. the nacelle cover), the yaw system (e.g. a yaw bearing), and the tower (Manwell et al. 2009: 276). I will come back to these different components periodically in the analysis of the Chinese wind turbine industry, because components manufacturers are important actors in the wind industry.

Figure 4: The principal components of a wind turbine



Source: Manwell et al. (2009: 4)

Much research on innovation and wind turbines has already been conducted, and this facilitates the analysis for China greatly. For instance, the developments in the Danish, Dutch, Swedish, U.S., and German wind industries, all pioneers at some point in wind turbine development, have been studied in detail (e.g. Garud & Karnøe 2003, Bergek & Jacobsson 2003, Kamp et al. 2004, Hendry & Harborne 2011). We now turn to a short description of China's modern history of wind turbines.

2.2.2 Wind turbines in China

The modern wind turbine history of China can be divided into two phases: one which lasted until the mid 1990s, where the focus was largely on expanding the smaller, decentralised, off-grid wind turbines, and a second which focussed on manufacturing and implementing large-scale, grid-connected wind turbines (Gan 1998). The first phase was characterised by government support programmes that emphasised rural electrification, as well as the build up of manufacturing capacities (ibid.). The first subsidy ever given to renewable energy in China was given from the Inner-Mongolian local government in 1986 for small-scale wind turbine projects (Lew 2000: 277). By the 1990s, China already produced more small-scale wind turbines than any other country (ibid.). Today China is a global leader in the manufacture and export of small wind turbines (up to 100 kW), and between 1983 and 2008 China produced a total of 508,712 small off-grid wind turbines, with an installed capacity of 57 MW (REN21 2009a: 17,18). However interesting this development is, the second phase is the main focus of attention here.

During the 1990s, regional government policies shifted focus from a household level, to larger wind farms that could produce electricity for whole villages (Gan 1998). The central government started to perceive wind power as a future source of large-scale electricity generation, and in 1996 the “Ride the Wind” programme was initiated to start up utility-scale grid-connected wind power (Zhao et al. 2009: 2884). This programme emphasised the introduction of foreign technologies, as well as supporting local manufacturing of turbines (ibid.). This dual path of both building a domestic manufacturing industry as well as ensuring actual electricity generation from grid-connected wind turbines from the outset has been a core strategy for the Chinese government (BNEF 2010). Naturally, most of the technology employed in the beginning was supplied from foreign wind companies from Denmark, the U.S., the Netherlands, or Germany (Gan 1998). This was despite the fact that wind turbine prototypes of 100-200 kW were tested and demonstrated by local manufacturing firms between 1985 and 1995 (ibid: 17). The failure in commercialising these Chinese designs resulted in a reliance on foreign turbines, which were cheaper at that time. In 1996, only 1.7 per cent of the 56 MW of installed wind capacity in China was produced by Chinese turbines (ibid: 18). Large foreign companies, such as Vestas and BONUS (today Siemens) became increasingly interested in the Chinese wind market at the end of the 1980s (ibid.), and Vestas is still ranked among the top ten largest wind turbine providers in China in terms of total market share today (CWPO 2010).

Even though the direct indications are difficult to deduce, it is highly plausible that the focus on small-scale wind power made it easier for the government to promote a legislative framework for grid-connected turbines. The development of the larger wind turbines started in the 1990s, and has grown almost exponentially since. Yet, to the knowledge of the author, not much spill-over in terms of technology innovation has happened. Instead, technology was either licensed from abroad or jointly designed with a foreign company, something which became the prime model of wind turbine development in China (Lewis 2011: 287). Today, some Chinese manufacturers possess the key manufacturing technology for MW-scale wind turbines, and are capable of doing independent research and development (R&D) (ibid.). Also, the industrial manufacturing chain for wind turbines is relatively complete domestically, although manufacturing capabilities for some key parts, including high-precision bearings, control systems and converters, are still weak and depend on imports (REN21 2009a: 18, BNEF 2010, CNRED 2011b: 17).

As an example, Goldwind is the oldest large-scale Chinese wind turbine manufacturer, established in 1998 (Lewis 2007: 222). This company started out as a wind farm developer in Xinjiang Autonomous Region, the western most province in China, and is 55 per cent state-owned (ibid.). Goldwind licensed their first turbine from a small German turbine designer, Jacobs, which was later acquired by the German manufacturer REpower (ibid.). Goldwind has since licensed turbine designs from REpower and Vensys, and another German manufacturer, which designs direct drive turbines (which do not have a gearbox). In 2008, Goldwind became the majority owner of Vensys (Lewis 2011: 287). Some of the licensing agreements have certain requirements, such as a prohibition of usage outside of China, or limitations on future design modifications, as, for instance, for the REpower licensed turbine for Goldwind (ibid.). This also applies to other Chinese manufacturers. For example, Mingyang, the fifth largest Chinese turbine manufacturer, is only allowed to manufacture and distribute their *aerodyn* licensed turbines domestically (Mingyang 2011).

Furthermore, the licenses are not cheap. As an illustration, the licensing agreement Goldwind had with Jacobs required the company to pay a EUR 5,000 royalty per turbine produced (Lewis 2007: 222), and Mingyang currently has to pay a royalty between 0.5 and 2 per cent of the sales price, depending on the amount of turbines sold (Mingyang 2011). In 2009, an estimated US$ 450 million, covering patent royalties, licenses and technical service, flowed from China to Europe and the U.S., financing research and development of wind turbines there (CWPO 2010: 50). All in all, the strategy the Chinese industry has chosen is perhaps best reflected in the slogan of the Chinese-Dutch wind turbine producer XEMC-Darwind: “Dutch design integrity & Chinese industrialization power” (XEMC-Darwind 2012).

The development of the industry will be examined more closely in later chapters, but two important issues should be noted for later reference: Firstly, the government has initiated several programmes to induce wind power growth. One important planned programme is often referred to as the “Three Gorges of the Air”, consisting of seven large wind power bases of more than 10 GW each, which was started in 2008 (CWPO 2010: 7). This programme covers a major part of the added wind power capacity, and a planned capacity of 138 GW will be produced from these bases in 2020, provided the grid capacity is adequate (ibid.). Secondly, the rapid development of the Chinese industry has lead to several technical challenges that need to be addressed. The main challenges are related to the performance and quality of Chinese turbines, with uncertainties over their long term performance, transmission constraints for remote regions, a lack of qualified personnel, and time lags in connecting wind farms to the electricity grid (Martinot 2010). As I shall later discuss, a common denominator for these problems is the speed with which the industry has developed; for instance, the short time-span that Chinese turbines have been in operation, which means that their long-term performance is unknown.

2.3 Why a wind turbine industry?

One might ask *why* China chooses to pursue such an aggressive manufacturing policy given the fact that imported turbines were both cheaper and better-performing at the outset. An immediate reflection is simply that they *can*. Manufacturing is something that China has much experience in; therefore it seems perfectly natural to attract this industry, since China has attracted industry after industry since the beginning of the reform period in 1978 (Kroeber 2011).[5] As a report from Bloomberg New Energy Finance (2010) puts it: "When there is demand for a new product, Chinese companies seek to supply it; PV modules and wind turbines are no exception". Nonetheless, there are several equally viable explanations for China's heavy engagement in the wind turbine industry. China's concern for energy security, climate change (Bambawale & Sovacool 2011), environmental degradation and pollution (Economy 2010), future comparative advantage in clean technologies, as well as domestic electricity shortages and political stability are all highly compelling explanations that cannot be understood solely on their own terms. The industry arguably mushrooms within a nexus of demands: energy, environment, politics, and economy. One particularly illuminating explanation that shall receive some attention here is China's quest for "in-

[5] Some examples include high speed rail transport, information technology, auto assembly, and the civil aviation sector (Moran 2011: 3).

digenous innovation"—where renewable energy serves one of the crucial future economic sectors.

In 2010 the renewable energy industry (solar, wind, and biomass) was one of seven new strategic industries the Chinese government named to help advance economic development, foster innovation, and promote domestic technologies (CGTI 2011: 28). According to this plan, an estimated US$ 231,000 million will be invested exclusively in wind power between 2011 and 2020 (Pan et al. 2011: 14). A much stronger government support signal than this is hard to find in China, making renewable energy one of the most important industries in the country (Medland 2012). In spite of—or perhaps because of—China's growing manufacturing industry, which has contributed to their rapid economic growth, an increasing concern for the government has been China's dependence on foreign technology. "Indigenous innovation" has been proposed as an answer to these concerns (Cao et al. 2009, Kennedy 2010, Kroeber 2011). China's new 15-year "Medium to Long-Term Plan for the Development of Science and Technology", issued in 2006, has as a goal the transformation of China into an "innovation oriented nation", and gives hints as to how China will deal with issues such as technological dependency and domestic innovation, environmental concerns and resource utilisation, as well as human resources and education (Cao et al. 2009). If one looks at China's export sector, the problem is that most of the high-technology exports are produced by multinational companies that own the technology (Moran 2011). Moreover, the technology spill-over effects from these investments, Moran (2011) claims, have been very low. So China seeks to acquire not only the manufacturing ability, but also the design capacity, and thereby the intellectual property rights. Chinese firms can then "collect rather than pay royalties and license fees" (Kroeber 2011: 63).

In the wind industry, the advantages of building a domestic manufacturing industry are perceived to be numerous. In addition to the "indigenous innovation" concern, the goal from the outset was not only to accelerate the development of wind farms, but also to make it cheaper than relying on imported turbines (Howell et al. 2010, BNEF 2010). In the period between 2006 and 2011the industry has created an estimated 200,000 direct jobs (Pan et al. 2011), contributing to a substantial increase in China's proportion of green jobs. While these explanations of *why* China chooses to invest in wind energy are illuminating, they do not tell us how the industry has come into existence. They give us important indicators, to be sure, but reducing China's technology dependency in terms of "indigenous innovation" does not seem to reconcile with the strategy of transferring technology to China. For this reason the rest of this thesis will focus on examining *how* China's industry has grown, and what the specific dynamics of the industry are. We seek to understand better how technology enters the country, how it is assimilated and developed within the country—and how the Chinese government influences these processes within the wind industry.

3. Theoretical framework

All theory, dear friend, is gray, but the golden tree of life springs ever green.

Johann Wolfgang von Goethe

For a tree to grow it needs the right temperature, nutriment, light and soil. Much like Goethe's tree, the act of describing the technical features of a tree cannot compare to the beautiful reality of how a tree looks, although providing such a description is still a worthy intellectual endeavour. Similarly, the overall objective of this study is to analyse how a green industry has grown. In order to succeed in this undertaking, we need hints as to what the right temperature, nutriments, light and soil for an emerging industry are. As we will see in this chapter, innovation systems literature provides a comprehensive account of how industries grow, and it is therefore convenient for our objective. Wind energy is still a marginal portion of the energy sector globally, and the technological innovation system (TIS) framework in particular has provided better insights into emerging technologies and how they face entanglement with a host of vested interests and actors.

3.1 Why an innovation system approach?

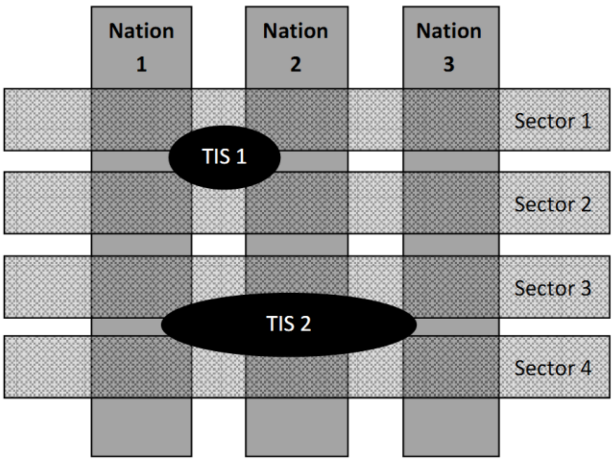
The innovation system literature developed in the 1980s as a response to mainstream economic theory, which treats innovations as extraordinary, exogenous events (Lundvall 2010: 8). Based on Schumpeter's definition of innovation as "already existing knowledge, combined in new ways", the innovation system analysts argue that innovation is ubiquitous, continuous and cumulative. Innovation should not be regarded as a single, isolated event, but rather as a process where interactive learning and collective entrepreneurship are crucial components (ibid: 9). A core assumption amongst innovation system researchers is that technology is structured by its environment, and that innovation processes take place within these structures (Smith 2011: 26). Conceptualisations of technological *regimes* and technological *trajectories* are frequently referred to when describing how the learning and knowledge environment shape the direction technology develops through tacit agreements of involved agents (Malerba 2005). Somewhat simplified put, coordinated activity in terms of organisational and cognitive routines shared by firms and engineers constitute a technological regime (Geels 2002). These shared routines in turn "decide" what type of innovations may take place within the regime, and hence the technological trajectory it takes (ibid.). Technology can therefore be viewed as part and parcel of a complex socio-technical *system*, a social and dynamic system where learning and interaction happens, and where positive feed-back spurs reproduction and re-combinations of knowledge. The different determinants of innovations processes include economic, social, political, organisational or institutional factors, as long as these factors influence the development, diffusion and use of innovations in one way or another (Edquist 2005: 182). Based on this definition, it quickly becomes evident that the build-up of *industries* is part of the scope, and that this has an important economic impact on a country. Therefore, the approach is suitable for understanding the formation and growth of an industry.

The systems approach to innovation has met criticism on several points: that it is weak in giving concrete policy goals (Bergek et al. 2008a), that power structures and political interests are not sufficiently taken into account (Kasa 2011), or that there is a too stark focus on public institutions in the innovation process, which can be compared to "trying to understand a disease by studying the doctors treating it" (Aasen & Amundsen 2011: 243, 244). Some of this criticism is incorporated in the technological innovation system framework, which has been chosen for this study. Under the innovation system umbrella there are several ways of defining the level of analysis, and these can roughly be grouped into two main approaches: one which "delineates systems on the basis of technological, industrial, or sectoral characteristics", and one which emphasises geography, such as national or regional borders (Fagerberg 2005: 12). Since this study will focus on the formation and growth of an industry, the former approach is applied here.

3.2 The technological innovation system scheme

The seminal studies viewing technologies, industries and sectors from a systemic point were done in the 1980s and 1990s (Hughes 1983, Carlsson & Stankiewicz 1991, Malerba 2005). According to Carlsson and Stankiewicz (1991: 112), technological systems differ from national systems in three ways. First, the former refers to a specific "techno-industrial area", instead of all areas of a national system. Second, technological systems are not necessarily restrained by national borders. This means, for instance, that industries that are international or even global in nature can be included in the analysis, as is illustrated in Figure 5 below. As China's growth today is based on the export sector and the inflow of foreign investments, interdependencies with foreign innovations systems are important factors to include in the analysis (Binz & Truffer 2009). Third, microeconomic aspects are given higher relevance because the macro-perspective is weak in pinpointing exactly *what* contributes *where*.

Figure 5: How a TIS relates to national and sectoral innovation systems



Source: Modified version of Markard and Truffer (2008: 600)

In general, one can say that the different levels of analysis address innovation dynamics at their respectively aggregated areas. These dynamics may just as well influence the technology in question for the TIS analysis. If we, for instance, picture TIS 2 in Figure 5 as the international wind turbine industry, we see that wind turbines are used across sectors, e.g. the energy sector and the agriculture sector, as well as across nations. Even though they are part of the explanation, national- or sectoral systems of innovation are not as effective as the TIS framework in capturing all potential influences for a specific technology. Nevertheless, one of the great challenges in using the TIS approach is to define the limits of the technological system in focus, because dividing a system from its environment is not a clear cut-matter. This challenge will be addressed several times throughout the study.

The goal of this paper is to study the growth of the wind turbine manufacturing industry in China in order to understand better the dynamics of the industry today, and to map the key influential factors. The technological innovation system framework not only maps the structural characteristics of a specific innovation system, but also attempts to develop concrete suggestions of "functions", or key processes, that need be fulfilled in order for an innovation system to operate optimally. Using these concrete suggestions, which have been developed based on a number of empirical studies, it is possible to make a judgement of *how* and *how well* an innovation system works (Bergek 2002, Bergek et al. 2008a, Hekkert & Negro 2009). In other words, the TIS framework is a tool which is particularly strong in "identifying bottlenecks and systemic strengths and weaknesses" (Hanson 2011: 2).

The framework is grounded in Carlsson and Stankiewicz (1991: 111) as the conception of a *technological system*, which may be defined as:

> a network of agents interacting in a specific *economic/industrial area* under a *particular institutional infrastructure* or set of infrastructures and involved in the generation, diffusion, and utilization of technology (original italics).

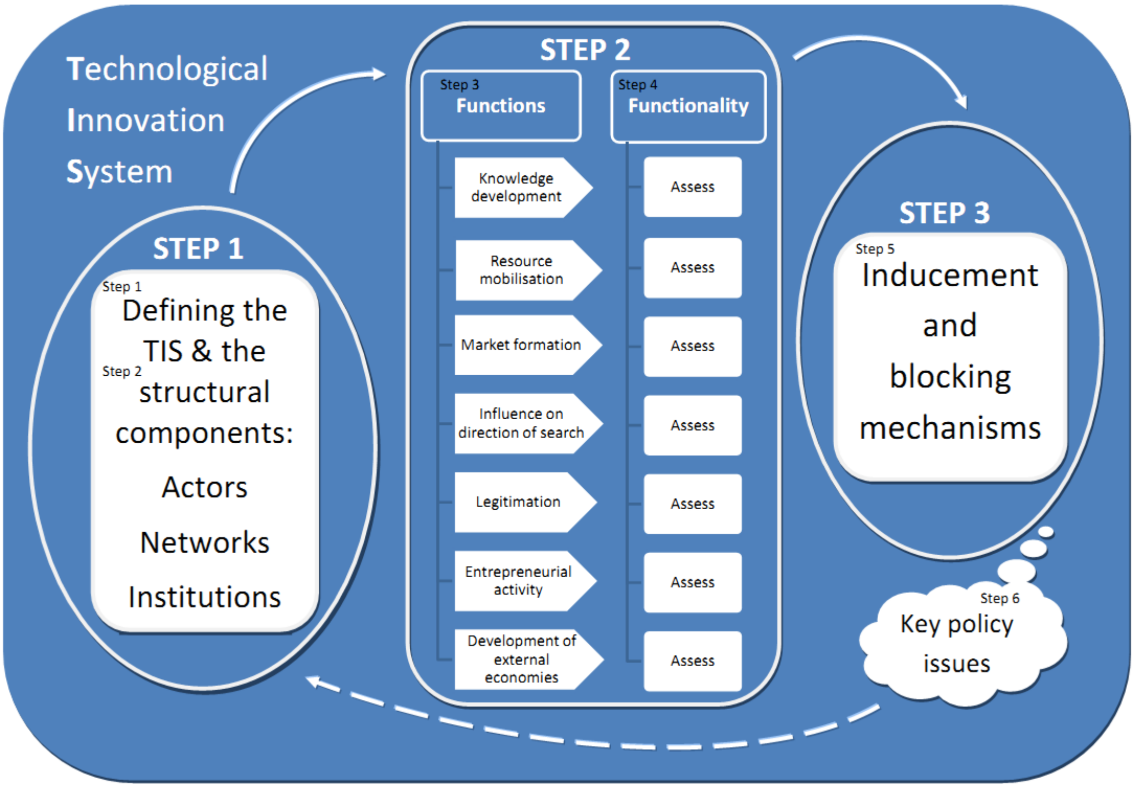
We see that this is in line with the innovation systems approach in general. Carlsson and Stankiewicz also make a distinction between technology as knowledge and competence flows (software) and technology as goods and services (hardware). They choose to incorporate only the former, whilst Bergek et al. (2008a: 408) include both these in their definition of technology, as well as a third component: knowledge as embodied in a physical artefact, i.e. technology itself. This makes the analysis broader, because the spectrum of possibly influential factors for technology development is enlarged, but the end-effect is highly dependent upon the nature of the questions raised. For instance, if a *product* is studied*,* the principal interest tends to be the *diffusion and usage* of a this technology, whilst a focus on technology as *knowledge* tends to be more concerned with problem-solving and the *generation* of new knowledge (Carlsson et al. 2002: 239). Irrespective of this distinction, the core of the argument remains the same, namely that by studying a technological system one follows the evolution of a technology and its surroundings, so that the dynamism over time of the involved components can be measured.

3.2.1 The meaning of "functions"

Thomas P. Hughes (1983: 5), one of the pioneers in studying technical systems, emphasises that the interconnected components of technical systems "are often centrally controlled", and this control is practised in order to "optimize the system's performance and to direct the system toward the achievement of goals". The goal of an electric production system, for instance, is to produce enough electricity for the end-user. Therefore, one may say that the different components of the system all contribute to the goal of the system; otherwise they are not part of that system. In the TIS framework, this *contribution of the components* to the goal is referred to as key processes, or "functions" (Bergek 2002: 28). The overall goal of the innovation system is often taken to be "to develop, diffuse and use innovation" (Edquist 2005: 190). By focussing on the functions that contribute to the overall goal, one can dissect the components which together constitute an organ. Hence, the functions indicate the performance of the innovation system in question, and this is also where the novelty of the TIS framework appears. Even though we shall continue to refer to these as functions, it is important to note that they in reality are *processes* that evolve dynamically as an industry develops.

Anna Bergek et al. (2008a) set forth a six-step guide, or scheme of analysis, with the objective of identifying key policy issues and set policy goals when analysing specific innovation systems. The paper formalises what in this study is taken to be the core of the TIS framework. Conveniently, the TIS approach has been developed chiefly with empirics from the renewable energy field (Hekkert & Negro 2009: 584). This may facilitate the usage of the framework in this specific research project, because it not only reveals the characteristics of the innovation system, but also the main determinants of renewable energy manufacturing industries.[6]

Figure 6: Steps for analysing a TIS



Source: Modified version of Bergek et al. (2008a)

Above, a brief sketch of how the scheme of analysis manifests itself is presented. A more detailed presentation of the framework will appear in Chapter 5 with the

[6] The functional approach has also received some criticism, for instance by Lundvall et al. (2009: 5), where they point out that a functional list can work as a check list for governments, but add that several other factors could be listed, such as competition, openness to international trade and capital flows, labour market dynamics, social welfare systems, and social capital.

analysis of the Chinese wind turbine manufacturing industry. Some of the steps that Bergek et al. (2008a) present have been merged for practical reasons, so that this study contains only three steps, namely: 1) defining the TIS and mapping the structural components, 2) assessing functions and functionality and 3) inducement and blocking mechanisms. This is shown in Figure 6, where the original steps are indicated in small black writing, and the new ones in large white writing.

Bergek et al.'s (2008a) six steps are highly interrelated, and by merging some of the steps the analysis therefore becomes more coherent when examining the dynamics of a TIS. Also, a last step, "Key policy issues", can be included. It is, however, not a part of this study, because this step involves an assessment of what *should be* done. Since the goal of this research project is to understand what *has been* done, including this last step would be an overstretch. Instead, in Section 6.8, I discuss what the industry dynamics look like with a given *overall goal*. In light of the interviews conducted for this study, many informants made it clear that exporting turbines would become a future challenge. Taking this as an overall goal, we can see if the functions currently are served, and how functional dynamics would correspond to such a challenge.

The arrow from step six, key policy issues, which leads back to step two, the structural components, indicates that the policy advice is actually addressed to the actors, networks and institutions of a TIS. To be sure, changes in policy might lead to unexpected changes in the functionality of the TIS. This would imply that the analyst should re-start at step one, since a TIS is not static. Apart from these changes, the procedure and build-up of the analysis remains similar to the original. Notably, these steps are not to be taken as a linear approach, and should be examined more or less simultaneously.

3.2.2 Step 1: Defining the TIS and mapping the components

It is crucial to initially identify the boundaries of the technological innovation system in question. As is thoroughly underlined by Carlsson et al. (2002), defining the system and mapping the components are two sides of the same coin. Defining the boundaries of the specific technology system can prove difficult, since the dynamic character of the system implies that actors, networks and institutions may change over time. The delimitation of a field of study is the main determinant for the definition of a TIS. Put differently, the questions asked will define the level chosen. According to Bergek et al. (2008a: 411) there are three main choices to make: 1) to choose between a knowledge field or a product, 2) to choose between breadth or depth, and 3) to choose a spatial domain. Carlsson et al. (2002: 239) maintain that the delineation of TISs is not as problematic when the focus is on a product group, such as wind turbines. However, the next two choices can be more elusive because they have implications for which structural components will be included in the analysis. In the case of the wind turbine industry, a decision has to be made as to how much of a cluster is to be included, since the focus is on a group of related firms. Fortunately, it is fairly clear who the user of a wind turbine is, how it will be applied, and what the boundary of the technology is. This will be outlined thoroughly in Chapters 5 and 6. The third choice above relates to the fact that TISs generally are of a global character, and therefore the global context needs to be closely examined and compared with the local TIS (Bergek et al. 2008a). Nevertheless, as we shall come back to at the end of this chapter, and in Chapter 5, the spatial characteristics of TISs has received less attention in the literature thus far (Coenen et al. 2012).

The three main structural elements in a TIS are the firms and organisations (actors), networks[7] and institutions (Jacobsson 2011: 45). This division is only an analytical construct, and in China one will find government involvement across

[7] Networks and systems are fairly similar concepts, however, according to Fagerberg et al. (2005: 13), ”a system will typically have more ‘structure’ than a network, and be of a more enduring character.”

the spectrum. On the one hand, the Chinese state is unique; yet on the other hand, fostering a new technology (system) anywhere in the world often requires the state to be present. The complexity resides in deciding, for this specific industry, what—if any—is the difference in the Chinese case? Certainly, determining the exact proportion of government involvement is beyond the reach of this research project, yet an attempt will be made to pinpoint the government influence throughout the innovation process within the wind turbine industry.

First, the *actors* of the chosen TIS need to be identified. These can be firms along the whole value chain, universities and research institutes, as well as public institutions or interest organisations, such as industry associations (Bergek et al. 2008a). When identifying the actors, it may be difficult to find all the actors in the system, and also to decide whether a specific actor actually belongs to the system. Most TIS theorists agree that firms are the key actors in an innovation system (Coenen & Díaz López 2010: 1152), because they are the ones actually carrying out most innovations. The actors within the wind turbine industry can be recognized by looking at industry association lists or trade statistics, yet it is more difficult to gain access to Chinese government institutions.

Second, the *networks* within the TIS should be outlined. Networks in innovation systems mushroom when there is a need for communication. This communication is crucial in building up trust and reducing the uncertainty that the marketing of an invention brings (Carlsson & Stankiewicz 1991). Networks include all formal and informal interaction and communication between the various actors. One example is learning networks, or problem-solving networks, which link the suppliers to the users, related firms or competitors, or link universities to the industry (Bergek et al. 2008b: 577). These networks are very important, because this is where an actor turns to for help when solving technical problems (Carlsson et al. 2002: 237). Equally important networks are political in nature. Lobbying and exercising influence on political issues is an important determinant for the success or failure of actors in a system (Bergek et al. 2008b: 577). As an example of how important political networks and power structures are, Kasa (2011: 64) shows that interests and networks in heavy industries in Norway are crucial for understanding why carbon capture and storage (CCS) has received massive investment in Norway. This type of network is closely connected to the institutional set-up.

Finally, *institutions* need to be addressed, and they include vague terms which are difficult to measure, such as culture, norms and routines, as well as more tangible laws and regulations (Bergek et al. 2008a). They have typically evolved over time, and regulate either directly or indirectly how actors relate to each other (Johnson 2010: 25). Important features of institutions include their abilities to coordinate the use of knowledge, to mediate conflicts, and to provide incentive systems for the involved actors (ibid: 27). Institutions create stability in a society, a stability that produces inertia but which also provides the platform necessary for changes to occur (ibid.). The success of an introduction of new technology, is determined by the way institutions change. This means that the actors in a system compete not only over customers, but also over gaining influence on the institutions in the system (Jacobsson 2011: 47). Knowledge is also an institutional artefact which influences the actors' decisions, by establishing "cognitive rules" in the shape of "knowledge products" or "frames that structure learning processes" (Geels & Raven 2006: 378). [8] These cognitive rules implicitly or explicitly guide the way actors make decisions and solve problems.

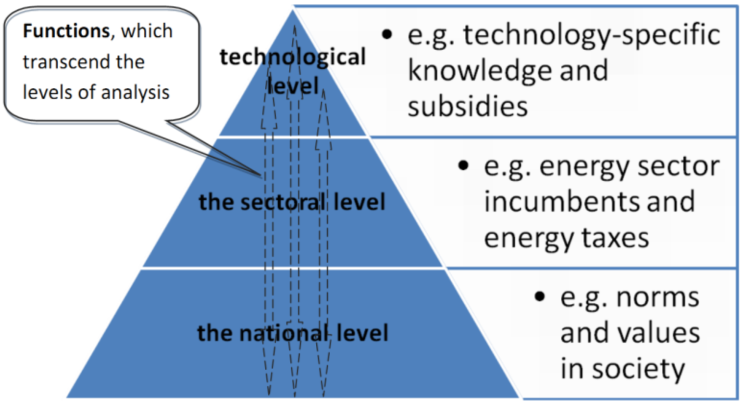
3.2.3 Step 2: Assessing functions and functionality

Whilst the first step predominantly focuses on issues common to most innovation system approaches, the two next steps reveal what makes the TIS framework different. In the second step, the aim is to describe the "functional pattern" of a TIS, and whilst doing this, assess how well these functions are fulfilled (i.e. the func-

[8] According to Geels and Raven (2006: 378) knowledge products can be "abstract theories, technical models, formulas", and frames that structure learning processes problem are "agendas, search heuristics, guiding principles, rules of thumb [or] exemplars".

tionality). The functions delineated here are adopted from Bergek et al. (2008a), who in turn have synthesised and further developed these functions from numerous studies on innovation systems. Other approaches covering the functions of an innovation system exist, where both similar and new functions are included (e.g. Edquist 2005, Hekkert & Negro 2009). One difference is that Bergek et al. (2008a) have a greater focus on using qualitative indicators such as interviews, as a means of identifying and assessing the functions (Markard & Truffer 2008: 603).

Figure 7: How functions aid the analysis of the wind turbine supplier industry



Source: Based on Bergek (2002: 64, 120)

One virtue of mapping the functions of an innovation system is that it allows the student to transcend levels of analysis, as depicted in Figure 7. The functions enable a focus on the key *processes* that influence the object of study. The seven functions, which may be partly overlapping and mutually influenced, are subsequently categorised.

Resource mobilisation is decisive when a TIS develops, and generally two main types of resources need be mobilised; namely, human and financial capital. When resources are mobilised, they often affect *knowledge development and diffusion*; for instance, by increasing the number of people in higher education, or through research and development (R&D) funding. Knowledge development and diffusion is often taken to be the most important function in an innovation system, because new combinations of knowledge determine how a TIS evolves, as well as how it performs both globally and locally. This function also depends on the existing knowledge base. Knowledge development is achieved, for instance, by R&D, learning from application, or imitation.

Influence on direction of search relates to the inducements mechanism that convinces actors to enter a TIS. This is crucial for a TIS to develop, and these pressures and incentives can come from within (e.g. competing technologies) as well as outside (e.g. government directives or established interests) the TIS in question.

Market formation is decisive for successful innovation, even though markets very seldom exist for an emerging TIS. This function is closely connected with institutional change, which often is seen as a requirement for market development.

Creating legitimacy for the technology in question is necessary for a TIS to develop. Legitimacy is a question of social acceptance. The relevant actors need to understand the relevance and value of the technology in order to support it. In this way demand forms, and political strength is attained.

Entrepreneurial activity functions as a hub that perceives and processes all relevant knowledge, networks and markets of an innovation system, and turns these into concrete actions (Hekkert & Negro 2009). For this study, the notion of entrepreneurial *activity* will be used in place of entrepreneurial *experimentation*, because it is perceived as more relevant to the Chinese wind turbine TIS. Entrepreneurial experimentation is arguably more important in early stages of technology development, where performance uncertainty permeates the TIS environment (ibid.). In Chapter 5, I will instead argue that the Chinese wind turbine TIS finds itself in a "bridging phase", which is between the early and the mature stages of a TIS. The notion "entrepreneurial activity" does not exclude experimentation, which can be a part of the function.

Development of external economies, also often referred to as "free utilities", is advantageous to a whole TIS. The entry of new firms is central to this function because 1) new entrants may increase the legitimacy of the TIS, 2) more firms in a TIS signals a certain momentum, which can induce more actors to enter the

TIS, and 3) the chances of new combinations of knowledge are greater, as more connections will occur. Also, external economies may spill over between sectors.

In order to measure how well these functions are fulfilled, we need to compare the functions against a base, so that a "desired functional pattern" can be developed (Bergek et al. 2008a). This is necessary, because the "goodness" of each function is best understood in relative terms (ibid.). Bergek et al. (2008a) admit that more research needs to be done on this, yet they suggest comparing performance along two lines: 1) establish which *phase* the TIS is in, thereby determining functionality, and 2) compare TISs of different locations (ibid.). Two more methods can be added to the list; namely, 3) compare similar TISs domestically, and 4) confer with the stakeholders in question. A combination of these four strategies will be adopted in this study, using the method most convenient for each function assessed. As a result, a comparison with both foreign wind TISs and the domestic solar TIS is fitting, and a discussion about which phase the wind turbine TIS is in will serve to provide an overall understanding of how the functions perform. This will be scrutinised in detail in Chapters 5 and 6.

It is important to bear in mind that even though some of these functions are frail or, conversely, particularly strong, it does not necessarily tell us anything about the *overall* functionality of the system. These functions need to be fulfilled individually, but the interaction dynamics between them are also of importance because they can lead to positive or negative feedback cycles within the TIS (Hekkert & Negro 2009: 587). For example, as is particularly the case in China, a government goal is set; for instance to limit environmental damage. This is registered here as an "influence on the direction of search", which in turn can spur a facilitation of "resource mobilisation" and an increase in "legitimacy". Furthermore, the resources, which may have been used to finance R&D projects, can result in "knowledge development and diffusion". Therefore, in Section 6.8 an attempt is made to measure the performance of China's wind turbine TIS in terms of how the dynamics of the functions contribute to achieving an overall goal.

3.2.4 Step 3: Inducement and blocking mechanisms

When a TIS is emerging it faces entanglements with more established TISs and industries which have had more time to shape—and be shaped by—existing actors, networks and institutions. Innovation happens within a technological *regime* which "decides" which new technologies succeed or not (Smith 2011). The way a new TIS deals with this is dependent on certain inducement and blocking mechanisms which can be found in the structural components of the innovation system, or in the larger context surrounding it (Bergek et al. 2008a). This means that not only factors internal to the TIS are decisive for its performance, but also external forces. According to Bergek (2002: 128) most inducement mechanisms come from government policy measures, whilst blocking mechanisms are more complex and relate to many of the structural components, such as weak networks, lack of organisational power or a lock-in to established technologies. Some of the key functions described in step 2 may also work as inducement or blocking mechanisms. For instance, "market formation", in the shape of increased green demand, could facilitate the mobilisation of resources for a start-up renewable energy technology (ibid: 50). The mechanisms influencing the Chinese wind turbine TIS will be thoroughly scrutinised in Chapter 7.

3.3 Technology transfer and catch-up

Before we jump to the analysis, some remarks on the specific circumstances of innovation systems need to be made. First, there is already a discussion of whether National Systems of Innovation approaches are suitable for application to developing countries. Since China is a developing country with its inherent characteristics, one might question whether the TIS approach is appropriate. As Lundvall (2011) points out, innovation scholars have suggested that developing countries do not have "innovation systems" but instead have "learning systems", because to a large extent they are dependent on technology transferred from abroad. Second, recent research points out that the TIS framework does not explain the spatial characteristics of innovation well, which is especially relevant when studying global innovation interconnections (Binz & Truffer 2009, 2010, Coenen & Díaz López 2010, Coenen et al. 2012, Binz et al. 2012, Truffer & Coenen 2012).

In response to the first issue above, Lundvall et al. (2009: 3) argue that learning actually is essential for innovation; for instance, by doing (manufacturing), using and interacting with the technology. In this study, learning mechanisms will be a part of a wider definition of innovation which includes not only "know-what" and "know-why", but also "know-how" and "know-who" (Jensen et al. 2007). As pointed out by Nelson (2007: 10), most now-developed countries in one way or another learned from leading countries, and this progress was no less innovative because they learned from others. In keeping with the innovation system approach, domestic conditions are regarded as important determinants as to whether a technology successfully transfers to the host country. Successful technology transfer therefore entails innovation at the receiving end, and is dependent on what is often referred to as the "absorptive capacity" of an industry (Binz et al. 2012: 157). The absorptive capacity of a firm was defined by Cohen and Levinthal (1990: 128) as the ability to "recognize the value of new, external information, assimilate it, and apply it to commercial ends". As we will see in Chapter 6 (Section 6.2.2), absorbing knowledge and learning is not a self-evident process that happens automatically by increasing R&D expenditure. Rather, it may be understood as something which develops together with the TIS, as know-how and know-who increases.

The second notion above relates directly to how the *TIS framework* can be applied to developing countries. From a TIS perspective, a core assumption is that industries are highly globalised (Bergek et al. 2008a: 412,413). This is also true for the wind industry in China, where several companies and experts from developed countries are actively engaged. The wind industry can be regarded as part and parcel of a global, dynamic industry. Although this global component is included in the TIS framework, there is confusion as to what geographical extension the institutions have, something which leaves “institutional structures to seemingly float freely across a boundless, global plane” (Coenen et al. 2012: 973). Thus, the TIS framework does not adequately address spatial characteristics of innovation. This has two implications for this study. First, since the TIS framework is developed largely with empirics from North-western Europe (and Scandinavia in particular) (Coenen et al. 2012), the functional dynamics may be rendered less relevant in a country with completely different actors, networks and institutions. As Liu and White (2001: 1112) point out, a possibility exists that “fundamentally different but equally viable national innovation systems could emerge in China”. Applying the TIS framework to China can be viewed as an opportunity to expand the theoretical framework by supplementing it with empirical input. Secondly, the international couplings with the Chinese wind turbine TIS can be illuminated further. Binz and Truffer (2010) and Binz et al. (2012) suggest that one can talk about global and local TISs, where “deficits identified in the national TIS may be compensated by couplings with international TIS structures” (Binz et al. 2012: 158). Although a fully-fledged analysis of this conceptualisation is beyond the scope of this study, the notion can be adopted to illuminate certain aspects of the Chinese wind turbine industry.

4. Methodology

Where you stand depends on where you sit.
Rufus E. Miles (1978)

While conducting a literature survey at the beginning of this research project I found that most reports had similar conclusions: the Renewable Energy Law was instrumental for the development of the industry. Yet, few of the dynamics behind the growth of the wind industry were described. Since I felt a comprehensive explanation was lacking, I decided that the overarching objective of this thesis would be to tease out some lessons from the historical record of China's wind turbine industry. The wind industry in China is the case we want to comprehend better, and the TIS framework is employed to improve our understanding of the phenomenon. The TIS framework contains certain basic propositions, for instance, on how technology develops, and is therefore treated here as a theory.[9] Since the case study method often takes a theory as a point of departure, whether to test or to develop the theory further (Yin 2009: 35), the method is convenient to use for this research project. It is not self evident, however, that the present approach is the most appropriate, or that it yields the best results. Insights on the limitations of a study are crucial for the validity of a research design, such as recognition that my own perceptions are projected into the study—that where I stand depends on where I sit.

The case study method has much in common with historiography (Moses & Knutsen 2007, Yin 2009), and as is evident with the present case, the goal is to analyse happenings of the past. Hence one may ask if the case study method really is appropriate. Why not, for instance, simply choose the tools adopted by the historical method, a method that I am, in fact, well versed in? Case study re-

[9] This is also debatable. Edquist (2005: 186), for instance, claims that the innovation system approach is "not a formal theory, in the sense of providing specific propositions regarding causal relations among variables". He then shows that other scholars disagree on the status of the approach as a theory or not. Lundvall (2007: 99) remains less definite, and claims that it "might also be argued that [the approach] serves as equivalent to what is normally defined as theory".

search is distinguished from history by employing two more sources of evidence that are not as commonly used amongst historians; namely, direct observation, and interviews with people involved in the events (Yin 2009: 11). Also, as the present study is an on-going and contemporary event, the case study method is more applicable. Likewise, other approaches are equally inadequate in answering the research questions of this study. Since the topic at heart of this study is to generate an understanding of how the Chinese wind industry has grown and how it works, purely drawing on statistics or survey data would not suffice, because they would not enable an analysis of a wide range of actors participating in a dynamically evolving context; they would have the same informative function as countless reports already written on the issue. At the same time, relying on in-depth interviews alone would be too myopic if we are to understand a whole industry.

Attitudes and beliefs that are brought into the field can lead to a bias in the collected data (Walsh 1998: 126). One cannot simply forget about these attitudes and beliefs—that would at best be self deceptive. Rather, they should be identified, and explicitly communicated (ibid.). My worldview is best described as "pragmatist", defined as a view which focuses on the outcomes of the research, on solutions to problems, and "what works" (Creswell 2007: 22). This worldview may have had implications for how the case has been studied, for instance in choosing the problem area before choosing a theory I wanted to test. A practical orientation may also lead to a focus on doing research which can be applied as policy advice later. According to McNeill (1999: 328), it is slightly troublesome for a research product to be policy oriented—as is the TIS objective— because it may lead to less rigorous research. Therefore, instead of weighing the order in which the case and the theory have been chosen, a main point of effort here is how the case, the theory and the research questions all are coherently and rigorously examined.

The subsequent section shall explain why the case study method is the most appropriate, followed by a description of the data collection methods and a discussion of the constraints for this thesis.

4.1 Case study research

Robert K. Yin (2009: 18) has provided a twofold definition of case studies, the first part emphasising the scope of a study, and the second concerning technical issues and how a case study can be conducted:

1. A case study is an empirical inquiry that
   - investigates a contemporary phenomenon in depth and within its real-life context, especially when
   - the boundaries between phenomenon and context are not clearly evident.
2. The case study inquiry
   - copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
   - relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
   - benefits from the prior development of theoretical propositions to guide data collection and analysis (ibid.).

This study seeks to understand the dynamics of a phenomenon—understanding the *how*—whilst retaining a holistic and meaningful conception of the Chinese wind industry. This is a good starting point for employing a case study method (Yin 2009: 4). Looking at the above definition, it is clear that much of the TIS approach has much in common with the case study method, such as through emphasising a clear delimitation of the case in focus, as well as aiming to explain a phenomenon by using the best-suited methods at hand.[10] The innovation systems approach takes on a holistic and interdisciplinary perspective, since it tries to cover all the important determinants of innovation, and does this by using perspectives from various disciplines (Edquist 2005: 185). Thus, we see that the case

[10] This is perhaps even more evident using this definition: "(...) the basic idea is that a case will be studied in detail, using whatever methods seem appropriate" (Silverman 2010: 138).

study method and the innovation systems approach deploy similar ways of eliciting "truths" from observations. This serves as yet another argument for employing the case study method to the Chinese wind turbine industry: as we have seen, the TIS framework is not only a theory, but also a blueprint for analysis, containing hints at how to best study an industry. Therefore, the method is already partly ingrained in the approach. Consequently, much of the discussion around the boundaries and characteristics of this particular case has been pointed out in the theory chapter, and will be scrutinised in depth in the next two chapters.

In general, three types of case studies can be distinguished, namely *fitting*, *misfitting* and *generalising* (Moses & Knutsen 2007: 133). The first two seek to explain how a case corresponds, or not, with a general proposition, and the latter seeks to generate hypotheses or build theory (ibid.). The starting point for this thesis is that the Chinese wind turbine industry can be explained by the TIS framework, and we can therefore regard this as a *fitting* case, because it "serves to demonstrate the explanatory power of a particular theory" (ibid.). Robert K. Yin (2009: 47) operates with the label "critical case", where the intention is to confirm, challenge, or extend the theory at hand. This label is perhaps even more suitable because, as we shall see throughout this study, certain extensions seem necessary when applying the theory to new grounds such as newly industrialising countries. In this way, we will not blindly accept all the propositions which are believed to be true in the theoretical framework, but attempt to refine, modify or develop them where necessary.

Attempting to complete a holistic, interdisciplinary, in-depth case study, one that is also rigorous and readable, seems indeed challenging. Undeniably, many complications occur, and few promises can be made. For instance, as is underlined by Robert Stake (1994: 238), one danger is to misrepresent the case when focusing too much on providing a theoretical contribution. Moreover, when attempting to conduct a holistic study, interdisciplinarity can be useful, but claiming to have equally in-depth knowledge in multiple disciplines would be misleading. Both these concerns are highly valid for this research project as well. Therefore, the intention here is to clarify the approach in as detailed and open a manner as possible.

As we shall see, this case has multiple sources of evidence, mainly from interviews and documents as well as some observation. One of the strengths of the case study method is precisely that converging lines of inquiry can be developed; this is frequently referred to as triangulation (Yin 2009: 115). The procedure of triangulation is employed in order to reduce the likelihood of misinterpreting a case study (Stake 1994). Essentially, triangulation means studying the same phenomenon from multiple sources, so that the validity of a case study increases (Yin 2009: 116). Whilst this allows for both in-depth as well as overarching perspectives, it can create a challenge that leaves the researcher in a methodological limbo: "The analyst's nearness to the empirical detail and his heavy reliance on theory mean that he is constantly forced to address the sundry ways in which theoretical claims and empirical evidence often collide" (Moses & Knutsen 2007: 140). The best remedy for this is to constantly be reassured that the overall objective, the research design and the case are all well aligned (ibid.). Keeping in mind Yin's definition for a case study above, I shall now turn to the practicalities of data collected for this study.

4.2 Methods of data collection

I had initially chosen a very broad starting point for this study, intending to cover both the wind turbine and solar cell industry in China, in order to compare and contrast their respective developments. Even though this lead to extra work in the beginning, encompassing far more preparatory research before entering the field, it ultimately proved to be useful for several reasons. For one, this study benefits from a comparison between the wind industry and the solar industry, something which has enriched the analysis greatly. Second, and more importantly for the fieldwork, it led to a broader network of potentially useful contacts. This yielded more interviews, as I employed sampling methods based on *purposeful*, *snowball* and *opportunistic* sampling (Scheyvens & Storey 2003: 43). Purposeful sampling means that individuals are selected based on their ability to "purposefully inform an understanding of the research problem and central phenomenon in the study" (Creswell 2007: 125). This sampling strategy contains some potential pitfalls, such as a risk of biased selection, and some virtues, such as saving time and resources. When selecting interviewees this way, the choice was often based on literature review or an explicit search for professionals, researchers or government officials within the wind industry. I was searching for people with insights on, or a thorough understanding of, how the wind industry had developed. Snowball sampling usually involves finding one person with relevant knowledge, and then asking if he or she knows others that suit the criteria (Scheyvens & Storey 2003: 43). The purpose of opportunistic sampling is to follow new leads and take advantage of situations as they arise (Creswell 2007: 127), a technique which was convenient in Beijing, where I occasionally had unplanned opportunities to speak to people with ties to the wind industy.

As was mentioned in the theory chapter, interview candidates were identified through online research, industry association lists or trade statistics, but most importantly by using the snowball method. The underlying principle when selecting and conducting the interviews was to map the opinions of the central actors, in order to get a representative picture of the important factors in the industry. The interviews would therefore involve inquiring the relevant stakeholders on their perceptions about the overall performance of the wind industry. Candidates that were perceived as relevant were informed experts at universities, organisations, consultancy firms and in the government, as well as wind turbine company employees. These groups were relevant both because of the knowledge they possessed about the industry, and because of the backgrounds they had from different segments of the industry. To be sure, this selection could, for instance, have been limited to government officials or company employees exclusively. However, according to Yin (2009: 130), the most preferred strategy of analysing the case study data is to rely on the theoretical propositions of the theory chosen. Therefore, following the TIS scheme, the collected data preferably should be broadly selected amongst the institutions and the actors involved in the TIS.

From the very beginning I had arranged meetings with potentially helpful sources that could help me find relevant interviews; an endeavour which continued throughout the fieldwork. There were many failed attempts to reach people, and as expected, many sent e-mails were never responded to. The five months long field stay was a great aid in circumventing this problem.

The interviews

Though 13 formal interviews were conducted, one withdrew later, leaving 12 interviews for the analysis. Only one of the interviews was not recorded, and all of the recorded interviews were transcribed afterwards. The interviewees are listed in Appendix 1. The informants have backgrounds from various fields, ranging from government officials and technical wind industry experts to company employees from large, medium and small wind turbine manufacturers. Three of the interviews were with women, and nine with men. Additionally, several informal conversations were conducted throughout the whole period with experts and people involved in the renewable energy industry. This includes wind farm developers, researchers, foreign wind industry experts and professionals, and both domestic and foreign wind turbine component manufacturers.

All the interviews were semi-structured, containing "a sequence of themes to be covered, as well as suggested questions" (Kvale 1996: 124). The idea was not to get hard facts from the interviewees, but to "elicit data on opinions and behaviour" (Scheyvens & Storey 2003: 41). This way, the interviews allowed for a change of theme which naturally corresponded with the interviewee's reasoning, and answers were followed up when suitable. The interviews always started by going through the purpose of the study, then clarifying the amount of time needed to complete the interview as well as the plans for using the information gathered, and finally informing the interviewee of the policies on confidentiality and anonymity (Creswell 2007: 134). Most of the informants had received a copy of the interview guide before the interview.

It is important to reflect on how the interviews will be analysed before the interviews are conducted (Kvale 1996: 178). Therefore, the interview guide, a sample of which is attached in Appendix 2, was shaped with a view to the problem at heart for this study, and in line with the theoretical framework. The use of follow-up questions during the interviews was meant to clarify the position of the informant, or to confirm or reject my own hypotheses about the nature of the industry. The interview guide was revised several times, and adapted to the individuals I interviewed. Also, as I learned more about the topic, some questions were added or removed.

Before I went into the field I contacted experienced researchers and professionals in China working on similar topics, in order to find out if getting enough sources would prove difficult. All responded that this would become a major challenge unless I had contacts, especially when contacting people at the government level in China. I also decided to do a *pilot* interview in advance, which was conducted as a phone-interview, in order to acquire information as well as test and adjust the questions in my interview guide (Widerberg 2001: 60). This interview is not, however, included in the final analysis.

One development was that it was easier to find willing interviewees in the wind industry than in the solar industry, something which lead to the decision to focus solely on the wind industry. As getting the interviews was no longer a large bottleneck, the question of quantity started to emerge: how many interviews would be sufficient? Ultimately, I had opportunities to get more interviews, but at one point I decided that I had enough material, because most aspects from the wind industry were covered. However, my sampling methods yielded a low number of informants from the research community, so I had to intensify my search in this sector. Unfortunately, this did not yield results, although I did have some informal conversations with researchers in the wind industry. Since no formal interviews from the research community are included the analysis, the discussion related to research and development was considerably undermined. Luckily, the experts interviewed had knowledge on these issues, and available secondary documents were used to build the argumentation.

Except for one interview, which I transcribed myself, all the recorded interviews were transcribed by a paid assistant. All the transcriptions were performed by the same person, and after each transcription was done, I read the transcript and listened to the audio material simultaneously in order to verify and correct the transcripts. The subsequent analysis was organised using the computer-assisted analysis software called NVivo. This software was of great assistance in coding and categorising the material so that the analysis could be conducted in a systematic fashion. All interviews were conducted in English, and in three of the interviews an interpreter was used. This interpreter also proved very useful in contacting and booking meetings with relevant informants. Using an interpreter has both advantages and disadvantages: it allows for flexibility regarding note-taking during interviews, but also heightens the probability of information manipulation when reiterated (Scheyvens & Storey 2003: 133). I cannot be sure that information transmitted was entirely accurate. Nevertheless, the translator I used had worked for several years as a professional interpreter, including on assignments within the wind industry. Based on the interpreter's experience and professionalism (e.g. using industry specific words), I felt assured that the interviews were interpreted as accurately as possible.

During the interviews, as well as the subsequent analysis, the utmost care has been taken to evaluate possible ethical concerns for the informants. The following three principles were particularly stressed: *informed consent*, *privacy of the informant* and a potential *conflict of interest* (Scheyvens & Storey 2003: 142). Appendix 3 includes the Information and Consent Form, which was used in all the formal interviews, and signed by both the interviewer and interviewees. This form ensures that the interviewee is adequately informed about the project, and that the participant freely agrees to take part in the research project. It also obligates the interviewer to comply with the ethical considerations stated in the form. The outline of the consent form was based on Scheyvens and Storey (2003: 143) and Creswell (2007: 123, 124).

All the interviewees were informed that they could remain anonymous, yet only a few chose to remain so. Nevertheless, throughout the analysis I have chosen to highlight names only when explicitly quoted, and not when the informants were referred to collectively, such as “many of the informants agreed that ...” After the analysis was conducted, the informants were consulted and asked to confirm, correct, or reject their quotes, as agreed upon in the consent form. None of the quotes were rejected, and one was corrected for grammar. The privacy of the informant was further ensured by constantly making sure that field notes, interview recordings, and transcripts were stored safely and only used for research purposes.

Observation and participation

Since the beginning of 2011, I have attempted to immerse myself in the Chinese renewable energy industry, signing up to various e-mail lists, such as the Beijing Energy Network, and participating in online groups; for instance, on LinkedIn, a professional networking website. I stayed in China for almost five months, from August to December 2011. The majority of the stay was spent in Beijing, with some excursions to renewable energy industry sites as well as a 10-day organised “China Energy Trip” conducted outside of Beijing. My attitude when entering the field was that of a learner (Walsh 1998: 99); the people I met within the renewable energy industry were the experts who had knowledge and experience I wanted to tap into.

When in Beijing, I attended several meetings organised by the Beijing Energy Network, where I also met people who could help me arrange interviews. I also attended other, similar functions that were relevant; for instance, events arranged by Greenpeace or Beijing Green Drinks. The most important occasion I participated in was the China Wind Power 2011 conference and exhibition, which yielded many fruitful leads in terms of new knowledge, written material, contacts and interviews. According to the conference web pages, the exhibition is one of the top events for the wind industry both inside and outside of China, and in 2011 had 612 exhibiting companies with almost 27,000 visitors (CWP 2011). The conference also had speakers from all the leading wind turbine and components manufacturers across the globe. Some of these speeches and debates were recorded, and serve as additional direct sources for the analysis. In December 2011, I also attended Intersolar China 2011, a conference and exhibition for the photovoltaic solar industry. This conference was highly informative as well, and laid the basis for a better comparison with the wind industry, where this was necessary in the analysis.

Documents

Before, during and after the fieldwork, documents were used as sources of information. Since the beginning of 2011 I have followed all the sources I could discover that dealt with the Chinese wind industry—predominately information accessed online. The documents reviewed for this thesis had the double function of providing information about the specifics of the wind industry, in addition to indicating which questions remained unanswered regarding the dynamics of the industry, and therefore should be brought up in the interviews. Given the rapid changes in the industry, an explicit effort has been made to use updated sources and recent literature on the industry. Nevertheless, incorporating the most recent changes is a chronic problem for students of China, as the access to relevant information often lags behind the developments themselves. Scott Kennedy (2011: 3) expressed the frustration in this way: "There seems to be a disjuncture between how quickly China is changing and how slowly we are adapting the way we study the country's politics".

The documents which lay the foundation for the analysis include scientific and technical articles, books and anthologies, proceedings from the China Wind Power 2011 conference, press releases and news articles, policy documents, technical reports, global wind market reports (e.g. from Mercom), statistics, articles in popular magazines on renewable energy, annual reports, and promotional material from manufacturers. In general, as the renewable energy industry in China is fairly new, statistical work is either weak or impossible to retrieve (CNRED 2011b), and has therefore not been used to a large extent. It was also difficult to access accurate and reliable data on financial transaction, company ownership details and patent applications. This has weakened the analysis somewhat, yet, I would claim, to some extent has been compensated by information retrieved by the interviews. Many documents were accessed during the fieldwork, for instance information material from CREIA, or from the various companies I visited. News articles online were especially useful in retrieving the latest information available on the rapidly developing wind industry in China. One of the great strengths of using written material is the impact they have on the reproducibility of the case study. Most of the sources were accessed online, or are in any case readily accessible for anyone who would want to reproduce or simply verify the information retrieved.

4.3 Barriers and ethical dilemmas

In China, access to information and relevant informants can be a function of the sensitivity of the research topic. Heimer and Thøgersen (2006: 13) claim that political sensitivity in China "becomes a question of timing as well as the audience and the use of the information". Having conferred with experienced researchers in the field of energy and China before I entered the field, it was established that renewable energy is not at all sensitive; on the contrary, it seems to be a field China is proud of. Rather than the sensitivity of the topic, what proved to be a barrier to access was the informants' schedules and availability combined with the small perceived gain for participation. This combination lead in the beginning to an ethical dilemma: it seemed—based on the few contacts I had—that potential interviewees wanted something in return for participating; for instance, that their company would be mentioned several times (favourably). Also, since I did not have any affiliation with an institution or a network of expertise in China—something which would increase my own status, as opposed to affiliation with an institution far away in a small country such as Norway—it seemed few of the informants would be interested in my project.

Fortunately, this conflict of interest did not turn out to become a real problem after the interviews were *already* booked and conducted. Getting in touch with relevant people of a certain rank, however, proved more difficult because of my lack of status in the domain of research. The easiest way to book an interview was through connections with affiliated people, or through direct interaction where I had already met the informant and exchanged name cards, as was the case at the conferences. Also, some of the people with experience within the renewable energy industry in China informed me that inviting people to interviews could be much easier if the invitation was sent from someone with higher rank. Therefore, on one occasion my supervisor helped me send an invitation to a high level government official, which was responded to positively within few hours.

Language was the largest barrier for both the fieldwork and the written information accessed, although I received great assistance from my interpreter. Luckily, the wind industry in China is fairly international, and many of the central actors spoke English well. Furthermore, a large number of foreigners engaged with environment, energy and business topics are situated in Beijing, all of whom I communicated with in English. In spite of the fact that the methodology literature does not recommend combining fieldwork with other activities, I found it convenient to engage in three months of intensive language training while in China. I thus acquired a basic knowledge of Mandarin, which was very useful in establishing a positive interview atmosphere, as it conveyed a sentiment of genuine interest.

Lastly, an ethical consideration arose with regard to the interviews; namely, that giving gifts is very common in China. I was advised by several people, both locals and foreigners with long-term experience in China, to bring a small personal gift for the interviewee, preferably something from my own home country. In order to avoid appearing impolite I took the advice, and decided to bring each interviewee a small Norwegian chocolate as well as a very small bottle of Scandinavian vodka.

5. The Chinese wind turbine TIS and structural components

The wind turbine is like a system, like a human body
Sebastian Meyer (interview 08.11.2011)

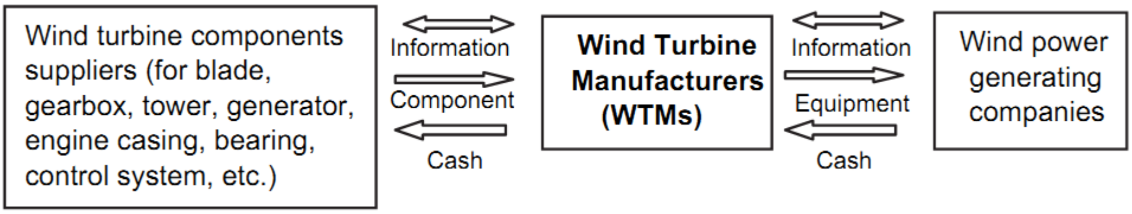
The emphasis on "functions" in the TIS framework does not mean that the structural components of the system should receive less attention. On the contrary, it is crucial to accurately map these structures in order to comprehend how the innovation system performs. Nevertheless, a whole book could be written on each of the following structural components within a Chinese context. Therefore, some key factors deemed important to the study are outlined below. The delimitation will be strictly related the wind turbine industry, even though there may be other factors influencing the development. These other factors, which are external to the technological innovation system, will be dealt with in Chapter 7.

5.1 Defining the TIS

As mentioned in the theory chapter, it is difficult to define the limits of a specific TIS. The technological system is merely a theoretical construct, and there exists no right or wrong way to define its boundaries. Yet, it is crucial to define the limits to a certain extent, because the boundaries of the system greatly affect the analysis (Markard & Truffer 2008: 600). Similar to the delineation suggestions made by Bergek et al. (2008a), Sandén et al. (2008: 3) propose that four aspects of system boundaries should be included; "technology, value chain, time and geography". Let us look at each of these respectively.

As for *technology* and the *value chain*, a wind turbine in itself is easily identifiable, and in this way we already have a strong indication on what to look for. A value chain includes all the activities that contribute to the end-price of a product (Porter 1998). These are here divided into down and up-stream actors and activities. Down-stream actors accounted for in this TIS comprise the buyers and users of wind turbines. The developers of wind farms are the ones who typically purchase wind turbines, and as we shall see, these developers are largely state-owned electric power producers in China. As seen on the right hand side in Figure 8 below, the users of the wind turbines are the wind power generating companies. Electricity-grid companies, however, are taken to be outside of the TIS, for the very same reason: even though they are obligated to connect all wind power to the grid, they have little direct influence on the wind turbine industry, since they are not the turbine buyers or wind farm operators.[11] Nonetheless, since they are operating the electricity grid system, they do have an indirect impact, and the grid companies will therefore be examined more closely in Chapter 7 under the heading *blocking mechanisms*.

Figure 8: Value chain for Chinese wind turbine manufacturers



Source: Zhao et al. (2012: 426)

All the components suppliers listed on the left hand side in Figure 8 count as upstream actors in the Chinese industry. Because the wind turbine industry is fairly global, it is difficult to limit our search to China alone, especially on the upstream side. The manufacturing of a wind turbine includes knowledge, technical components and personnel which come from many different places, both inside and outside of China. Yet, as we have seen, a distinct feature of the industry is the domestication of manufacturing along the whole wind turbine value chain. Although the main focus will be directed towards the domestic Chinese turbine manufacturers, the degree of foreign influence inevitably needs to be addressed. With regards to the end-use of turbines, it is easier to limit the spatial parameters to China alone, as most Chinese turbine manufacturers do not yet export their

[11] State Grid has invested in wind farms, although it is still a relatively minor actor (Li et al. 2012: 58).

turbines to a great extent. In other words, up-stream development by necessity needs a broader *geographical* boundary, whilst down-stream events can be uniquely limited to China.

A matter of key importance in understanding how a TIS performs is *what stage* the TIS is in, something which has to do with the *time-aspect* mentioned by Sandén et al. above. The time frame chosen for this investigation is relatively short, because the intent is to capture the rapid growth phase, which took off around 2003, and has endured into 2011. Even though there has been support for a growing wind industry in China since the 1980s and 1990s (Taylor 1982, C. Wu et al. 1994, Lew 2000), most of this development was focussed on small-scale wind turbines, and the real explosion of utility-scale wind turbine markets started after the introduction of the first concession round in 2003 (Howell et al. 2010).

This short time-span has some implications for the phase the Chinese wind turbine industry is currently in. The TIS framework was developed to understand formations of new TISs, yet it is somewhat unclear how well the framework works for later stages of technology development. Markard and Truffer (2008) purport that "a TIS begins at some point in the formative phase and ends at some point in the growth phase". This is to say that the TIS framework can only be used within a specific timeframe of the development of a technology. The two authors confess that mapping conditions which define the end point of a TIS is difficult. In any case, since the gap between the formation and the rapid growth phase of the Chinese large-scale wind turbine industry is so narrow, the framework can still be used to explain the industry.

As touched upon in the theory framework, the framework is not as well equipped to understand the TISs of countries that are "catching-up", where technology often enters in shape of foreign investments, and where the economy often is more export-oriented than that of a developed country (Binz et al. 2012). In order to compete, China has had to catch up with the global industry. As a result, it is easier to picture the Chinese market as an extension of the global market, where the goal is to move towards cost reduction and ultimately a mature mass market which can compete with conventional electricity production. This means that the Chinese market quickly passed from the "nursing" phase into the "bridging" phase, which is characterised by an expansion of market volume (Dewald & Truffer 2012: 407). We can therefore take the TIS to be in a "bridging phase", between the "nursing phase" where the technology is still a small niche, and a "mass market" phase, where large scale deployment of wind power is the case (Bergek et al. 2008a: 416). Wind power technology still is *not* a mature technology which can compete with conventional energy technologies on the market (Jørgensen & Münster 2010).[12] In short, which phase the TIS is in will have serious impacts on what the ultimate goal of the TIS is; which, after all, is what the functions are supposed to fulfil. The implications this has for the analysis will become clearer in Chapter 6, when assessing the functionality of the TIS and looking at the dynamics of the functions (Section 6.8). An important remark made by Carlsson et al. (2002: 239) which also has a bearing here is that "there is no reason to hide that the delineation may often be somewhat arbitrary and partly based on informed guesses by the researcher". As we go on to plot the structural components, a clearer picture of the system delimitation will be formed.

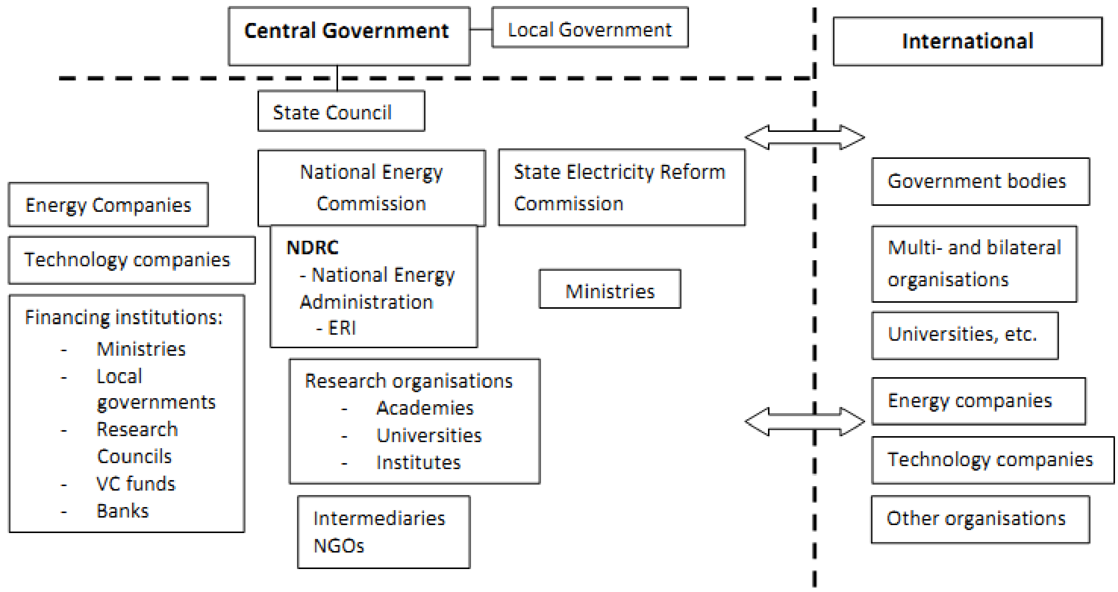
5.2 Actors

No matter how one looks at it, the government is a central actor in the Chinese wind turbine industry. The government exercises its influence in a variety of formal and informal ways, and exact information about its workings is difficult to acquire. All the largest Chinese wind turbine manufacturing enterprises are partially or fully state-owned, and the development plans which are outlined and followed by the government have an important part in the success or failure of an

[12] Since wind power still is not competitive, one cannot say that the market phase is a "mass market". According to estimations by the International Energy Agency ("New Policies Scenario"), wind will become competitive around the year 2020 in Europe, and around 2030 in China (WEO 2011: 507).

industry in China. Given the elusive role of the government, its influence will be highlighted and contrasted where it occurs throughout the analysis. For the wind industry, the government is particularly relevant because of its policy-creation capacity, which will be discussed in detail. For now, some instrumental government bodies can be highlighted. Thus, in Figure 9 below a general overview of the key actors in the wind turbine innovation system is displayed.

Figure 9: Key actors in China's wind energy innovation system



Source: Modified version of Delman and Chen (2008: 25)

Most of the above actors will be touched upon at some point in the following description and analysis. The intermediaries mentioned in the figure are loosely government-connected bodies that sustain the industry in some way, such as professional or business associations, or chambers of commerce (Delman & Chen 2008: 28).

5.2.1 The enterprises

According to the China Wind Power Outlook (2010: 36) there were 86 wind turbine manufacturing enterprises in China at the end of 2009, of which only around 15 engaged in mass production (CWPC 2012). The top three manufacturers, Sinovel, Goldwind and Dongfang respectively, accounted for nearly 60 per cent of newly installed capacity in 2009, and the top ten firms accounted for approximately 85 per cent (ibid.: 38). This means that the remaining 76 companies share a relatively small portion of the newly installed market. Amongst the top ten firms by the end of 2009, six were Chinese and four were foreign companies, and the latter had a market share of new and cumulative installed capacities of around 11 per cent (ibid.: 34). All these foreign companies manufacture their wind turbines locally in China, something which creates major learning-opportunities for Chinese domestic companies, as we shall see in Section 5.3 (Lewis 2011: 286).

The China Wind Power Centre, which has relatively up-to date information on the wind industry, lists 41 partially or fully state-owned enterprises (SOEs) in China, and this includes most of the largest ones (CWPC 2012). According to statements from some of my informants, it is an advantage to be a SOE in the wind industry, for reasons ranging from easier access to capital and better connections, to a larger control of the whole value chain.

A general assumption amongst the analysts and scholars I talked with is that over 80 manufacturing companies is too large a number for the industry to support, and that this number will be dramatically reduced over the next five years. Mr. Sebastian Meyer (interview 08.11.2011), a China wind expert from Azure International, holds the view that the large companies that are now established will keep their positions, but the industry will become less concentrated and stabilise with around 20 equal players. However, as Mr. Li Junfeng (interview 30.09.2011), president of CREIA, points out, this does not necessarily mean that the smaller companies will all disappear, but rather that those with weak technology will phase out. This will happen primarily as a response to government policies meant to enhance the quality of the Chinese turbines, as we will see in Section 5.4.

In addition to the turbine manufacturers, the industry consists of a string of contractors and parts providers. In contrast to other countries, the Chinese wind power equipment industry is sharply divided between the turbine manufacturers that produce mainly one or two parts themselves (usually the blades), and professional parts manufacturing enterprises (CNRED 2011b: 20).[13] In China both foreign and domestic companies produce turbine components, many of them being joint ventures. By the end of 2009 there were 52 blade manufacturers, 10 gearbox manufacturers, 16 bearing manufacturers, and 12 power electronics manufacturers (CNRED 2011b: 20).

Amongst the turbine blade manufacturers three companies capture a large market share; these are China National Aviation Teng-hui Wind Electricity Equipment Co. Ltd., Zhongfu Lianzhong Composites Group Ltd., and LM Fiberglass (Tianjin) Co. Ltd. (CNRED 2011b: 21). Amongst the gearbox producers, there are two domestic-funded enterprises which account for more than 50 per cent of the market share; these are Nanjing High-Speed & Accurate Gear Group Co. Ltd. and Chongqing Gearbox Co. Ltd. The largest turbine manufacturing company, Sinovel, receives gearboxes from its *subsidiary* Dalian Heavy Industry Group (ibid.). Bearing manufacturing is also provided by Chinese companies, yet gearbox and generator bearings are today fully dependent on imports, because of the technical requirements involved in their manufacture, which Chinese companies have not yet fully mastered (ibid.: 21).

The last group of relevant companies are the buyers of the wind turbines; namely, the developers. By the end of 2009 more than 50 companies had invested in wind parks in China, yet the top ten companies accounted for 71 per cent of the installed capacity (CWPO 2010: 38/39). Of these ten, eight were owned by the central government, and the top five were all state power utilities, covering 54 per cent of the market (ibid.). As we shall come back to, the top four of these developers are all large thermal-power producing companies (the “big five”).

[13] According to the China Wind Power Outlook (2010: 78) relationships between manufacturers, parts producers and developers need to be well handled, and the present state cannot be a permanent solution.

5.2.2 Organisations and associations

As maintained by Scott Kennedy (2005: 26), many industry associations in China have little autonomy (albeit, far from all). For the wind industry in particular, there are mainly two industry associations that are relevant. These are the China Wind Energy Association (CWEA) (a subsidiary of the All-China Federation of Industry and Commerce) and the Chinese Renewable Energy Industry Association (CREIA). The Global Wind Energy Council is also present in China, and supports various arrangements, such as wind power conferences. The main tasks of these associations are to draft laws, plan research and policy decisions, and mediate between the industry and policy makers (CWPO 2010: 42), as well as arrange venues for industry players to gather. However, because of the rapid development of the whole renewable energy industry, these associations have not yet gained the influence and capacities that they desire (ibid.). This was also confirmed by my informants from the industry, many of whom did not regard the associations as imperative for their development.

Other relevant organisations are the Chinese Society for Electrical Engineering (with a professional committee for wind power), standard organisations, such as the National Technical Standards Committee on Wind Power Equipment, and several local organisations and associations administered in the provinces (CNRED 2011b: 46, 47). There are also numerous international environmental NGOs and public sector agencies, such as the National Resources Defence Council, WWF China, The Climate Group, Carbon Disclosure Project, Joint US-China Collaboration on Clean Energy and the World Resources Institute (Medland 2012).

5.2.3 Universities and research institutes

A central university dealing with wind power research is the Shenyang University of Technology, which has a history of 25 years in wind power generation technology (CNRED 2011b: 89). The university has been able to independently develop turbines, recently with capacities as high as 3 MW (CWPO 2010: 34), which it licences to various Chinese wind turbine companies. North China Electric Power University and Lanzhou Science and Technology University have also established wind power research institutes (CNRED 2011b: 89). Additionally, Changsha Science and Technology University, Hebei University, Hehai University and Inner Mongolia Industrial University all have wind energy engineering programmes (ibid.).

There are several national research and development (R&D) centres, such as the National R&D Centre for Wind Power Engineering Technology, and the newly established (2010) centres on Wind Power Blade R&D, Large-scale Wind Power Grid-connected Systems R&D, and Offshore Wind Power Technology and Equipment R&D (CWPO 2010: 41). The National R&D Centre has had an especially slow start, due to the very restricted access to resources, as well as weak implementation of policy (ibid.). As we shall see in the next chapter, the common perception is that these institutions have not made a great impact on the industry in general, and that their development capacities are still mediocre compared with the international standards (ibid.).

5.3 Networks

Networks between the various players in the Chinese industry are crucial to look at if we are to comprehend the dynamics in the industry. Informal networks within the industry are naturally hard to detect, and will include some guesswork. The formal networks, however, are easier to map. As mentioned in the theory chapter, two important types of networks are learning networks and political networks. Purely political networks are common in China, and are usually informal. For instance, one important way of achieving success in China is having connections with central decision makers, something which facilitates the operations of a firm. As I shall come back to in Chapter 6, two of the firms interviewed here emphasised that either the CEO's connections or the company's influence in a particular region was important for the company's development.

According to some of the informants from the industry, one arena for encounters are the various conferences that are organised in the wind industry, such as the China Wind Power conferences. Here, the various players from all segments of the turbine industry meet each other and exchange information. A similar networking function is assumed by CREIA, which may function as an arena for discussion between the different wind turbine enterprises.

When it comes to learning networks in terms of research and development in the wind industry, for instance, there seems to be a general consensus that networks are weak in China. According to the Sino-Danish Renewable Energy Development Programme, there is a lack of general coordination mechanisms in the Chinese renewable energy industry (CNRED 2011a: 164), something which has been pointed out by several reports and studies on the industry (REN21 2009b: 27, Z. Wang & Li 2009, Martinot 2010). This was also reiterated by many of the interviewees. Amongst others, Li Junfeng (interview 30.09.2011) from CREIA and the Energy Research Institute affirmed this lack of coordination and added that pricing, R&D, and industry funding are managed by different sectors. This lack of coordination only increases with the rapid growth of the industry, and can potentially harm industry dynamics.

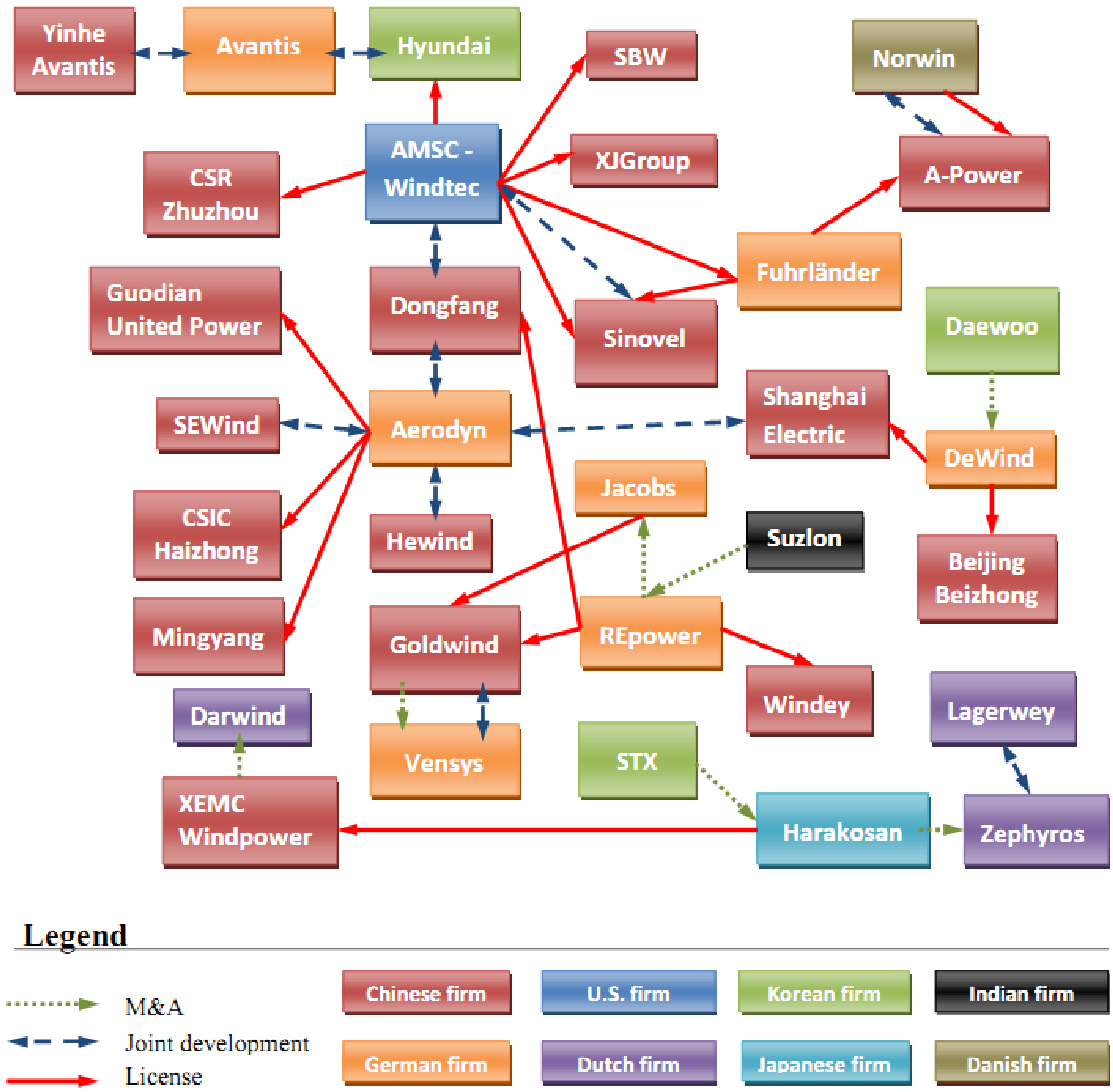
To be sure, competitors in the industry do not willingly share key information, and therefore networks of learning can be more indirect. For instance, as was voiced by some of the companies interviewed, knowledge often flows between companies when personnel change workplaces. It is not a secret that Chinese companies actively try to attract skilled personnel from competitors, both domestic and foreign. In it's earlier days, Goldwind frequently hired employees trained by foreign-owned firms that were based in China, which enabled the company to tap into state-of-the-art knowledge (Lewis 2007: 228). Based on information provided both from the interviewees and from personal conversations with professional, one can assume that this is a widespread practise in the Chinese wind industry, and is not only limited to a domestic-foreign axis, but also occurs between "indigenous" companies in China.

5.3.1 International networks

According to Joanna Lewis (2007, 2011), highly important learning networks for the Chinese wind industry are the ones established with the foreign companies that are either license-owners or joint developers. She argues that these global and regional learning networks have been crucial ever since the formation of the wind industry, and that the emerging markets in China and other Asian countries serve as "valuable regional learning networks for new firms" (Lewis 2011: 283). Furthermore, she argues, these new markets have also made an important contribution to "global learning networks of knowledge and innovation", because of the global character of the industry (ibid.).

In China, as was mentioned at the beginning of this study, much of the wind turbine technology has been transferred in one way or another from abroad. Arguably, this has also lead to many connections between the players, and these networks are important for the ultimate performance of the joint developers or the licensing firms. To illustrate the case in point, Lewis (2011: 297) has developed a most informative chart that maps the linkages between turbine manufacturers and technology source agreements. Depicted in Figure 10 below, this chart has been updated and modified partly by the author.

Figure 10: Wind power technology transfer networks for Chinese firms



Sources: Based on Joanna Lewis (2011: 297), and modified by the author to include more Chinese firms. It should be noted that this chart is not exhaustive, and that more connections and/or agreements may exist than portrayed here. Note also that relative box-sizes do not reflect the actual sizes of these companies.

As is easily observable from the chart, most of the Chinese firms have licensing agreements with German firms. The nature of these networks can vary, and whether information is shared or not depends on the agreement. Joanna Lewis (2011: 296) maintains that these networks can be both positive and negative, because on one hand they can "increase access to global learning and experience worldwide, which is likely beneficial", whilst on the other hand they can "create competitors and make it harder to safeguard valuable or sensitive information". What is certain is that such a global wind turbine network leads to new encounters. For instance, when Goldwind acquired a majority stake in Vensys in 2008, it became engaged with research and development activities in Germany, although the company thus far had been uniquely focussed on China (ibid: 297). Other Chinese wind turbine manufacturers have also established R&D centres abroad, as we shall see in Section 6.1. Hence, the flow of resources goes both ways: expensive license and trademark fees motivate Chinese firms to develop their own designs. This is difficult, as the money paid to the designers of the turbines is spent to design newer and more competitive models, potentially leaving Chinese manufacturers one step behind.

From Figure 10, we can also observe that relatively few merger and acquisition (M&A) deals are carried out by Chinese companies. As revenues of Chinese firms grow, combined with relatively difficult times in the global industry, it seems unavoidable that more such deals will be closed. For instance, a rumour is currently circulating that Goldwind and Sinovel are both competing to acquire the world's largest wind turbine maker, and long time player in the field, Vestas (Morales & Sulugiuc 2012). Such an acquisition would have serious implications for the learning possibilities of the Chinese firms, since this way they would own and have full insight into the design of the technology.

Another important learning network for Chinese manufacturing firms is more regional, and can be found at the sites where both Chinese and international firms perform their wind turbine testing in China. Lewis (2007: 228) illustrates this with the case of Goldwind, which has placed its testing operations in a popular wind farm site where almost all of the leading global wind turbine manufacturers in China have also installed turbines. This may have lead Goldwind to benefit from the learning shared amongst "these manufacturers coming from the other wind learning hubs of the world, as they all tested their designs in China" (ibid.). The same can be assumed about most large wind turbine manufacturers in China. This implies that international networks are effective both locally and globally, meaning that they share knowledge, in terms of licensing agreements and other encounters, and they share experiences and routines, from which Chinese manufacturers can learn. Section 6.2 delves deeper into these learning mechanisms in the Chinese wind turbine TIS. Already now we are starting to understand the importance of foreign knowledge in building up a Chinese industry. Therefore, we can confirm Binz et al.'s (2012) observation, that shortcomings in the Chinese TIS are compensated by connections with international TIS structures.

Furthermore, many learning networks have been established in the form of direct cooperation on a governmental level, as well as between universities and research institutes in order to sustain China in its wind turbine industry development. There are a host of projects and bilateral cooperation institutions, and an exhaustive list of all such agreements is beyond the scope of this study. Some examples of cooperation between China and the Nordic countries are provided by Delman and Chen (2008):[14] the Danish wind energy development programme (WED) in cooperation with the National Development and Reform Commission (NDRC), the Danish-Chinese Renewable Energy Programme (RED) also located at the NDRC, the Swedish-Chinese exchange programme on renewable energy between the Royal Swedish Academy of Engineering Sciences (IVA) and the Chinese Academy of Engineering (CAE), and the EU-China Energy and Environment Programme (EEP) (ibid.). In addition, several other countries have activities within the renewable energy field in China, such as France, UK, Germany, Japan, the Netherlands, Spain, the UK, and the United States. For example, Germany's GIZ, a federal enterprise which supports the German Government in international cooperation for sustainable development, had a wind power project in China between 2005 and 2010, which "Strives to improve the 'technical capabilities of private and state institutions for the nationwide development of grid-bound wind energy use'" (CWPP 2010: 12). One of their core tasks was to educate personnel

[14] Yet, the authors warn that given the lack of coordination within the Chinese renewable energy system, the Nordic countries might "easily waste resources and the mysteries of the system would remain" (Delman & Chen 2008: 33).

and managers, since China was, and perhaps still is, lacking this particular expertise within the wind sector (ibid.).

5.4 Institutions

In the theory chapter it was explained that within the innovation systems framework, institutions are taken to include culture, norms, laws, regulations and routines, which in one way or another regulate either directly or indirectly how actors relate to each other. When looking at culture and norms, it becomes evident that institutions and networks can easily be conflated. For instance, strong family networks or the strengths of *guanxi* (relationships / connections), could simply be placed under the network heading, whilst within the innovation system framework they should be understood as cultural (Serger 2009). First, some formal rules and regulations in the wind industry will be dealt with, and then a small discussion on the impact of culture and norms in the wind industry will follow, although the latter topic to a lesser degree will be strictly limited to the wind industry. Institutions are important for an industry to be functional, and a central concern is that institutions fail to align themselves to the needs of the new technology (Bergek 2002). As an illustration, M. Wang (2007) has showed how the Chinese Energy Efficiency Law, in sharp contrast to the Renewable Energy Law, failed to be effective because the process of creating the policy could not keep up with rapid the development in the energy industry.

5.4.1 The laws and regulations in the wind industry

I find it convenient to divide the legislative measures undertaken by the central- and local governments into two main policy areas; namely, 1) policies which promote industry development directly, and 2) regulations that are aimed at increasing renewable electricity production—although, to be sure, the two are interconnected, so this division is far from clear-cut. The following by no means represents an exhaustive list of the various policies that have influenced the wind industry, but seeks to elucidate some of the more influential policies.

Industry development

There are at least three important determinants that promote China's wind industry development directly: the domestic content requirements, speedy approvals, and policies promoting large renewable energy investments in China (Yadav 2011). First, the domestic content requirement on wind turbine manufacturing in China has lead to the development of its supply chain markets; second, speedy approval for wind power projects at a provincial level has resulted in the huge number of additions each year; and third, according to Bloomberg New Energy Finance, in 2010 China attracted $49,000 million in renewable energies investment, 78 per cent of which went to wind projects (BNEF 2011: 18, 20). This means that China attracted the most new financial investments for renewable energy in the world, far ahead of the U.S. which was in second place with around $25,000 million in 2010 (ibid.).

China's economic development of the last thirty years has been induced to a great extent by attracting foreign investments and building manufacturing industries (Long 2005: 316, Y. Wu 2006: 1), and it is within this fine-tuned industry machinery that the domestic Chinese turbine industry has grown. Infrastructure-building, as well as supply of cheap labour, energy, and land, have therefore become key issues of concern to local governments that want to attract industries (Gu & Lundvall 2006: 11). This has given China experience with a host of measures in industry-building, ranging from financial mechanisms and preferential taxes for manufacturers, to geographical content restrictions on products.

Before 2002 the development of large-scale wind energy in China was slow, even though several policies were in place to promote the development, such as low electricity tariffs for wind electricity and local government support, as well as assistance from abroad (CWPP 2010: 20). In 2002 the government wanted to stimulate the development through a national wind concession programme, which allocated selected sites for wind farm construction to the company bidding the lowest electricity tariff (ibid.). Some prerequisites were made in order for projects to be accepted, such as turbine size and local content restrictions.[15] In effect, the price of electricity not only decided who won the bid, but also to what extent the turbines were manufactured locally (Q. Wang 2010: 705). According to a government statement in 2000, the domestic content requirements of wind turbines became a policy because the dependence on imported turbines and lack of local manufacturing of key parts were hampering the development of wind power in China (Howell et al. 2010: 50). During the first concession round which started in 2003, the local content requirement of turbines was set at 50 per cent, a requirement which increased to 70 per cent in 2004, and was finally phased out in 2009 (Q. Wang 2010). In addition to the content requirements, import tariffs on preassembled wind turbines were at 17 per cent in 2007, whilst tariffs on their components were set to only 3 per cent (Martinot & Li 2007: 20). This policy, together with the removal of the local content requirements in 2009, is thought to have "allow[ed] domestic manufacturers to more easily access wind components from foreign suppliers as they build the prototypes for their larger turbines" (BNEF 2010: 9). This helps the industry in its goal of building larger turbines, as will be examined closer in Section 6.3. According to Eric Martinot (2010: 288), the local content policy alone "marked a turning point in wind industry and technology development in China."

Other regulations of relevance were issued by the Ministry of Finance in 2008, where turbine manufacturers received a VAT and import tariff rebate on certain wind turbine components, which applied to companies with annual sales of more than 50 turbines of minimum 1.2 MW per turbine (CWPP 2010). Estimations made by Bloomberg New Energy Finance (2010: 20) show that this policy alone produced US$ 80 million in R&D funding in 2009 for the top three wind turbine

[15] We shall come back to the implications of turbine size restrictions in the next chapter.

producers. Also, the Ministry of Finance issued another incentive policy in 2008 under the label "rewards replacing subsidies", which applied to all domestic brands (with over 51 per cent Chinese investment ownership) (CWPO 2010: 71). This policy gives the 50 first wind turbines over 1 MW a reward of 600 Yuan per kWh from the government, given that the company uses domestically manufactured components, and that the generator enterprise and the key components manufacturer share the subsidy fifty-fifty (Q. Wang 2010: 707). These policies show that the government aims to increase the size of turbines, something we will return to in the next chapter.

The wind power concession rounds have been successful in promoting the development of wind projects in China, and developers and manufacturers both local and international have been convinced to invest in the industry (He & Chen 2009: 2893). This is also reflected in attractiveness indices conducted by Ernst & Young Environmental Finance team, where the Chinese wind industry is by far the most attractive renewable energy investment area globally (EYEF 2011). Yet, they note that this may change in the coming year, because of stricter government regulations regarding wind farm approvals. The importance of financial mechanisms will be further scrutinised in the next chapter.

Up until 2011, however, the swift approval of wind farm projects has been an important contributor to the rapid wind industry growth in China. Large-scale projects of 50 MW or more all had to be approved by the central government. Projects of sizes up to 50 MW, however, could be approved by the provincial authorities, albeit with the verification of the NDRC, and in total this represents a large share of the wind farm development. The provincial governments are interested in attracting wind farms to their areas, because this would increase their tax base, and could attract local manufacturing capacity (CWPP 2010). To attract wind farm projects, the provinces offer higher prices than the centrally-administered projects, something which attracts investors as well as makes the projects more financially viable (ibid.). According to the China Wind Power Centre (2010: 25), in 2008 most registered projects were below 50 MW in order to circumvent the national approval process. In principle, several 50 MW projects are built right next to each other, making the real sizes of the wind farms often much larger, perhaps even 10 times or more (Jiang 2011: 94). This practise has come to an end as of November 1st 2011, when the much debated "grid code" was implemented in China, which, amongst other standards, requires that all projects be centrally approved through the NDRC (Jiang 2011). After this policy came into effect, the approval of wind farm projects slowed down considerably, and it marked an important change in government policy regarding rapid wind farm expansions.

Wind electricity generation

Most of the measures which are aimed at increasing the proportion of renewable electricity production in China are covered in the Renewable Energy Law (ReLaw), which was enacted in 2005, and brought into force on January 1, 2006, with amendments effective from April 2010. The measures include government installation goals, mandatory market shares, a tariff system, a cost sharing principle, and a special fund (Jiang 2011: 105).

In Chinese government plans, such as the Medium and Long Term Development Plan for Renewable Energy of 2007 (until 2020) or the 12th Five-Year Plan of 2011, there are clear future installation goals, which are equivalent to market-size guarantees at a certain point in the future. For instance, in the 12th Five Year Plan, there is a goal of 90 GW of installed wind power in 2015, even though these goals change rapidly, as the development happens quickly.[16] Now, by the end of 2011, it is estimated that the installed capacity is at 62.7 GW, and if the added capacity continues at the same pace as between 2010 and 2011 (18 GW), the 2015 goal will have already been reached by the end of 2013.

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[16] In the Medium and Long Term Development Plan for Renewable Energy of 2007, the goal of installed wind capacity in the year 2020 was set to 30GW, although this goal was already surpassed by 12 GW in 2010. The function these goals have will be returned to in the next chapter.

The largest investors in wind farms in China are four state-owned power generation companies, all of which are part of the "big five" government power generation companies, Guodian, Datang, Huaneng, Huadian and China Power Investment Group (CPI) (CWPO 2010: 39).[17] The reason these utilities invest in wind energy to such a large extent is that they are mandated by the government through the 11th Five-Year Plan for Renewable Energy to install at least 3 per cent non-hydro renewable power as a portion of their total capacity in 2010, and 8 per cent in 2020 (ibid.). This applies to all utilities that have a capacity of more than 5 GW of thermal power electricity generation (ibid.). These mandated market shares undoubtedly lead to an increase in wind power investments, but a downside may be the fact that these large power utilities only care to fulfil their installed capacity criteria, and have less of an incentive to focus on the kWh produced (CWPP 2010)—something which demands more resources in terms of operation and maintenance. Also, in accordance with the ReLaw, electric utilities are obligated to purchase all wind power produced; an important change in this regulation appeared in the 2009 amendment of the ReLaw, when the utilities were obligated to purchase all the wind power even when there is not sufficient power demand on the grid (Martinot & Li 2010).

The feed-in tariff of the 2005 Renewable Energy Law was based on "government guided" prices, which were adjusted year-by-year based on competitive bidding (Martinot & Li 2010). In 2009, a fixed feed-in tariff (FIT) was established, which varies according to available wind resources and project construction conditions (Jiang 2011: 107). This has divided the country into four different classes for onshore wind power, all with different FIT benchmarks, ranging between 0.51 and 0.61 Yuan per kWh, where the lowest tariff applies to the regions with the best wind resources, and the highest to the regions with least favourable farm wind conditions (ibid.).

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[17] CPI was listed as the eighth-largest wind power developer in China in 2010—the four others were listed as the first four in the order with which they are listed above.

Implementing feed-in tariffs is not free, and the gist of the cost-sharing policies is to evenly share the additional costs of renewable energy through a combination of civic duty and responsibility by various stakeholders. This has been achieved by an overall electricity price surcharge in China, which started out on 0.001 Yuan per kWh in 2006, increased to 0.002 in 2008, 0.004 in 2009, and finally 0.008 Yuan per kWh in November 2011 (Jiang 2011, Reuters 2011). This money is to be spent on three main areas: the FIT, operation and maintenance costs, and grid integration costs (Jiang 2011: 108).

There was also an intent in the ReLaw of 2006 to establish a special fund for renewable energy which could be used to finance science and technology research of renewable energy development, and standards development and demonstration projects (Jiang 2011: 110). But this has proven more difficult to implement, because no specific amount of money is proposed in the legislation measures, and how the fund would be used has been vaguely defined (CWPO 2010: 77).

5.4.2 Culture and norms

During informal conversations with the R&D director of a German wind turbine bearings producer subsidiary in China, it was pointed out that culture was a main difference between China and Germany. As one example, the director explained that workers refrained from asking for advice when a problem occurred, apparently because they were afraid of "losing face". This slowed down progress, because it would take more time to detect the problem. Even though this incident tell us little about the general manufacturing conditions in China, it gives a small hint as to what kind of cultural differences might occur for foreign companies there.

Strong opinions exist on the influence of culture, norms, and routines in terms of innovation performance in China. For instance, after the death of Steve Jobs, a discussion surged in China regarding "Why can China not produce its own Steve Jobs?" (e.g. chinadaily.com.cn 2011, Mourdoukoutas 2011). Attempted explanations ranging from cultural to systemic issues were provided by experts from China and abroad. For instance, one observer wrote that “China's traditional Confucianism cannot integrate with the Western Schumpeter corporate spirit, so throughout Chinese history, we rarely see respect for innovators and businessmen” (chinadaily.com.cn 2011). However, there is scant evidence backing up such claims. Moreover, these types of statements are oftentimes based on an old-fashioned view that innovation is a Western phenomenon, and that Western institutions need be replicated in order to innovate. This is not in accordance with what the innovation systems literature claims, where a combination of mechanisms is emphasised, and where culture is but one influencing factor.

In any innovation system, people are the most important resource, but, of course, people cannot be forced to innovate. Although we shall not engage in a discussion on the appropriateness of the term “social capital” here, it is commonly referred to as a measure of people’s willingness and likelihood to share knowledge and information, defined as “shared values, norms and trust that reduce transaction cost” (Serger 2009: 63). It can thus roughly be equated to what we are looking for in this section. In a study on innovation in China, Gu et al. (2009: 385, 386) purport that

> (...) Chinese people believe in the positive role of science and technology while there is a weakness in social capital —values, norms and trust that are shared by the social community. Weak social capital is reflected in the low level of willingness by either academia or business enterprises to interact, cooperate and engage in knowledge sharing with individuals and organizations outside their family circles or immediate “neighbors”. (...) [S]ocial capital underlies interactive learning; well-developed social capital is a prerequisite for absorbing, diffusing and using knowledge in the innovation system. In the increasingly complex division of labor and collaboration in innovation, education and social capital are necessary elements in order to create new ideas and the economic value deriving from them.

If it is correct that there is a low willingness to engage in knowledge sharing in China, then this is no small obstacle for successful innovation, recalling from the theory chapter that diffusion of knowledge takes a central part in the overall goal of an innovation system. Although sharing knowledge with family circles or immediate personal networks, commonly referred to as *guanxi*, seems no different in the wind turbine industry than in other industries in China, it is difficult to say whether this hampers knowledge sharing outside these relationships. Given the industry's close connection with foreign manufacturers, one might say that the wind industry is forced to share knowledge with outsiders.

Sylvia Schwaag Serger (2009: 64) claims that the reason for this low willingness to share knowledge with outsiders in China is that there is a low level of trust. Corruption and intellectual property rights (IPR) infringements are taken as proxies to measure the level of trust, where high levels mean low trust (OECD 2008: 406).[18] To the author's knowledge, there is currently one IPR infringement case in the Chinese wind industry, and that is the still-unresolved issue between China's largest wind turbine manufacturer, Sinovel, and the U.S. based energy technology company American Superconductor (AMSC). Without entering into the details of this particular case, it is clear that one such case may jeopardise the trustworthiness of the whole Chinese wind turbine sector, something which would have a huge impact. As voiced by the interviewee from Goldwind, customers were concerned that Goldwind would "turn around and stab us in the back like Sinovel did to AMSC". If the case is decided against Sinovel, and if more such cases occur, it could indicate that there is indeed a low level of trust in the wind turbine sector; but it could also in itself make the industry seem less trustworthy. However, ascribing such a turn of events to cultural values would be too

[18] Corruption seems to be a chronic problem overall in China and is not specific to the wind industry, even though solving the problem is high on the agenda in the Chinese government (Saich 2011: 373). Corruption could be one major difference from other countries, and according to the Transparency International corruption perception index of 2011, China ranked 75th in the world, with a score of 3.6, where 0 is highly corrupt and 10 is very clean (CPI 2011).

hasty, knowing that there are similar cases of IPR infringements in countries commonly associated with a higher level of "social capital".[19]

Another scholar, Erik Baark (2007: 354), concluded in a study on knowledge and innovation institutions in China that:

> (...) the predicament of innovators [in China] today may still be difficult, swimming as they do in a sea of acidic attitudes towards the new and un-tried, with precious little effective support from peers, officials, or the population at large.

This quote alludes to the fact that the education system in China still seems to be too heavily influenced by earlier legacies as a plan-based system. With regards to the wind turbine industry, this highly broad discussion of education and cultural impact will be addressed in the next chapter, where the functions "knowledge development and diffusion" (Section 6.2) and "entrepreneurial activity" (Section 6.6) are particularly relevant.

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[19] For instance, there is currently a dispute between the multinational enterprise General Electric Company (GE), based in the U.S., and the Japanese Mitsubishi Heavy Industries. Both parties have filed wind power patent suits against each other, started by GE in 2008, a case which still remains unresolved (Lane 2012).

6. The functions and functionality of China's wind industry

In the following section the functional pattern of the Chinese wind turbine industry will be described and an attempt will be made to judge to what extent these functions are successfully filled. I shall address each of the functions elaborated on in the theory chapter, and the functionality, or "goodness", of these functions is continually assessed, alternating between the four methods described. These four methods are: 1) establish what phase the industry is in and thereby judge functionality; 2) compare TISs of different locations; 3) compare similar TISs domestically; and 4) confer with the stakeholders in question. Lastly, in Section 6.8, the dynamics of the industry is assessed by employing the described functional pattern, and a given overall goal for the industry.

6.1 Resource mobilisation

Mobilising resources is crucial in many ways for an industry, and its importance is often closely connected with the function "influence of the direction of search", because of the implication this has for the break-through of a technology. The case of Germany's wind turbine industry is illustrative, where resource mobilisation proved to be large and flexible enough to sustain several directions of research and development, something which made the industry comparatively successful (Bergek 2002: 151). The resources can be both financial and human, and they are crucial contributions to all activities within an innovation system (Hekkert & Negro 2009: 586). As we shall see, in China both financial and human capital have contributed to development in recent years, yet whether this is due to government or private initiative is more difficult to judge. This section will start by looking at the financial mechanisms, followed by an examination of human resources.

6.1.1 Financial resources

It should be emphasised at the outset that there is gap between financial investments undertaken by global as well as local investors in China, and government investments in the shape of funding and subsidies. To give a rough figure, it is estimated that the total financial investments in the Chinese wind industry were US$41,400 million in 2010 (BNEF 2011: 20), whilst the government portion of these investments is seemingly marginal. This was pointed out in the interview with Li Junfeng (30.09.2011), where he underscored that the government accounted for a marginal share of the investments, perhaps as little as 0.1 per cent of the total direct investments; amounting to around US$50 million. According to him, some of this money goes directly to R&D, and some is allocated through an "industrialisation fund". Yet, the picture is more complex than this. For one thing, this government funding figure does not seem to include the subsidies that go to the generation of wind electricity, where the government spent approximately US$1,000 million, between January and September 2010 alone (Jiang 2011: 108). To be sure, this subsidy is covered by money from the electricity price surcharge, which would total about US$1,500 million based on the electricity consumption of 2009 (ibid.), and around US$3,000 million with the doubled surcharge of 0.008 Yuan per kWh as of 2011 (with the same electricity consumption). One can therefore argue that this subsidy is not covered by the government, but by the consumer. At any rate, the figure mentioned by Li is not in congruence with the available annual financial statements of the two large and publicly traded companies, Goldwind and Mingyang. According to their annual reports for 2010, Goldwind, the second largest Chinese company, received approximately US$ 30 million, and Mingyang, the fifth largest company, approximately US$ 17 million (Goldwind 2011a, Mingyang 2011). These funds were given mainly in order to compensate for R&D expenses of the companies. If these two companies together received almost US$50 million, it is natural to assume that the industry in total would receive much more.[20] Still, if we include these subsidies, the government contribution does not come close either to the total financial investments in the wind industry, or to the fossil-fuel subsidies, which according to the International Energy Agency, cost the Chinese government US$21,000 million in 2010 (WEO 2011: 514).

For the functionality of the innovation system, it matters more that resources are mobilised at all than where the resources come from. However, in order to completely understand the performance of the function, it is necessary to look behind the numbers and figures. Mapping the role the government has apart from the direct investments is a real puzzle, since much of what happens behind the scenes in China is never revealed to the public. This goes for the Chinese banking sector as well, where, according to three interviewees (two of them specialists in wind energy financing in China) the government exerts a great deal of influence in the wind industry. It is no big secret that the Chinese banking system overall is government-controlled, and that there are four major commercial banks which accounted for over 70 per cent of China's financial assets in 2009 (Walter & Howie 2011: 27).The main task for Chinese banks has largely been to support the SOEs, even after restructuring the banking and finance sector as a part of the economic reforms (ibid.: 43). According to Tony Saich (2011: 293, 294), the commercial banks are directed to lend to state-owned enterprises even after the three so-called "policy banks", which would specifically look after government-mandated lending, were created in 1994. In effect, this means that the banks are instruments that the government can use to achieve development goals.

In order to fully grasp what this means for the wind industry, recall that the largest investors in wind power projects are large energy investment companies owned by the central government. We can assume that these SOEs obtain loans more easily than private competitors. Also, a preference for SOEs may cause

[20] These estimates, together with the subsidy-policies mentioned in Section 5.4.1., constitute the renewable energy subsidy figure mentioned in Table 1. This estimate excludes the FIT subsidies.

price advantages, as was pointed out by one interviewee: “In general for such kind of agreements [the SOEs] will order in large quantities and of course this will give them an advantage in negotiating the components price, and that of course will get the price down”. There are at least three dangers related to this. First, there is a possibility that private companies will encounter barriers to entry into the market if SOEs are preferred, risking new and useful knowledge being potentially barred from access. This is especially true for periods when the market is more difficult, as it became in 2011. Second, even though the support of large SOEs has created rapid growth thus far, their preference might lead to a lack of project evaluation behind credit decisions. This concern was expressed by Sebastian Meyer (interview 08.11.2011), who said that:

> The government approves the projects and the money is going to state owned companies, so within the state sector there is no major perception of risk. So on the one hand, there is no technical and commercial diligence, or specifically what we would call project finance behind most wind farms. But on the other hand, when the signal is alright, every loan officer or every bank knows it’s not a bad idea to lend money to wind projects, and that has enabled the wind industry to flourish. But it flourished also at a time when investment and infrastructure also experienced massive growth.

We thus see a potentially destructive combination in preferring low-quality state-owned projects, induced by government investment. In conversations with the turbine manufacturers, this picture was confirmed. For instance, in a discussion with an employee from Geoho, a private wind turbine producer, it was emphasised that since they were not able to move as quickly as the SOEs, they decided to focus on making high-quality products. There is reason to believe this strategy will become difficult when the market growth is slowing down. Liming Qiao (interview 12.09.2011), the China Director of the Global Wind Energy Council (GWEC), put it this way:

> for the manufacturers: quite a lot of them belong to the state, so it’s easier [for them to access capital]. And for others, like private companies, it’s also easy to get financing because wind was a promising sector; but all this is changing now, this year [2011]. What I just said, was the old story; now this year everything is becoming tight.

One reason things became tighter was that the deposit reserve ratio (i.e. the minimum reserves each bank must hold of customer deposits) was increased several times respectively, making it more difficult for the banks to lend out money. According to Bryan Davis (interview 01.11.2011) from Bloomberg New Energy Finance, this is one key measure the government has to control the market. But presumably the main reason things became tighter in the wind industry is the aforementioned government game-change as of 2011, with the "grid code" adjustments and the shift from provincial to central approval of wind projects.

The third danger is connected to the relationship this function has with "influencing the direction of search", as the quest for ever-larger turbines may outstrip the marketing potential for the turbines. As showed by Anna Bergek (2002: 159) and Staffan Jacobsson, this happened in the Swedish wind turbine industry, when in the early 1980s they were already pushing towards 2 and 3 MW-scale turbines. Sweden was therefore considered a world-leading wind turbine nation (ibid.). In spite of this, the market and the industry for wind turbines developed very slowly in Sweden, perhaps due to a serious lack of legitimacy for wind power as compared with nuclear power (ibid.). Similar stories of failed large-scale turbine research programmes have been observed in Denmark, the Netherlands and the U.S. (Garud & Karnøe 2003, Kamp et al. 2004).

In China, even though most interviewees for this study reflected upon larger turbines as exclusively positive, a concern was voiced amongst *foreign* turbine manufacturers at the China Wind Power Conference 2011. Henning Cruse, the Director of Governmental Affairs of Siemens, the world's 9th-largest company in 2010 (REN21 2011), and Wolfgang Jussen, the CEO of REpower (Beijing), also amongst the world's largest wind turbine companies, both warned that focussing too much on large turbines could be disastrous. Mr. Jussen put it this way at the conference:

> I would say that for China I would recommend, by all these bad experiences from onshore, with technical problems: take it slowly, develop it

> step by step. You have the technology—finally, Sinovel has this proved technology of intertidal turbines—but don't aim to be the first to have a 10MW machine in the deep sea water somewhere from China. This is a dimension we as a leading company on deep water installations—we know how these challenges can ruin a company.

Presumably, these challenges that can "ruin a company" are related to too-high expenditures on R&D, which would have disastrous consequences should any of the designs meet with bottlenecks too serious to overcome, causing the investment to fail to pay off. Nevertheless, too high R&D expenditures are not yet a major concern for Chinese turbine manufacturers.

Lastly, another feature of the Chinese financial sector is its venture capital system, which according to Xielin Liu (2009: 134) is still immature both in terms of financial resources and capabilities of the actors involved. Even though venture capital in theory has a potentially important role for innovation performance by not only supplying financial capital, but also competence (Bergek 2002: 119), there is still not enough empirical evidence to back up these claims (O'Sullivan 2005: 250). However, it is curious that the Chinese wind industry, which is the largest in the world in terms of manufacturing capacity, received no venture capital funding deals in 2011 (Mercom 2012), and only modest sums in the period between 2004 and 2010 (BNEF 2010).

6.1.2 Human resources

Education institutes were briefly touched upon in the previous chapter, but no real evaluation was made of how adequate education is in assisting the wind turbine development in China. Considering the fast growth of the industry, one could expect that skilled personnel would be scarce. What typically distinguishes a skilled worker is that he or she possesses "know-how" which often has been learnt in apprenticeship-relations (Jensen et al. 2007: 682). Interviewees were asked about the access to "qualified personnel", and interestingly there was a divergence in responses between the industry, and the government officials and industry experts. The industry largely claimed that they had no troubles finding enough personnel, whilst the latter two groups claimed that it was a serious problem. Weiquan Wang (interview 29.09.2011) from CREIA expressed it this way: "For the long term we do not have enough human power for renewable energy, because [the industry] is very new. And in the meantime it grows very quickly, so sometimes the industry has a lack of human resources." The difference in responses might simply be explained by a diverging focus of the interviewees; whilst the manufacturers perhaps see no large human-resource bottlenecks in producing the turbines, the government officials and industry experts include operation and maintenance in their analysis, where the personnel constraint seems more prevalent. For instance, Sebastian Meyer (interview 08.11.2011) presented the following rough equation:

> Basically every new wind farm needs about 10 dedicated staff to operate it as soon as it's installed. So you look at last year, 20 Gigawatts being installed, divide that by a 50 megawatt project, so it's like 1000 projects. You need 10000, 20000 workers to just service on an ongoing basis, and it's not easy to turn out the technicians.

This problem is dealt with both on the firm and government levels in China. First, by far the most established university for wind power engineering education is North China Electric Power University, which in 2005 established a four-year degree programme on a recommendation from the NDRC (Howell et al. 2010: 59). Second, many wind turbine companies have their own training facilities, and Goldwind has even established a corporate university, which was founded to "enhance the competitiveness of Goldwind and advance the competency of the company's personnel while fulfilling its corporate social responsibilities" (ChinaWindEnergy 2011). On another note, qualified personnel shortages are not limited to China; the European offshore wind industry lacks access to a trained workforce with skills needed to further develop the industry (Jacobsson & Bergek 2011: 50).

6.2 Knowledge development and diffusion

Obviously, access to resources is not tantamount to successful industry development. A prominent testament to this is the Danish – U.S. comparison of "breakthrough" versus "bricolage". As was argued in a seminal paper by Garud and Karnøe (2003), Denmark's development of a wind turbine industry was comparatively ahead of the game, even though the U.S. wind turbine industry, with their breakthrough strategy, was deploying more resources into R&D projects. Learning processes and input from local actors was important in the Danish case (ibid.), and learning mechanisms arguably are at the core of any innovation system. Therefore, knowledge development and diffusion are important prerequisites for a successful industry (Hekkert & Negro 2009: 586). Knowledge is taken to be a vital resource for innovation, whilst learning is often understood as an essential activity accompanied by innovation (Coenen & Díaz López 2010: 1154). Knowledge can be classified into different categories, and depending on what knowledge one draws from, two modes of learning can be distinguished:

> One mode is based on the production and use of codified, scientific and technical knowledge, the Science, Technology and Innovation (STI) mode, and one is an experienced-based mode of learning based on Doing, Using and Interacting (DUI-mode) (Jensen et al. 2007: 680).

According to Jensen et al. (2007) both these modes are important; in fact they claim that mixed strategies that combine the two modes are what really improve innovation performance—but the science-based learning mode commonly receives more attention than the experience-based. As the example of Denmark and the U.S. shows, no optimal amount of investments in research and development can be pin-pointed. This notion is reinforced by the contrasting experiences of the German and Swedish wind turbine industries, where both allocated large sums to R&D; but whilst the focus in Germany was on a variety of turbines, in Sweden it was almost solely on large-scale turbines, which ultimately lead nowhere for the Swedish industry (Jacobsson & Bergek 2011: 48). It is suggested by Bergek et al. (2008a) that one can measure knowledge development and diffusion by looking at the number, size and orientation of R&D projects, assessments by managers or others, and learning curves. We will here concentrate on R&D projects and assessments by interviewees. Nevertheless, incorporating a focus on both R&D and on more tacit forms of learning and innovating, as implied in the DUI-mode above, conveys a more complete picture of the Chinese case.

6.2.1 Science-based learning

To start by looking at R&D activities, according to the China Wind Power Outlook (CWPO 2010: 34) all of the top 10 Chinese enterprises have established their own R&D centres. Furthermore,

> (...) seven enterprises - Sinovel, Goldwind, Dongfang, Zhejiang Windey, XEMC, Guodian United Power and Guangdong Mingyang - essentially possess the design capability and key manufacturing technology for MW-scale wind turbines, and are in an excellent position to carry out independent research and development through introducing or developing advanced design software and control strategies, establishing high level laboratories and other R&D platforms and cultivating professional technical personnel. (...) Generally, however, there is still a large gap between the R&D level of China's wind power industry and the international standard in terms of the numbers of institutions, their employees and the quality of work (CWPO 2010: 34, 41).

The CWPO is, on the one hand, focussing on the R&D level already achieved in the Chinese wind industry, and on the other hand, contrasting this with the comparatively low level in a global perspective. The latter perspective was reinforced by the interviewees; for instance, Mr. Li (interview 30.09.2011) expressed that "the research institutions and universities are very weak". Nevertheless, several companies are able to independently develop their own designs. In fact, even though there is a gap between the domestic and international R&D level, conversations with researchers and professionals in the industry revealed that several Chinese wind turbine manufacturers have established research centres in leading wind turbine research and development communities globally, such as at Risøe in Denmark (e.g. Mingyang and Envision). Presumably, this enables these companies to tap into highly valuable knowledge or skilled personnel, crucial to further develop their turbine designs.

There is a general propensity in China to invest more in research and development, and an overall goal is an increase in R&D expenditure to 2.5 per cent of GDP by 2020, up from 1.42 per cent in 2006 (Cao et al. 2009: 247). In comparison, the OECD average R&D spending as a percentage of GDP was 2.3 in 2008 (OECD 2011: 179). To delve into the specifics of the wind industry, let us look at the available numbers for R&D spending. Even though the interviewees did not know any specific figures, it was commonly assumed that the portion spent on R&D in comparison to the total revenue, the R&D intensity, was very low. The example from the only U.S.-listed Chinese wind turbine manufacturer, Mingyang, is illustrative. Their 2010 annual report states that the 2010 R&D intensity was 0.78 per cent, in 2009 it was 4.5 per cent and in 2008 it was 9.6 per cent (Mingyang 2011). The company started in 2006, and it is therefore natural that their R&D expenses were higher in the inception, but a decline to 0.8 per cent in 2010 is interesting. Available figures for Goldwind shows a R&D intensity of 0.75 per cent in both 2010 and 2009 (Goldwind 2011b).[21] Seemingly this is the standard for the more established large companies in China. Unfortunately, access to detailed information is limited because of low transparency and few listed companies. Yet, a comparison with some other large wind companies reveals that this level is fairly low. For instance, according to Vestas' latest annual report, even though 2011 was not a good year for the company they still spent 6.9 per cent of their revenue on R&D (Vestas 2012). Furthermore, Suzlon, an Indian company that in 2010 was the sixth-largest wind turbine manufacturer globally, spent 3.3 and 1.75 per cent respectively in 2009/10 and 2010/11 (Suzlon 2011).

To take a quick peek into R&D projects, there are several projects funded by both international and national institutions. Sinovel, for instance, received US$ 1.2

[21] All figures are calculated by the author as a ratio between the companies' investments in R&D and net sales according to annual report figures.

million in government funding in 2009 for a centre that would "develop a large scale wind power generator unit driving set, speed change control system, and a massive data collection and management system" (Howell et al. 2010: 31,32). Other examples include the China Renewable Energy Scale-up Program (CRESP), which is a collaboration between China, the World Bank and the Global Environment Facility, to support concrete turbine development projects. As an example, between 2007 and 2011 they financed five Chinese wind turbine companies, amongst them the three largest, with a total of approximately US$ 41 million for what they call wind turbine technology transfer projects, which includes design, assembling and testing of various MW-scale prototype turbines (CRESP 2012). Furthermore, whole teams with experts from other countries have been involved in research and development activities in the Chinese wind industry (CWPO 2010: 41). Even though an independent assessment of the value of these R&D projects has not been conducted, there is little doubt that they have contributed to the development of independent designs for the Chinese companies.

6.2.2 Experience-based learning

Especially when talking about tacit or localised knowledge, including the notion of doing, using, and interacting (DUI) in a broad definition of innovation becomes important (Lundvall et al. 2009). According to Jensen et al. (2007: 682) different types of knowledge can be distinguished, where "know-what" and "know-why" relate mainly to the STI learning mode referred to above, and "know-how" and "know-who" are produced by the DUI-mode. So if one part of the learning in the Chinese industry refers mainly to R&D efforts, one can assume that another part relates to the DUI-mode. As we saw in the last chapter, much of the technology in the Chinese wind industry is based on licensing agreements with foreign companies. A good deal of communication happens with the licensing company so that a diffusion of knowledge occurs, and wind turbine companies today have a global reach (Lewis 2011). Also, joint designs and

M&As occur as methods to obtain independent technology for Chinese companies (CWPO 2010: 34). Therefore, one could say that the Chinese industry taps into a global knowledge base, with the goal of adapting and developing the knowledge at a local base. This type of learning can be classified as learning by interacting—and relates to how knowledge is *diffused* through networks (Hekkert & Negro 2009: 586). How far such learning may take a company is not easy to determine, yet it proved highly propitious in the Danish wind turbine industry, where interaction between the turbine users and turbine producers was helpful (Kamp et al. 2004). However, when talking with an employee of Geoho, a private turbine manufacturer, it was pointed out that licensing turbines prevents a company from applying adaptive changes to turbine designs. Depending on the licensing agreement the different firms have, this may inhibit the companies in China actually developing and adapting the technology, and they may be confined to merely production and assembly of the turbines. An increasingly common strategy in the Chinese wind industry is therefore to acquire a company (M&A) which has developed its own turbine, and cooperate on designing a Chinese turbine locally. In this way the companies circumvent any restrictions within licensing agreements, and also avoid future potential intellectual property lawsuits.

In Denmark, the users and producers of a wind turbine maintained a close and persistent connection, and the feedback this yielded improved the turbine designs (Hendry & Harborne 2011: 780). This kind of learning-by-using has been prevalent in Europe, where both manufacturers and developers are the ones establishing demonstration projects and learning from those experiences (Borup et al. 2009: 97). In China, the most frequent users of the turbines manufactured are the state-owned utility and grid companies, even though some manufacturers also operate wind farms. Because many Chinese turbine manufacturers are so new, their lack of a track-record is arguably a major barrier for further developments of products as well as in convincing buyers that they have the best product. Vivienne Lu (interview 03.11.2011), the marketing manager for Nordex (Beijing), a German turbine manufacturer in China, emphasised that their long track-record enabled the company to learn from past experience:

> We are continually doing technical improvements or upgrading the existing technology. To do this we take the experience from the past to make the future turbines better. (...) For our 1.5 [MW turbine] we already have more than ten years global track record, and that is an experience that cannot be replaced.

The Chinese manufacturer with the longest track-record is Goldwind, which arguably has an advantage in its technology development. Therefore, not only the fact that the company built its test-facilities close to the international companies, as we saw in the previous chapter, but also their longer track-record of wind farm operations have potentially been significant for Goldwind's advancement. Nevertheless, in 2010 their longest-serving wind turbine had only been in operation for six years (Goldwind 2011a). Another interesting case of learning-by-using is Guodian United Power, a subsidiary of Guodian, one of the five state-owned electric power companies (the "big five"), and by far the largest wind power installer (CWPO 2010, gdupc.com.cn 2012). Since Guodian United Power was established in 2007, it grew to become the fourth largest Chinese turbine manufacturer in 2009—and this in the world's largest wind turbine market. Presumably, the company has benefitted greatly from the unique position its parent company has in wind farm development. This was also emphasised in an interview the Deputy Director of United Power's Chief Engineering Office, Mr Xiao Jinsong, did with DNV (2011):

> (...) United Power has the advantage of control throughout the entire supply chain. In addition to providing the complete machine, we also produce major components—blades, gearboxes, generators, pitch systems, inverters, etc. Furthermore, our parent company, Guodian, *is the largest wind power developer in Asia* (emphasis added).

According to Jensen et al. (2007: 683), experience-based learning "is acquired for the most part on the job as employees face on-going changes that confront them with new problems". Given the fact that the Chinese industry manufactured around 87 per cent of all installed turbines in 2009 (CWPO 2010: 37), Chinese companies have considerable learning-by-doing experience, and their learning curves have been steep. Many of the interviews and conversations with manufacturers indicated that a large portion of the innovative activities in the Chinese turbine industry relate to adapting the turbines to local geographical and climatic conditions. For instance, in conversations with a Goldwind employee, it was indicated that they have adapted the turbines to the rough conditions found in Xinjiang and Inner Mongolia, by increasing the protection against dust, humidity and extreme weather. According to Mr. Meyer (interview 08.11.2011), since Goldwind uses air-cooled direct-drive turbines, it was crucial to find an isolation which was robust enough to cope with air containing more sand and dust than in Europe.[22]

Another common feature of the Chinese wind turbine industry is that experience from different sectors is used when producing the turbines and their components, since many of the players have grown out of large industrial companies (Schwartz & Hodum 2008). For instance, the central government administered Dongfang Electric, the third-largest Chinese wind turbine manufacturer, has a history of more than 50 years in manufacturing heavy-duty machinery and equipment, such as steam and hydro turbine generators (DEC 2012). This company, which is one of the largest steam turbine producers in China, did not engage in the wind industry until 2005, when it started cooperating with European turbine design companies (Zhao et al. 2009: 2886). Also, the XEMC group which was founded in 1936, had previous experience in machinery and electricity equipment manufacturing before jumping into the wind turbine industry (XEMC 2012). According to the interviewee from XEMC Windpower, their experience with electric generators in particular gave the company a large advantage in developing their wind turbine technology. Looking at the list of top ten wind turbine manufacturers across the globe (REN21 2011: 39), it is clear that previous

[22] In fact, for precisely this reason, Goldwind has been listed for two years in a row as one of the 50 most innovative companies in the world, by the MIT Technology Review (MIT 2012).

experience in a different sector is highly common, and according to my own knowledge this applies to at least six of the ten major companies: Sinovel (2nd), GE Wind (3rd), Enercon (5th), United Power (6th), Siemens (7th) and Dongfang (9th).

6.3 Influence on the direction of search

What kinds of incentives and pressures exist for actors seeking to enter the Chinese wind turbine industry? As we have seen already, more than 80 manufacturers and several up- and down-stream firms are engaged in the industry, and understanding what drives this engagement is important to saying something about how the wind turbine industry works. It is clear that this function has a close connection with the functions “market formation” and “resource mobilisations” since these are clear indicators for industrial actors seizing new opportunities (Bergek 2002: 155, 178). Jacobsson and Bergek (2011: 49) indicate that “influencing the direction of search” has much to do with institutional factors, many of which were described in the previous chapter. Several circumstances influence the direction of search; for example, expectations, visions and beliefs in growth potential, incentives from factor prices, and the extent of regulatory pressures (Bergek et al. 2008a: 415). The government is a core player in determining beliefs in growth potential through goals set in five-year and longer-term plans. These types of government targets are closely connected with increasing the legitimacy of the wind industry, something which increases the attractiveness of the industry, and this will be further scrutinised in Section 6.5. Yet, it is challenging—if not impossible—for a government alone to delimit a path of development. As will be explained further in Section 7.2, environmental deterioration and climate change are forces that may have influenced the increased interest in renewable energy in China.

Within the Chinese wind industry two basic directions of search can be clearly distinguished; namely, a drive towards larger turbines, and a divergence between direct-drive and double-fed technology turbines. Even though the government is directing much of the influence in the Chinese wind turbine TIS, other factors are important as well. As we have seen already, government funding for wind turbine R&D was potentially destructive for the industries, such as in the Netherlands, the U.S., and particularly in Sweden, where the focus was on ever-larger turbines. In China, this influence is exercised in terms of restrictions on turbine size usage for wind farms, and is motivated by a concern for quality (Lewis 2011: 285). Since the beginning of the concession rounds, minimum turbine sizes have been postulated, beginning with minimum 600 kW, then increasing to 750 kW and finally 1 MW in 2009 (CWPP 2010, Howell et al. 2010).[23] As was expressed by Weiquan Wang (interview 29.09.2011) at CREIA, "[with this policy] they can produce wind turbines with more quality and improve their technology. I think generally speaking it's good for the development of the industry". Nevertheless, according to the European Chamber of Commerce, in China these restrictions are not only harmful to the industry, but will "increase the risk of installing turbines that are unsuitable and inefficient" (Howell et al. 2010: 57). Also, in terms of R&D funding, the government has explicitly mandated that the money is to be used to develop larger turbines: Chinese companies were impelled to "think big" (BNEF 2010).

From a TIS perspective, supporting a *variation* of turbines has been the most successful policy in other countries, for the formation of a wind turbine industry (Bergek 2002: 173). Yet, looking at the industry from a global perspective, the Chinese industry has quickly caught up, and it tries to adapt to international standards and mass production, where there is a trend towards large-scale wind turbines aimed especially for the offshore-market (CWPO 2010: 2). Since standardisation, codification and formulation of "best practises", or what Geels and Raven

[23] The policy-suggestion as of 2010 restricted "the operation of wind turbine manufacturers that did not have the capability to produce a 2.5 MW or larger turbine, did not have at least 5 years of experience in a related industry and did not meet various financial, R&D and quality control requirements" (Lewis 2011: 285).

(2006: 378) call “aggregation activities”, have come so far internationally, it is necessary for the Chinese manufacturers to reach this level in order to capture market share abroad. It is clear that reaching the goal of larger turbines is important for the industry, given that the Chinese wind industry finds itself in a “bridging phase”, as discussed in the previous chapter.

So scaling up might yield positive results in terms of market possibilities, but then another problem appears, namely the long term performance and electricity generation of a wind turbine. At the China Wind Power conference 2011, compelling concerns were raised: First, foreign turbine manufacturers were concerned that a focus on installed capacity in terms of MW would prevail over a focus on long-term performance in terms of MW*h.* Second, the equipment manufacturers worried that price-competitions would lead to a deterioration of quality. These two concerns are related, because a turbine with poor-quality components will not produce electricity efficiently during a 20-year lifecycle. Especially now that Chinese manufacturers are looking to export more turbines, it will be challenging to convince international buyers of the long-term performance of the turbines. In any case, we see that international standards are influencing the direction of search in China, and that influence is likely to increase with the overseas expansion of the Chinese wind industry.

China has chosen to sustain a relatively new technology, the direct-drive permanent magnet wind turbine generator.[24] Goldwind and XEMC Windpower are leading this development, and together with the German company Enercon they are the three largest direct-drive design turbine producers globally (REN21 2011: 40). The total global market captured by this technology is almost one-fifth of the total (ibid.), and within China the direct drive technology has increased steadily from an estimated market share of 0.1 per cent in 2006 to 21.5 per cent in 2010

[24] Hybrid solutions have also received increasing attention, where the gearbox and permanent magnet generator both contribute to electricity generation of one single turbine.

(Jiang et al. 2011: 41).[25] According to Mr. Meyer (interview 08.11.2011) from Azure International, this development was intentionally promoted by the government:

> (...) there was a clear signal for instance at the government for direct-drive technology in that a lot of grant money was given to develop commercial prototypes, then there were different tax rebate systems designed to enable the roll-out of scale manufacturing for first turbine companies.

Goldwind and XEMC Windpower are the only two large turbine manufacturers in China that have chosen this technology in place of the double-fed turbine, and it is interesting to see what lead to that choice. According to Owen Chan (interview 27.10.2011), key account manager at XEMC Windpower, they were contrasting these two models before they made a final choice:

> When we made the choice over whether we choose double-fed technology or direct-driven, we really hesitated for a long time. Based on trend and tendency, we finally chose direct-drive units. (...) In the past, the power companies only thought the double-fed turbines were acceptable, but now these electricity power companies have begun to think our direct-drive models are acceptable.

Even though it is difficult to assess based on these statements what ultimately lead to this direction of search, this illustrates that it is possible to make a bold choice in the Chinese industry even when the largest investors, the electricity power companies, are hesitant to the technology. One might ascribe the choice to the comparatively cheap prices of permanent magnets in China, since China provides around 95 per cent of all rare earth elements, and at the same time has an export quota for these elements, making them cheaper to purchase domestically than abroad (DOE 2011: 16, 20). Also, as suggested by Geels and Raven (2006: 375), the direction of search and development activities is influenced by expectations and visions that are oriented towards the future. The interviewee from

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[25] The permanent magnet commonly used for direct-drive turbines is Neodymium iron boron, a rare earth element (DOE 2011: 19).

Goldwind (interview 14.11.2011) emphasised expectations of future performance when talking about their direct-drive technology:

> About 2005-2006 Goldwind basically took a 180 [degrees], they got rid of the gearbox design; it wasn't the future—and went into the permanent-magnet design with the Vensys turbine. (...) and that's when you had companies like XEMC follow suit with their direct-drive turbines.

We see, therefore, that a change in direction took place in the industry, based on expectations, trends and tendency. One can only speculate what exactly lead to this change, but at the time conventional turbine gearboxes were problematic. The direct-drive turbines, which do not need gearboxes, provided a quick and simple solution (de Vries 2007). Nevertheless, the choices made by the individual companies were likely influenced by local factors, for example government funding—hence "resource mobilisation"—as well as global factors, such as the links XEMC Windpower and Goldwind had with their licensing or joint design and, finally, fully-acquired companies.[26]

6.4 Market formation

Market formation is perhaps the strongest function in the Chinese wind turbine technological innovation system, at least until 2011. The wind industry is based predominately on a domestic market, in sharp contrast to the sister TIS of the Chinese solar cell manufacturing industry, which is also world-leading, but exports almost all modules to Europe and the U.S. (CNRED 2011a). Given the fact that China today has the largest market for wind power production, the market formation policies must be considered a great success, even with the constraints the market is now experiencing. According to the latest figures, China captured 44 per cent of the total world installed capacity in 2011, almost as much as the

[26] Both XEMC and Goldwind have had licensing agreements with direct-drive design companies. In the case of XEMC, they first licensed and later rebranded the Dutch-Japanese Lagerwey/Zephyros (owned by Harakosan), and later, in 2009 they took over the assets of Darwind, a direct-drive offshore wind turbine company (XEMC-Darwind 2012). Goldwind first licensed from, and later became the majority owner (70 per cent) of the German company Vensys (Lewis 2011: 287).

rest of the world put together (GWEC 2012). As explained in the previous chapter, it was first the concession programme, and later the Feed-in tariff, along with the mandated market share for power companies in the ReLaw that spurred market growth in the industry. In contrast to some European countries, China has not encountered large barriers related to space allocation for wind farms (Jacobsson & Bergek 2011). Market formation is naturally crucial in a formative phase of a TIS, but it is equally important when the goal is to build up an industry which ultimately competes with conventional power sources. Considering this as the overarching goal of the Chinese wind turbine TIS can help us understand how this function is performing.

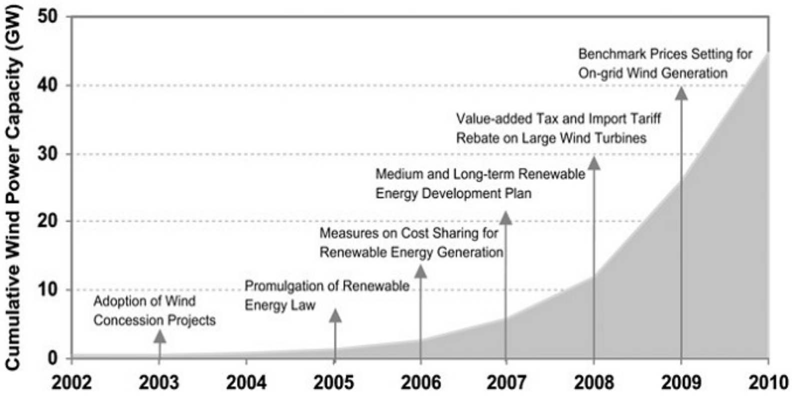
Much literature has drawn attention to the role government legislation has had on wind turbine market development in China, such as the aforementioned concession rounds and the ReLaw. To be sure, this is an important focus, but research on market formation activities points out that a unique focus on the strengths of a national subsidy scheme as a main market formation mechanism for emerging technologies may be too simplistic (Dewald & Truffer 2012). Studies on the Feed-in tariff for solar panels in Germany have shown that there are regional differences in market dynamics, and that local processes can be important in forming markets (Dewald & Truffer 2011, 2012). Article 9 of the ReLaw states that "opinions should be solicited from relevant units, experts and *the general public* (...)" (emphasis added), yet this is commonly ignored by the developers (M. Wang 2007: 243, 244). If we look at the geographical distribution of wind farms, most are installed in Inner Mongolia, which contains 36 per cent of the total installed capacity, mainly because this is where the best wind resources are found (CWPO 2010: 15). Local governments there actively sustain the development and are often eager to attract wind projects (REN21 2009a: 19). There are currently plans to build two 10GW scale wind power bases in Eastern and Western Inner-Mongolia, yet curiously, most of these plans are centred around specific cities; for instance, Chifeng City where almost half of the planned projects in Eastern Inner-Mongolia will be built (CWPO 2010: 25). Whilst this area has high-quality wind resources, such a high concentration of projects could also imply that this area has been more effective in drawing attention to the market opportunities there. As suggested by Dewald and Truffer (2012: 415), such initiatives could range from "motivating actors from conventional business sectors to join the business networks", to simply "providing legitimacy" for the local wind market.

One market mechanism which has not been discussed thus far is the Clean Development Mechanism (CDM). Briefly put, the CDM allows industrialised countries to reduce their greenhouse gas (GHG) emissions by developing or financing projects that reduce GHG emissions in developing countries. China has been the largest host country for CDM, with wind power projects accounting for 23 per cent of the total projects in 2010 (CWPO 2010: 54,55). An important part of the CDM legislation is that the projects will only be approved if they are considered "additional"; that is, without the CDM support they would not have been put in place (Schroeder 2009: 239). The developer must prove that the project needs CDM support in order to start up. Without *additionality* a wind project is regarded as business-as-usual, and will not receive CDM support (ibid.). Interestingly, more than one-third of the wind farms that were built in 2008 and more than half in 2007 were supported by the CDM, something which *de facto* makes this mechanism a truly important contributor, given that these projects would not have been built without the support (Lewis 2010b: 2879). Nevertheless, further investigation into the matter reveals that CDM is rarely the primary reason a wind farm gets developed in China, and can be viewed more as a useful subsidy (ibid: 2884); thus, one can assume the additionality criterion is broken. So even though the initial intent of the CDM was to form new markets, one can instead regard it as a market propulsion mechanism which made project development more attractive for investors (WWF 2008).

6.5 Creating legitimacy

In order for a market to be shaped, it is necessary that the technology in question has gained enough legitimacy; that is, gained "social acceptance and compliance with the relevant institutions" (Bergek et al. 2008b: 581). Increasing legitimacy for a TIS is a process which takes time, and as we shall see, there are several strategies to adopt. Creating legitimacy is also dependent on positive feedback mechanisms; when new actors enter the market, legitimacy may be increased. One issue which was not debated in the section on institutions is the legitimacy that the central and local governments provide in China when signalling an area of priority through long-term plans. The Five-Year Plan is the most important government document, and the attention given to new and renewable energy has increased over the course of 12 Five-Year Plans, starting with the 6th, and culminating with the latest plan for the period 2011-2015 (Yuan & Zuo 2011). These government indications without a doubt play an important role in paving the way for emerging industries. If we look at the timing of establishment for the largest wind turbine manufacturers, we see that most of them were created fairly recently, between 2004 and 2007 (CRESP 2009), something which coincides with the announcement of wind-friendly government policies.[27] This increase also corresponds to the increase in CDM projects, and a rapid growth of the market, as illustrated in Figure 11. On a less aggregated level, we shall see that legitimation processes have had an impact as well.

Figure 11: Correspondence between policies and market growth



Source: Yang et al. (2012: 146)

[27] With the exception of Goldwind.

One way of aligning institutions, and thus increasing the legitimacy of a TIS, is related to “conformance”, which means to follow the rules of the already existing institutions (Bergek et al. 2008a: 417). A clear example of this is when the government decided to introduce the mandated market share of non-hydro renewable energy for the established power producers in China.[28] Another strategy of legitimation is to “manipulate” the rules of the game (ibid.). In a way, these two strategies are related, because the wind TIS has gained legitimacy in China within established institutions, and also by using this existing legitimacy to shape new outcomes through exploiting existing practises. Many of the large, influential SOEs have engaged in wind turbine manufacturing, and it is clear that their political influence in a region has facilitated their growth. According to the informant from XEMC Windpower, the company “has a certain influence in Hunan province, because the head of the Hunan province came from XEMC”. As a result of the political connections this company has, one can assume it also does its fair share to convince policy-makers of the benefits of wind turbines. Apparently this link between state-owned companies and political career is not infrequent. When Mr. Recknagel (interview 26.09.2011) talked about the mandated market share, he noted that:

> (...) the incentive for the leaders of the power companies: if they don’t fulfil this requirement, they will be held accountable, that they didn’t fulfil the goal that the party said, and this will directly impact their personal careers.

Rosen and Houser (2007: 19) point out that the executive leadership of these large energy SOEs is appointed by the Ministry of Personnel, and this ministry is synchronised with party politics. Therefore, as many energy SOE professionals have political ambitions (ibid.), one can expect that government legislation is complied with, and perhaps even over-achieved.

[28] These companies in turn, because they are mostly large, central government owned companies, take part in shaping government policy (Rosen & Houser 2007: 19).

In the first section of this chapter it was mentioned that the government does not really give much direct funding to the wind turbine industry. Yet in several of the interviews it was indicated that state support oftentimes meant more in terms of politics than in terms of economics. Again, XEMC Windpower (interview 27.10.2011) serves as an example:

> **Interviewer:** If you would compare the amount of investment XEMC Windpower does and the amount the government gives, how important would government funding be then?
>
> **Interviewee:** The company's investment is larger than government funding, but state funding is also very important to us, just to show that the state encourages [us] to keep up. Especially for our group, a very large SOE with a long history, the state funds mean more [for the] encouragement than the real impact. After the state funding, we have more voice in Hunan province, which means the Hunan provincial government would be more supportive to us.

A similar line of argument was presented by Huang He (interview 08.11.2011) from the Energy Research Institute of the NDRC:

> [The government] has promoted R&D a bit—some national research centres and test centres have been supported by the government—and that has been enough because it proved the legitimacy of the industry.

What we observe here is a divergence between provincial and central government interests that characterise Chinese politics. According to M. Wang (2007: 244-246) local governments increasingly care only about local economic growth, and "are enthusiastic about, and spare no effort in, starting thermal power plants, while renewable energy generation projects are often 'pending discussion'". Although provinces have become more economically independent from the centre (Saich 2011: 183), it is clear that central government approval also shapes the provinces' opinions on where the profitable investments are. As a result, when a company or a sector receives central support, it indicates a safer bet for provincial governments that seek to build up an industry. This makes a difference when the local governments face the choice to start a wind project rather than a thermal power project.

On a closer examination of the legitimacy of the Swedish wind turbine TIS, Jacobsson and Bergek (2011: 582,583) show that the media played a negative role in shaping expectations and desirability of wind power. The role of the media was particularly observed with the downturn in the Chinese wind turbine industry in 2011. Yet, as the media is largely state controlled in China, we again see the influence the government can exert. This was highlighted by Liming Qiao (interview 12.09.2011) from the Global Wind Energy Council:

> [The government] can one day say that "we think this industry is very promising" and everything [is] good about it, that's why you see in the past two years this massive developments and everything you can see related to wind in the news are good. And this on the other hand reinforces the industry to expand, and we would say a bit too rapid, and now this year it's a time when some of the problems that were hidden started to get exposed. Like the quality issue, like the standards issue, like the grid issue - everything started to get out, and (...) then you suddenly see a change of everything. Like media, like the banks and others that would switch away, and go to solar. (...) Every problem was there two years ago, it's just that you were not allowed to say that, so it didn't seem to be there. But now we are suddenly allowed to say that, and people get a feeling that wind started to show its side effects. But it's not true, the side effects have always been there, it's just that you allow them to be exposed at this stage; people will get a bad feeling, that this sector is going away or something like that. And that's really not good.

This striking quote illuminates to a great extent how important the media is for the legitimacy of the wind industry. What we basically observe is a government which uses legitimation as a tool to increase or decrease interest in the wind industry, fluctuating with the current development goals. To be sure, highlighting the challenges that the industry faces regarding turbine quality or grid connection issues is important for the overall performance of the industry. Yet, the fact that these issues have been evident for some years without having repercussions before 2011 testifies for the importance of information control in China. Legitimation seems, therefore, to be a well trained muscle of China's institutional body, and the strength of this function for the wind industry ultimately depends on the degree that the government and industry goals are in-sync.

6.6 Entrepreneurial activity

The role of the entrepreneur in innovation and economic changes has been recognised since Schumpeter's early work (1911) (Fagerberg 2005: 6). The main task of entrepreneurial activities is to reduce uncertainty in a new TIS, and according to Carlsson and Stankiewicz (1991: 106), the entrepreneur "has to perceive the (future) need, identify the necessary ingredients, secure the resources that may be missing initially, and communicate his vision to the relevant agents". The entrepreneur can therefore be understood as a facilitator, a crux, or a node which drives innovation. As has been argued here, the Chinese wind turbine TIS is most adequately referred to being in a "bridging" phase. Entrepreneurial activities are important not only in an early phase of a TIS, but in later stages as well (Bergek et al. 2008a: 415). Literature on entrepreneurial activity in China tends to conclude that "entrepreneurship is unfortunately a very scarce resource in China. This has much to do with incentive systems as well as with education and training" (Gu et al. 2009: 381). Also that "the Chinese government seems to have less understanding of the importance of managerial initiatives and objectives, especially towards building internal organizational capabilities and a culture of entrepreneurship" (Liu & White 2001: 1107), and in the same vein that "despite Chinese firms being acutely aware of the need for creativity, the application of [management] techniques would still seem to run deeply against traditional management culture" (Alcorta et al. 2009: 456). From these quotes we derive that the problem is perceived as highly institutional, and we can flesh out two main concerns; management issues and education and training. For the Chinese wind industry specifically, the latter point was discussed in the human resources section, but the first will be further illuminated below. Unfortunately, an institutional understanding of entrepreneurship has yet to be developed, and we therefore lack precise criteria for how to assess this function (Lundvall et al. 2009: 382).

Even so, Bergek et al. (2008a: 416) suggest mapping the number and variety of experiments taking place in the TIS, by measuring, for instance, the amount of new entrants, as a means of measuring entrepreneurial activities. As we have already seen, there were many new entrants between 2004 and 2007, and most of these are engaging in developing and testing and have not started mass production of many turbines (CWPC 2012). At a first glance, it looks like entrepreneurial activities are very present. However, the role these new entrants have is less clear. Liming Qiao (interview 12.09.2011) expressed, in response to the question about new entrants, that "it's not really that way; the vibration is not coming from the new entrances, because a new entrance doesn't really mean they really own the technology that way."

Based on the above definition of an entrepreneur, management is closely connected to entrepreneurial activities. All the informants were asked how entrepreneurial activities in the Chinese wind industry were managed, something which yielded some examples of how the companies actually improved products. As a case in point, Owen Chan (interview 27.10.2011) from XEMC Windpower recounted the following story:

> Also I would like to give you another example of a staff installing the equipment. The nacelle, when he equipped the nacelle, he found a new way to equip the nacelle so as to save much time, energy and labour. So, after we [got to] know his way, his good idea, we just named this way with his name, and also translate his installation way to become the standard, and promote his way around the whole group. And this person, for installing the nacelle, felt respected.

We see therefore, that in some companies creative activities are cherished—a sign that leeway for alternative methods may exist. Yet, this example most likely belongs among the exceptions. This was especially reflected by Mr. Meyer (interview 08.11.2011) from Azure international, who remained sceptical towards the significance of these Chinese innovations:

> You have the original engineers and the pedigree behind somebody who would understand it, but you take it out of the context and the Chinese are fast to innovate things, but as often as not the innovations that they may make may be leading to an imperfect solution.

Keeping in mind that the kinds of innovations Mr. Meyer here discusses are often the ones which lead to price reductions, one can recognise these innovations as failures in understanding the trade-offs when changing a product.

An interesting comparison in terms of management is the Chinese solar manufacturing industry, which ranks as the largest manufacturer of solar panels globally, and has developed in a similarly astonishing pace as the wind industry (CGTI 2011: 15). Two recent studies on innovation in the Chinese solar manufacturing industry, namely Marigo et al. (2010) and de la Tour et al. (2011), indicate that managerial competences and the presence of internationally trained managers have been advantageous for the Chinese solar industry. These highly-skilled executives bring "capital, professional networks, and technology acquired in foreign companies or universities to China", and more than 60 per cent of the board members of the three largest photovoltaic manufacturers have experience from abroad (de la Tour et al. 2011: 765). In the wind industry in China, the international presence is low both at the management and the personnel levels. Yet, many of the largest companies are trying to attract skilled workers from foreign companies. As was mentioned in the last chapter, Goldwind has been able to attract skilled workers from many of the largest international players, and, in fact, this ability has gained momentum with the growth of the company (Lewis 2011: 287). Attracting workers is not enough, however, and it remains to be seen how the management will deal with these resources. In terms of entrepreneurial activity in the Chinese wind turbine TIS, it seems plausible that firm management is a weakness, especially when the companies now are facing outwards.

6.7 Development of external economies

Even though the definition of this function in the theory chapter places importance on the amount of new entrants to an industry, as we saw in the previous section, it is difficult to measure what function new entrants have for the Chinese wind industry. We do know that there were many new entrants between 2004 and

2007, but the end effect of the great number of new entrants for the industry as a whole is dubious. “Development of external economies” is perhaps one of the least autonomous functions, since it induces feedback into the other six functions, thus strengthening the dynamics of the whole TIS (Bergek et al. 2008a: 418). Some examples of external economies, often referred to as free utilities, can be a base of mobile and highly skilled workers, a pool of goods and services that are needed by the manufacturers, or the integration of knowledge and experience from other fields (Carlsson & Stankiewicz 1991: 102). For example, in the Danish wind industry in the 1980s, the experience from agricultural equipment manufacturing was brought into the industry, and close, collaborative networks between wind turbine users, owners, and research institutions created positive feedback into the industry (Kamp et al. 2004: 1632). In this way, the virtues of external economies can be understood as the added value, which is more than the sum of each component.

We have seen that many Chinese wind turbine manufacturers have previous experience from the heavy machinery industry (e.g. Sinovel), equipment manufacturing and electrical generators (e.g. XEMC), and other turbine industries, such as steam turbines (e.g. Dongfang). In the wind industry it is a common phenomenon for new entrants to come from related industries. Entrants to the German wind turbine industry, for instance, came from shipbuilding, gearbox manufacturing or agriculture machinery (Bergek & Jacobsson 2003). To give one more example from the Chinese wind industry, Shanghai Electric is one of these large industrial groups which entered the wind turbine business in 2007 (shanghai-electric.com 2012b). The company started out producing air conditioners in 1959, and then diversified into other industries, such as diesel engines, and the thermal and nuclear power generator industries (ibid.). Today, the company is the 6th-largest Chinese turbine manufacturer, and ranks amongst the top 15 turbine manufacturers globally. According to the company itself, this is in large part thanks to its ability to quickly absorb knowledge from their licensing (DeWind) and joint development (Aerodyn) agreements, and finally independently design their own turbine (shanghai-electric.com 2012a). The specific competences that these related industries bring to the industry can be regarded as powerful external economies. It is important to recognise this previous experience, this local knowledge base, as an important contributor to their success in quickly absorbing knowledge. Thus, we can say that external economies are largely developed from new entrants with a background in related industries.

According to Bergek et al. (2008b: 585) knowledge spillovers are central in shaping external economies, but also important are structural components, such as shared networks or institutions. This is especially relevant if there are several similar minority TISs, for instance in China where new renewable energy companies are marginal in comparison to the coal power producers. These TISs could then be visualised as "running in packs" in order to increase their influence on the incumbent system (ibid: 587).[29] In China, it is clear that the ultimate goal of the government is to increase the production of *renewable* electricity, not just wind electricity alone. As a result, the mandated market share for the electric power companies did not specify which source the electricity should come from, except that hydro-power was excluded. In the interview with Huang He (interview 08.11.2011) from the Energy Research Institute, he confirmed that the political power of the renewable energy industry has increased:

> The lobbying power is increased; they are taken more into account. One proof of this is how much more they are mentioned in the national media now. (...) Also, the National Energy Administration actually received increased status within the NDRC because of the promotion of renewable energy.

This is closely connected to increasing legitimacy, but the fact that renewable energies together have achieved a higher status within the National Energy Administration, an important organ under the NDRC which is "responsible for

[29] This way of competing in policy influence is also sometimes referred as "advocacy coalitions", or for new technologies, one can talk of "technology-specific coalitions" (Jacobsson & Lauber 2006). Scott Kennedy (2005) shows that such lobbying also is important for businesses in China's political sphere.

planning within the energy sector, industrial policies and standards (...)" (Delman & Chen 2008: 26), testifies to the added value of "running in packs".

Another interesting feature, which may be regarded as a positive externality, is the effect that the CDM has had on the Chinese wind industry. In addition to propelling the market, the Clean Development Mechanism has had other beneficial functions which have removed barriers from investment:

> (...) CDM has contributed to increase market transparency, improve data availability, raise product quality in turbines across the board, and finally relieved part of the high demand on local manufacturers by allowing increased market access for more efficient foreign manufacturers (WWF 2008: 24).

Interestingly, this is very similar to the way performance-publishing contributed to enhancing the performance of Danish wind turbines (Kamp et al. 2004: 1632). The performance of several Danish turbines was disclosed in a magazine set up by a Danish wind association, something which put pressure on the manufacturers (ibid.). In fact, because the Danish industry was able to prove their performance through these statistics, their chances of capturing a substantial portion of the Californian market in the 1980s was increased substantially (ibid. 1633). In the same way, as the above quote shows, the CDM has had feedback effects into several functions of the Chinese wind turbine TIS, including market formation, resource mobilisation, and knowledge development and diffusion. Also, with increased market transparency, one can say that the legitimacy of the Chinese industry has been enhanced amongst foreign investors.

6.8 Overall goal and dynamics of the industry

Having looked at the structural components as well as the key functions in the Chinese wind turbine TIS, it is now time to take a step back and highlight some of the dynamics between the functions we have scrutinised. As we saw in the description of the functions, the government has powerful ways to exert its influence. In terms of the two functions "resource mobilisation" and "legitimation", we have seen that the government can quite effectively steer the development in a given direction. Nevertheless, each function taken individually has strengths and weaknesses, depending on the focus one has for the Chinese wind turbine TIS. For example, it is not exclusively advantageous for the industry if the function "market formation" very strong, if the installed turbines have quality and grid connection issues. This leads to lower electricity generation, and could have repercussions for the legitimacy of the industry, and subsequently the dynamics of the whole TIS. Depending on the *overall goal* set for the industry, on can determine the functional dynamics, and ultimately the performance of the TIS. As we saw in Section 6.3, the direction of search is increasingly influenced by international developments, because the Chinese industry now increasingly seeks to export their turbines. Overcapacity and increased competition domestically induces this trend. This was for example voiced by the Deputy Director of Guodian United Power's Chief Engineering Office: "As an old Chinese saying goes, distant water won't help to put out a fire close at hand. So exploiting the overseas market has become the only way out for Chinese manufacturers" (DNV 2011: 30).

We can therefore say that conquering international markets is now an important overall goal for the industry. Taking this as a point of departure, we can assess the dynamics of the industry in light of the seven key functions. For starters, because the government influence presumably does not stretch far outside China's boarders, the function "legitimation" is weak. However leashed this function may seem, in the near future its performance will be less dependent on domestic conditions. Chinese turbines must first prove themselves outside of China before international legitimacy is ensured. In fact, the main topic of concern for the wind turbine industry at the moment is the legitimacy of Chinese turbines abroad. Many of the larger Chinese manufacturers search to expand internationally, but so far buyers have been reluctant due to "thinner documentation" of their wind turbine performance, as well as questions related to operation service and maintenance abroad (Rechargenews.com 2011). Therefore, many of the projects that are installed abroad at present act as demonstration projects. For instance, Sinovel recently erected two test turbines in Sweden with the stated purpose of a "demonstration effect":

> If Sinovel turbines are accepted by local users for the quality and technology, and meet no problem in access to the grid, it will pave the way for its turbines to enter the European market (Sinovel.com 2012).

As I have highlighted throughout the analysis, the mandated market share for power-producing companies has been important for attracting investments, and therefore "resource mobilisation", and perhaps as well "legitimation", given the role these centrally-owned companies have domestically. If Chinese wind turbine companies' markets are found increasingly abroad in the future, these two functions need to change—institutions need to be aligned for export. This could induce the following functional dynamic: "market formation" would no longer be dependent on domestic favourable policies, rendering the government less influential. Financial "resource mobilisation" would become more difficult for the large SOE wind farm investors if their projects are found abroad, because they do not have the same political influence as domestically. Therefore, it would be difficult to convince banks abroad to finance projects (i.e. establish "bankability"), especially when turbines have not yet been tested over a long amount of time within China—thus being perceived as too risky investments (BNEF 2010). Consequently, human resources would need a boost, as exported turbines presumably increases both total demand and quality demand from the buyers. In the same vein, "legitimation" would become less dependent on political connections with the government, rendering this function more or less dependent on the actual quality of the product delivered. Another potential risk for Chinese state-owned companies is that they are perceived as national entities when they expand into other countries' energy sectors. For instance, in the U.S., being a Chinese state owned company "carries heavy political baggage", and could have serious implications for the legitimacy of the Chinese actors there (BNEF 2010: 13).

When the Danish industry in the 1980s suddenly noticed market opportunities in the U.S. in what is called the "Californian wind rush", an increased focus on research and development was triggered because of a different customer demand there (Kamp et al. 2004: 1633, Hendry & Harborne 2011: 781). Hendry and Harborne (2011: 788) suggest that experience based learning was important in the *formative* phase of the Danish wind industry, but that in a later phase, where the market was expanding, learning by search became more important. As we have seen, much of the "knowledge development and diffusion" of the Chinese wind industry thus far has been based on learning from experience, as well as adapting designs to Chinese geographical circumstances. In following Hendry and Harborne's (2011) explanation of the Danish industry, a shift to science-based learning is needed in China, in order to cope with challenges of an overseas market. If one agrees with this argument, then a consequence is that Chinese companies need to start spending more money on research and development. Thus, one can say that whilst "absorptive capacity" was important in order to understand and manufacture the technology which entered into the Chinese wind turbine TIS, we might also observe an industry which is actively taking part in global wind turbine technology development.

One other consequence is seen in the "entrepreneurial activity" function. It was mentioned that firm management might be a weakness in the wind turbine TIS, compared to the solar photovoltaic TIS. One determinant for how successful the TIS becomes is how well firm managers are able to convince foreign buyers. It is hard to imagine that companies would be able to succeed in this task without increasing transparency in terms of how their turbines perform. If performance statistics are revealed to a greater extent, it could have positive feedbacks on the whole industry, as we saw in the Danish case (Section 6.7)—and hence, the development of "external economies". Also, given that the solar industry to such a large extent has been successful in exporting their products (Section 6.6), the wind industry might consider adapting similar strategies, such as by increasing the amount of internationally trained managers and personnel.

Keeping in mind as well that the function "influencing the direction of search" was heavily guided by developments abroad, e.g. with regard to turbine sizes, the Chinese TIS is constantly abreast with which direction the international industry is moving. One direction both internationally and in the Chinese industry today is an aim, at least amongst the largest Chinese companies, to produce offshore turbines. Such a change in the direction of search would spur repercussions in the "knowledge development" function, which needs both financial and human resources, and legitimacy from the established institutions. If this "legitimation" happens through the large coal-power producers, one could imagine that they would be less interested in investing in projects that are too far away from their own production facilities, and the function could therefore be weakened. This comes in addition to how the media is negatively influencing the legitimacy of the wind industry in general, as we saw in Section 6.5. This brings us to the topic of the next chapter where we shall discuss the external impacts that may shape the outcome of how these functions are fulfilled in the wind turbine TIS.

7. External mechanisms influencing the wind turbine TIS

You cannot solve a problem using the same thought process that created it
Albert Einstein

In this chapter I shall pinpoint the major blocking mechanisms preventing the wind industry from developing, and the external forces that are inducing the advancement of the industry. As we shall see, these mechanisms are highly related to the discussion on carbon lock-in and incumbent energy technologies. In the TIS framework, the inducement and blocking mechanisms are ways of incorporating potentially influential factors that are outside of the system in focus. For the wind turbine TIS these can be found within the energy sector, such as the grid companies, or in a wider context, such as the discourse on climate change. Because this context is widely defined, this last step of the analysis has received criticism. Markard and Truffer (2008: 610) point out one weakness in treating these mechanisms as purely exogenous: that it rules out a way to internally deal with these potentially influential factors. A similar critique is presented by Wieczorek and Hekkert (2012: 75), who add another problem, namely that "it is not clear whether all possible mechanisms have been identified or whether the list can further be extended". As we shall see shortly, one influential blocking mechanism which is not included in the TIS is the Chinese grid-system, which has to absorb all the newly installed wind power. Although the above critiques have been taken into consideration, due to the lack of an appropriate alternative method, an attempt will be made here to map relevant blocking and inducement mechanisms at hand.

7.1 Blocking

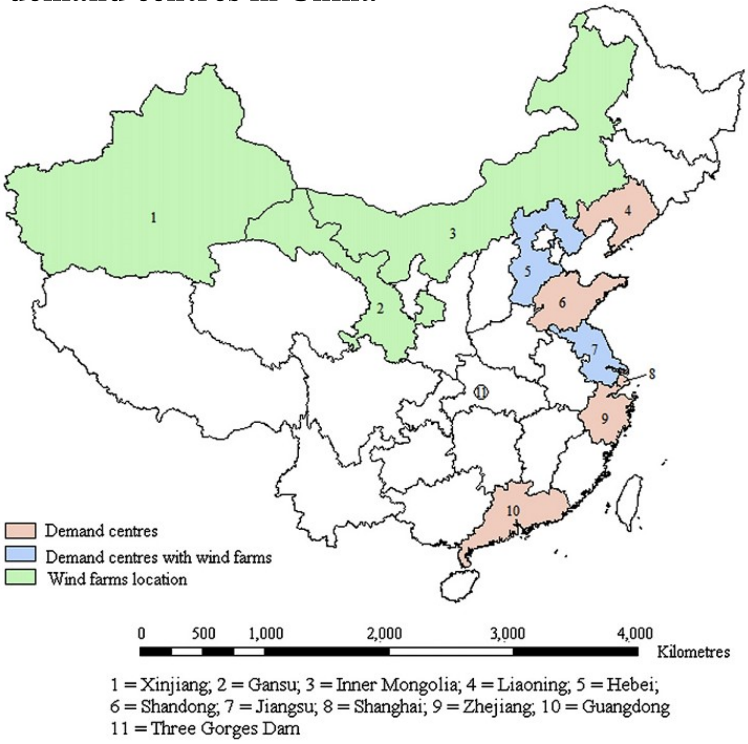
In just about any article one reads about the Chinese wind power development, it is mentioned that a significant portion of the turbines have not yet been connected to the electricity grid (e.g. Yang et al. 2012). Hitherto we have focussed on the influence of the large, state-owned electricity producers, who, since wind electricity represent a minimal part of their generating capacity, perhaps do not take their wind farm management that seriously (WWF 2008: 24). One group of actors which take serious notice of the added capacity of wind power are the electricity grid companies, which are obligated through the ReLaw to connect all renewable energy to the power grid (Martinot & Li 2010). It is frequently reported that around 30 per cent of the installed capacity is not connected to the electricity grid, which is a large amount. Martinot and Li (2010) claim that this mostly has to do with time lags in testing the turbines before connecting. Indeed, the installed wind power capacity doubled annually between 2004 and 2010 (Ni & Yang 2012), and increased almost 50 percent in 2011. In this respect, a grid-connected ratio of 70 per cent does not seem all that bad, yet, for the wind turbine TIS, the problem is deeper than this.

No transition without transmission?

In terms of carbon lock-in, electricity grid companies take on a doubly challenging role, because on the one hand they represent the established electricity regime, and have sunk costs and vested interests in that system (Unruh 2000), whilst on the other hand they are necessary in order to transport the electricity from new renewable technology. In Germany, for instance, large grid utilities were initially fiercely against the introduction of more renewables, and used several means to combat the progressive German Feed-in tariff policy (Jacobsson & Lauber 2006). In China there are only two electricity-grid companies that manage the whole national power grid system: State Grid Corporation of China ("State Grid") and Southern Grid (Ngan 2010: 2146). Nevertheless, the power grid is separated into regional clusters which are operated rather independently (IEA 2011: 12). The most important grid company for the wind farms, and for China in general, is State Grid, which operates four of the six regional grid clusters, mainly in the north of China (ibid.). As is testified in the joint report between

Vestas and State Grid, managing such a large grid system is a huge task (Jiang 2011), so one can easily understand that problems with connecting the rapidly growing wind power supply.

Map 1: Distance between wind farms and power demand centres in China



Source: Li et al. (2012)

One of the core issues is the distance between electricity demand centres and wind power generation areas in China, as Map 1 shows. Transmitting electricity over distances from 1500 to 2500 kilometres requires a high-voltage transmission grid which is expensive and challenging to build. It is estimated that a bit more than half of all the electricity generated from wind in 2015 must be transmitted on long-distance lines, whilst the rest will be consumed locally (Ni & Yang 2012: 38). China's investments in power grid development as a portion of total investments in the electricity sector have been low in comparison with developed countries (Li et al. 2012). This has lead to an unbalanced development of electricity generation and transmission infrastructure, and this in turn reduces the generation capacity (ibid.). All the interviewees were asked what factors they thought might inhibit the development of wind energy in China, and several answered that grid companies could take such a role. The interviewees were also asked about the future challenges of the wind industry, and many mentioned grid connection as a major bottleneck. For example, Weiquan Wang (interview 29.09.2011) from CREIA expressed the following concern:

> For the interests, I think the biggest interest conflict is between the renewable energy producer and the power grid, but inside the renewable energy field I think there are few conflicts. They can work together to move forward instead of conflicting with each other. But for the producers, for example the owners of the wind farms or the owners of the solar power stations, they have a conflict with the power grid you know. Renewable energy is not stable, it's unstable compared to fossil fuel power plants. So sometimes the power grid rejects them, they don't allow the wind farm to connect to the power grid.

According to the Vestas and State Grid report, successful and long-term electricity deliverance from wind farms requires both grid-friendly wind farms and wind-friendly grid systems (Jiang 2011). The reason grid companies are hesitant to accommodate wind energy is that the stability of power systems needs more attention when balancing the unstable inflows of wind power, as we see in Wang's comment above. As a result, if enough electricity is generated, wind farm operators are often asked to stop the electricity production (referred to as *curtailment*) in order to keep the balance on the grid (ibid: 35). This obviously decreases the total electricity production of a wind farm. According to Liming Qiao (interview 12.09.2011) from the Global Wind Energy Council, this issue could have been managed better by the grid company:

> If [the grid operators] invest more time to improve their management, then they should be able to cope with [the wind farm], but now they don't really have the incentive to change their current management; *it has become a routine*. The easiest way for them is to inform you to shut down (emphasis added).

Interestingly, the wording Ms. Qiao is using here conforms to how technological regimes are described, and how carbon lock-in is self-perpetuating. In a technological regime, one expects firms "to behave in the future according to the routines they have employed in the past" (Nelson & Winter 2002: 30). This makes it particularly difficult for an established firm to change practices. Elsewhere, this type of organisational routine has been perceived as a barrier to the adoption of low-carbon technologies (Unruh 2000). Optimal integration of wind electricity in the Chinese power grid therefore necessarily takes time.

A second issue relates to the low flexibility of Chinese power system operations, due to the large proportion of coal-fired power (Jiang et al. 2011). The combination of wind power and a high penetration of thermal electricity production is disadvantageous because its poor balancing capacity creates high energy inefficiency (Li et al. 2012). As an example, in Inner-Mongolia, where the largest wind power capacity is found, the proportion of wind and coal electricity is 4.7 and 92.6 per cent respectively (ibid: 56). Using coal-fired power plants to balance out the electricity from wind may reduce efficiency, and actually increase CO_2 emissions because of the efficiency loss which occurs when ramping up and down the steam-turbines (ibid.). This would have the opposite effect of increased wind power supply, which is supposed to reduce CO_2-emissions. This, in turn, is an argument that energy incumbents can use to stay in power, and hence securing their role within the regime.

Nevertheless, looking at the grid companies exclusively as an obstacle to wind industry development may be simplistic, as they also are the ones holding knowledge and potential solutions for a successful wind power development. This was pointed out in a conversation with a Danish wind industry expert, who emphasised that grid companies in Denmark were giving feedback and constructive solutions to the wind turbine industry. The two Chinese grid companies are large, have access to resources, and possess a high degree of ingrained legitimacy in the Chinese power sector. This is perhaps a defining feature of blocking agents: they embody both the problem and the potential solution to that problem.

Other blocking mechanisms can be considered relevant as well, one important being international trade, and possible trade restrictions. This goes both for Chinese wind turbine component exports, and for future complete wind turbine exports. If complete wind turbines are to be exported, they may face intellectual property rights litigation issues. This goes perhaps especially for the U.S., which had over 1500 wind energy-related patents in 2010, most of which have repercussions for wind turbine to grid connection (BNEF 2010). Almost all entrants to the

U.S. market face these challenges, and some turbine manufacturers are even barred from access because of intellectual property rights issues (ibid.). Even though such cases are not always valid, litigations are often costly and time consuming to pursue through the courts (ibid.). Regarding component exports, there are ongoing anti-dumping and anti-subsidy investigations into Chinese wind tower exports (Rechargenews.com 2012). Irrespective of these claims being well grounded or not, it is clear that they are effective blocking mechanisms that can jeopardise China's export possibilities, and seriously affect the development of the industry.

7.2 Inducement

It is widely acknowledged that the Chinese government has, through legislation and industry incentives, induced the development of the wind turbine industry. As mentioned several times already, long-term plans and ambitious policy has induced the growth of the industry. Therefore, we shall here direct our attention to two potentially underestimated mechanisms: the effect of environmental pollution amongst Chinese citizens, and a concern for adverse climate change effects in China.

Interestingly, only two informants mentioned environment or climate concerns as important contributing factors for the rapid development of China's wind turbine industry. Bryan Davis (interview 01.11.2011) from Bloomberg New Energy Finance expressed it this way: "(...) obviously the environmental side of it is very important. I think there are people who have a real commitment to reducing the number of days with skies as polluted as today". On that particularly grey day in Beijing, perhaps the interviewee was forced to think more about the environment as a critical issue, but it is a fact that people in China are increasingly noticing pollution in their daily lives (Keeley & Zheng 2011). Countless public environment-related health crises have emerged over the last three decades, ranging from dietary and water pollution, to cancer and skin rashes from toxic waste (Economy

2010: 87-91). This has lead to considerable social unrest in China, and in 2005 alone there were 51,000 pollution-related protests (ibid.). Rural instability and social unrest is something which the Chinese Communist Party (CCP) seeks to avoid at all costs (McGregor 2010). One way this is avoided is to control information, so that Chinese people do not get a full view of the existing environmental problems (Saich 2011: 270). Yet, given the scale of these protests, and with today's wide-ranging social media in China (e.g. *weibo*), concrete government action is demanded, and the development of clean electricity can be viewed as one such mitigation measure. Therefore, one inducement mechanism is the Chinese people themselves, and the environmental pollution and degradation that economic growth has carried with it.

Climate change clearly does not differentiate between geographical borders, and affects people all over the world. CO_2 represents the largest source of green house gas emissions growth since the 1970s, with the use of energy as the source of about 65 per cent of these gases, and power generation capturing the largest share (Barker et al. 2007: 27). At the same time CO_2 is the most important contributor to radiative forcing (ibid: 38), affecting Earth's radiation budget and thereby inducing climate change. Therefore, within the energy regime, climate change is perceived as a major problem (Geels & Raven 2006: 386). The realisation that climate change can have negative effects on the country's future has also become more widely acknowledged amongst China's leadership (Economy 2010: 191).

If we take a closer look at what role the media is playing, it is evident that climate change awareness has increased during the period the wind industry has grown. According to a recent survey on climate change media coverage in China, it was concluded that:

> The emphases are almost always on two issues: Firstly what China and Chinese industry need to do to be better prepared for the future uncertainties caused by global warming and secondly, seizing the opportunities to

> become the leader in the low-carbon economy of the future (Midttun et al. 2012: 18).

Renewable energy investments and climate change attention in the media have both increased in China and especially after the 2009 Copenhagen Climate Change Summit, where the increase in media coverage was quite noticeable (Geall 2011). Of course, this does not imply that there is a causal relation between the two. Yet, this inducement mechanism likely has an influence on several functions, such as "legitimation" or "resource mobilisation", because with increased climate change attention, a realisation grows that carbon-emitting electric power production needs to be substituted. This means that the climate change discourse has probably spurred change in Chinese energy politics. Ironically—although the inverse would be preferred—it seems climate change is what induces political change.

8. Conclusions

Today, wind energy is the world's fastest growing energy source (Jørgensen & Münster 2010), much thanks to the People's Republic of China. Within China, however, wind energy is the third fastest growing energy source, far behind coal power, and right after hydro power (CWEA 2011). Armed with a theoretical framework that explains the growth of industries, 12 semi-structured interviews, several conversations with wind industry experts and professionals, and hundreds of written documents, I set out to examine the growth of the Chinese wind turbine manufacturing industry. The main endeavour of this case study was to find out how it has flourished and what the industry dynamics look like today. In answering these questions, light was also shed on what role the Chinese government has played, and how important technology transfer has been in the process. More significantly, this study provides a better understanding of what the growth of the wind turbine industry means for a future transition from a "grey" to a "green" electricity supply in China.

Make no mistake; coal power will likely remain the dominant electric power source for a long time to come in China. History shows that large scale transformation processes may take decades to unfold, and that novel technologies often face numerous obstacles that hinder rapid diffusion (Geels et al. 2008). This is no different for renewable energy technologies in China's electricity sector, yet the pace with which things happens in China might imply that a "green" transition will come about more quickly—given that the key processes in emerging renewable energy technology systems are sustained. There are no neat solutions to complex problems, and innovation systems constitute perhaps some of the most multifaceted relationships in society. This thesis is only commencing the huge task it is to understand how an industry grows in China. Chinese circumstances are in themselves complex: as Tony Saich (2011: 4) puts it: "China is a maze of intricacies, complexities and contradictions". Low transparency, limited access to reliable data, and control of information do not facilitate the work for a student of China (Heimer & Thøgersen 2006). This study has taken on the task and gives some initial suggestions as to where to look, and what to look for.

There seems to be a general consensus that the global competitiveness of China's manufacturing industry is grounded on factors other than innovativeness (e.g. Zhang et al. 2009: xv). The discussion on China's innovation-performance is therefore all the more important. According to Edward Steinfeld (2010: 143) the stances in this discussion can be divided into "believers" and "doubters". Arguably, both stances have important points, yet, ultimately, how one *defines* innovation decides whether "innovativeness" is crucial. Perceptions that rest on innovation as being a specifically "Western" phenomenon are simplistic at best and dangerous at worst. This research project has adopted an innovation system approach—which studies innovation as resulting from socio-technical processes—in an effort to bring new perspectives on innovation in a non-Western context.

"Transition" is not an uncommon way to define the rapid changes seen in China the last three decades, with transitions ranging from demography and economy, to the role of the individual (Saich 2011). Predictions of whether the end-result of China's economic development is a "market" economy, "capitalism with Chinese characteristics", or liberalisation and democratisation are all possible (Kennedy 2005, 2011). In the innovation system literature, economic performance and innovation are viewed as two sides of the same coin. Countries that today are defined as "developed" cannot be grouped under one uniting political heading—but they are all, *ipso facto*, defined by similar economic characteristics in terms of innovation and technology development. Using technology as a point of departure, this thesis says something about how innovation can affect the trajectory of a changing China, yet, without defining this within a specific political context. Let us now turn to some of the results emerging from this thesis.

Industry growth and dynamics

In Chapters 5 and 6 the instrumental factors for the growth of Chinese industry were mapped. Progressive industry policies have been important, as have policies focussing on generating more renewable electricity, such as the Renewable Energy Law. Furthermore, other interconnected factors have been emphasised as crucial, for example mobilising resources for large wind power projects, creating legitimacy for the wind industry, nurturing the absorption of wind turbine technology, and inducing the entry of large industry conglomerates to the wind turbine manufacturing industry. Especially after the wind farm concession rounds were initiated in 2003, the growth of the industry took off. Most companies entered the industry between 2004 and 2007, and many of these were diversifications from large multi-industry corporations. The two major exceptions to this rule are Goldwind and Mingyang. Nevertheless, the conglomerates have brought their competences to the industry, and contributed substantially to the growth. Therefore, the rapid growth of the industry can partly be attributed to the velocity with which these large industry conglomerates have absorbed and developed the wind turbine technology.

When looking closer at the dynamics of the industry, we have seen that the mentioned functions are highly intertwined. Section 6.8 emphasised that the industry dynamics depend partly on the overall goals set for the industry. Taking wind turbine export as an overall goal for the industry today, we can scrutinise the dynamic pattern of the TIS. For one, "legitimation" needs to deal with interests outside of China, where the Chinese government institutions are not as penetrating. This may weaken "resource mobilisation", as this function largely has been dependent on the favourable position that large state-owned power companies have in the financial sector. As we saw in Section 6.1, research and development activities are fairly low in the Chinese industry, with weak networks between established research institutes, universities and the industry (Section 5.3). These networks have proved propitious in pioneering wind turbine industries, and could be paid more attention to in China. Weak "knowledge development and diffusion" can have repercussions for “market formation”, as we know that success in the export-markets is dependent on the comparative advantage (e.g. price) and quality of the Chinese turbines.

Furthermore, the function “entrepreneurial activity” is perceived as stunted in terms of expanding markets abroad. For one, the Chinese wind turbine TIS may learn from the solar cell TIS, where a sizeable portion of the managerial staff have been educated abroad or have substantial international experience. This is important in order to gain legitimacy abroad, and can be determined by how well managers can handle media or government relation issues, for instance. Second, management practises in China do not seem to grease the wheels for experimental activities amongst engineers and workers. Even though an occasional novelty might develop, entrepreneurial activities need to be fostered in order for China to take over the technology development wheel in the future, as was highlighted in Section 6.6. Also, in Section 5.4.2 on cultural aspects, “acidic attitudes towards the new and untried” were mentioned as hindrances to technology development.

Regarding the “development of external economies”, one issue which comes forth from this study is related to the political position and the self-sustaining practises that the wind industry can develop. One of the characteristics of established technologies is that they generate positive feedback-loops which further manifest their position in a technological regime (Unruh 2000). When institutions are forced to align with new technologies, there necessarily will be challenging encounters, where the likelihood of dwarfing the newcomer is high. It was mentioned that the National Energy Administration has increased its status within the NDRC as a result of the rapid renewable energy expansion (“running in packs”). Also, the fact that China is manufacturing such a large amount of wind turbines might in itself produce positive feedback loops—as was part of the case with Denmark. Nevertheless, as markets are increasingly sought abroad in the wind turbine industry, the momentum that wind energy has had thus far in China may be weakened, and the energy incumbents might regain, or at least retain, their institutional position. Ultimately, this may prolong the sustainability transition that takes place in China—a transition which is necessary in order to avoid dangerous climate change effects.

Lastly, the technology licensing agreements that the various Chinese wind turbine companies have, can potentially harm the dynamics of the TIS. Details of these agreements are seldom publicised, yet, many of them typically contain restrictions on design modifications or on their use outside of China. In seeking to export turbines, it seems few other options are left than for Chinese wind turbine manufacturers to independently develop their own designs—designs that do not rely too much on other turbine designs. As we have also seen, some external forces may inhibit the development of the Chinese wind turbine industry. The most urgent of these are related to characteristics within the Chinese electricity transmission management, where bottlenecks are presently perceived

Role of the government

The government—for better, for worse, for richer, for poorer—plays a key role in China. Yet, there is no consensus amongst China specialists as to how, and to what extent the government controls the system (Saich 2011). The abstruse ways in which this influence is exercised in the wind industry have been highlighted in this study. In all of the functions mentioned, the Chinese government to a varying extent has had a finger in the pie. For instance, we have seen that through the functions "legitimation" and "influence the direction of search", the government has facilitated the build-up of the wind turbine industry. Also, state owned enterprises have advantages that are conditioned on their closeness to government. What is remarkable, is that the government constantly seems to be adapting and revising its policy-approaches; be it by creating incentives for research and development on larger turbines, and thus influencing the direction of search, or in regulating the market expansion through the new "grid code". In these respects the government is facilitating wind turbine industry dynamics. Nevertheless, "the government" is not adequately addressed as one, unified entity, and local governments or state-owned enterprises are fully capable of hampering industry dynamics, irrespective of central government intentions.

The ultimate success of China's wind industry rests largely on the grace of the government. If there would be a sudden turnaround in China's renewable energy aim, one could not expect that the industry survives in competition with the cheaper coal-electricity. The Chinese government set the stage for a flourishing Chinese wind turbine industry, especially by forming a wind turbine market in combination with a domestic content policy. This engendered a keen interest for building a green industry, both in and outside the country.

International wind industry

Setting the stage is only part of the answer; the actors filling the stage are just as important for the performance. As has been stressed in this thesis, the global wind industry has had an important impact on the development of the Chinese industry in several ways. If one looks at the wind turbine industry development through a global lens, one might say that China jumps into the technology development stage which deals with technology diffusion and firm expansion, and where an innovation system shifts towards cost reduction. Such a shift is "in part achieved by exploiting economies of scale. The system must, thus, identify and facilitate the formation of mass markets." (Bergek 2002: 148). The Chinese industry is found in a "bridging phase", helping to expand markets and reduce costs both locally and globally.

In China, there is a vibrant community of foreign and domestic wind turbine manufacturers. In one way or another, wind industry organisations, components manufacturers and turbine producers share knowledge, routines, technical capabilities and personnel. It is therefore simplistic to say that technology is introduced from abroad through licensing agreements alone, and produced in China. As we saw in Section 5.3, the Chinese wind industry takes part in a global technology network, where turbine designs are either licensed, joint designed, or where companies are merged and acquisitioned. Learning takes place in clusters of domestic and foreign companies, for instance, where turbines are tested. Moreover, Chinese companies have established research and development centres abroad, which presumably enable them to tap into valuable knowledge from experienced research communities.

Edward Steinfeld (2010) claims we must speak of a new era of *globalised* innovation, where China's market is used to drive innovation-programmes in multinational companies. This goes perhaps especially for the energy sector:

> In the energy domain in particular, China today faces serious challenges across virtually every key issue: assurance of adequate supply, depletion of domestic resources, and dire pollution problems. For each of these areas, the Chinese government, broadly speaking, could have thrown up the barriers and waited—perhaps for an eternity—for an indigenous solution to arise (ibid: 173, 174).

Instead, China has attracted both foreign investments as well as research and development activities. China cannot be viewed as a passive "receiver" of technology, but as a participant, dynamic adapter and developer—in effect; an important contributor to enhancing innovation processes globally. For this reason, Steinfeld (2010: 174) claims it is very likely that "in an area like climate change remediation, technologies that prove indispensable globally will have had their origins in the Chinese market".

Steinfeld's reflections on China have important implications for transition processes: they are not only locally, but also globally determined (Coenen et al. 2012, Binz et al. 2012). In fact, we may conclude that partly because there is an international dimension to innovation, certain aspects are outside of government influence. The Chinese government may turn its influence to certain directions, but all in all, the direction chosen is affected by external trends. This recognition leads to another insight regarding inertia in transition processes: if we agree that technological regimes exist globally, and that carbon lock-in is true, then this also has implications for technology diffusion (Unruh & Carrillo-Hermosilla 2006). As argued in this thesis, since innovation happens in a socio-technical context, the diffusion of technology implies not only knowledge absorption, but also an extension of routines and practises—implying that old practises are withheld, and that renewal can take as long in developing countries as in developed. Simply put, developing countries may risk entering the same carbon-intensive path as developed countries, meaning the leapfrogging effect will be minimal (ibid.). Ironically, therefore, these routines and practices—which are crucial in learning processes (Nelson & Winter 2002)—can be helpful in building a new industry, but can create further inertia for the established technological regime. For the wind industry more specifically, this recoils upon mechanisms both internal (e.g. learning) and external (e.g. energy incumbents) to the TIS. Understanding how such international coupling affects the development of industries is a topic which deserves more scholarly attention in the future.

The "quickstep" strategy

Government measures alone cannot successfully solve China's green electricity supply bottleneck. A range of concurring measures need to be supported in order to speed up China's transition from a grey to a green electricity supply, many of which have been highlighted in this study. In a way, the Chinese wind industry can be compared to a fast growing broiler chicken. It grows fast, producing a lot of meat, but the bone-structure is underdeveloped and too weak to carry it. This is perhaps the most evident when looking at how the electricity grid cannot to a full extent absorb the rapid increase in wind power production, as we saw in Chapter 7. Many scholars agree that the Danish wind turbine industry was successful because they developed their turbines step-by-step (Wicken 2011: 76). The Danish strategy has been named *bricolage,* which connotes "resourcefulness and improvisation on the part of the involved actors" (Garud & Karnøe 2003: 278). If I had to give the Chinese approach a name, I would call it a "quickstep" strategy—a strategy which builds on existing local and global knowledge bases, and which enables the industry to step up their manufacturing capacities with unprecedented velocity. China has gone from tiptoeing gently in the early 2000s, to quick-stepping up the development whilst tapping into a global knowledge field, and finally taking the lead in terms of manufacturing and installed capacity at the turn of the decade.

We cannot predict the future, but we can learn from the past—and as we all know, history tends to repeat itself. Looking at how the Chinese wind industry has grown has helped to pinpoint the key contributory factors for the growth of this green industry. What will eventually lead to changes in an established regime, and ultimately a break from the carbon lock-in, remains to be seen. The history of industrialisation has shown that emerging technologies can disrupt an existing regime, and the rapid wind industry development may well represent the dawn of such a change in China.

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Appendices

Appendix 1: List of the formal interviews

No.	Company/ Organisation	Date	Person	Background of interviewee	Topic	Affiliation
1	Global Wind Energy Council	12.sep	Liming Qiao	China Director of the Global Wind Energy Council (GWEC)	Wind	Policy / Research
2	Hanergy (solar manufacturer and wind developer)	15.sep	Anonymous	Representative of Hanergy Holding Group Limited	Solar	Industry
3	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	26.sep	Paul Recknagel	Project Manager, Renewable Energy Programme, GIZ	Wind	Policy / Research
4	Chinese Renewable Energy Industry Association (CREIA)	29.sep	Weiquan Wang	Vice Secretary General, CREIA	Wind / Solar	Policy / Research
5	Energy Research Institute (ERI) of the National Development and Reform Commision (NDRC).	30.sep	Li Junfeng	Deputy Director General of ERI and Secretary General of CREIA	Wind / Solar	Government/ Policy
6	XEMC Windpower	27.okt	Owen Chan	Key Account Manager of XEMC Windpower	Wind	Industry
7	China Creative Wind Energy Co. Ltd.	31.okt	Weihua Liu	Sales Manager	Wind	Industry
8	Bloomberg New Energy Finance	01.nov	Bryan Davis	Wind Analyst	Wind	Policy / Research
9	Nordex China	03.nov	Vivienne Lu	Marketing Manager, Nordex China	Wind	Industry

10	Azure International	08.nov	Sebastian Meyer	China Wind Expert, Director Rearch & Advisory (Renewables) at Azure International	Wind	Policy / Research
11	NDRC, ERI	08.nov	Huang He	Research Associate on Economy and Energy Policy, Sino-Danish Renewable Energy Development Programme, Energy Research Institute of the NDRC	Renewable energy policy, Wind / Solar	Government/ Policy
12	Goldwind	14.nov	Anonymous	Technical Support Engineer, Goldwind Science and Technology Co.	Wind	Industry

Appendix 2: Interview guide (sample)

The industry refers to the wind turbine manufacturing industry in China. When interviewing a company, *the industry* was replaced by *this company,* depending on the context of each question.

1) **In general**

- Can you briefly describe *the industry's* development the last 5-10 years?
- In your opinion, what was the main contributory factor for *the industry's* success?

2) **Government institutions or industry associations**

How has state funding contributed to *the industry*'s development the last 5-10 years?

How have state policies, such as the Renewable Energy Law, affected the development?

How has government funded research and development (R&D) investment contributed to the success of *the industry*?

What measures are taken by the Chinese government to coordinate pricing, funding and R&D institutions with *the industry*?

The policy on turbine size restrictions (of 1000KW), implemented in 2009 – What have the effects been for *the industry*?

How important are associations, like the CREIA, for China's innovative capabilities?

3) **The companies**

How has *the industry* acquired and developed the technology you use?

- Why is this strategy chosen?
- Are there any downsides with this strategy?

What is the nature of the R&D conducted at *the industry*?

In your opinion, is *the industry* innovative and capable of developing competitive technology?

To what extent are workers responsible for innovation in your technology?

How freely are entrepreneurs in the firm allowed to experiment?

Do you happen to know the overall R&D intensity (% spent on R&D out of the company's total revenue)?

What are major forces that inhibit the development of *the industry*'s (technology) development?

Learning from others and sharing knowledge

How much communication happens in *the industry*, between firms, research institutions or technical expertise regarding specific knowledge / technologies?

- How important has this communication been?

How important are new entrants, or company clusters in a geographical are, to *the industry*'s learning process?

- Have the increasing amount of firms changed the political power of *the industry*?
- Has communication with foreign companies played an important role?

How decisive has easy access to financial capital been, for the development of *the industry*?

4) Research institutions

Are the connections between universities and *the industry* strong?

To what extent have research institutions contributed to *the industry*'s development?

Are enough people educated within *the industry*, to meet the demand created by the rapid growth? Has *the industry* difficulties finding qualified personnel?

5) Other factors

To what extent would you say that established interest groups with vested interests influence the development of renewable energy in China? And for *the industry* more specifically?

6) Looking ahead

What are the main challenges at the moment for further development of *the industry*?

Appendix 3: The Information and Consent Form

Beijing, [month, day], 2011

Information and Consent Form

Research project: China's Renewable Energy Development

Interviewer: Marius Korsnes, Centre for Development and the Environment, University of Oslo

Interviewee: …

Purpose of the study: The general purpose of this study is to improve our understanding of processes involved in the formation and growth of China's renewable energy industry, using the wind turbine- and solar cell manufacturing industry as examples. This involves analysing the acquisition and development of technology in the different firms in China, comparing and contrasting the experience in the wind turbine- and solar cell manufacturing industry. To gather information for this analysis, semi-structured interviews will be conducted with people from different segments of the industry in China, ranging from the companies themselves, to experts, researchers and government officials.

Expected duration of research: Will be finalised in June 2012.

Usage of information: The information gathered will be used for the analysis undertaken to complete this specific research project. Upon completion, the study will be published internally at the University of Oslo, possibly also externally, if the involved parties agree. The final product, in shape of a M.Phil. thesis, will be publicly available.

Participation: The interviewee is not in any way obliged to take part in this study, and may decline to participate. Also, the interviewee may withdraw from the study at any time. If the interviewee decides to withdraw, the information provided will be removed from the collected data, and will not be used in the analysis. If the interviewee wishes, he or she can remain anonymous. The interviewer will take all precautions to assure the privacy and confidentiality of the interviewee. The interviewee can ask questions about the research at any time, and may receive information about the research results and conclusions if desired. If the interviewer chooses to use any quotes from the interview, the interviewee will be consulted in advance, and it will only be used if the interviewee agrees.

By signing this document, the interviewer confirms that he will commit to the description above.

By signing this document, the interviewee confirms that he or she is familiar with the above information, and agrees to participate in the research project.

______________________________ Interviewer

______________________________ Interviewee