Eco-innovation Dynamics at a Large State-Owned Wind Turbine Manufacture in China

Learning and Stakeholder Relations

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Abstract

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Key words

Jelcodes:M10,M00

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Key words eco-innovation dynamics, learning, stakeholder relations, triple helix, state-owned enterprise, China

1. Introduction

"Nearly a third of the world's energy consumption and 36% of carbon dioxide (CO_2) emissions are attributable to *manufacturing industries... Overall, industry's use of energy has grown by 61% between 1971 and 2004, albeit with rapidly growing energy demand in developing countries and stagnating energy demand in OECD countries. "* (International Energy Agency, 2007: 19).

Under the increasing concerns toward global warming induced by mass CO_2 emission, firms, in special the ones in manufacturing industries, are expected to be the important environmentally friendly innovators instead of polluters (Andersen,2008a). How can firms integrate environmental concerns into their innovation and business strategies while consolidating their core-competences proactively? It can be answered from various perspectives, such as policy and regulation push/pull, market pull or technology push (Cleff&Rennings,1999;Rennings,2000). However, studies from these perspectives are somehow deviated from the mainstream innovation study and it has led to a neglect of analyzing the industrial dynamics in the greening of industry (Andersen,2008a;Marchi,2010).

This paper discloses how eco-innovation activities were developed in a large state-owned wind turbine manufacture in China in the past 7 years under sub research questions of:

●What roles did external stakeholders play in its developing wind power business?

●What was the learning process in case company's developing eco-innovation activities?

Taking a multi-perspective of learning, triple helix and path dependence into consideration, we propose an analytical framework of eco-innovation dynamics focusing on the internal learning process, external stakeholder relations and how intangible resource of experience and knowledge as well as industry environment affect firms' innovation path. In this paper we choose to focus on the former two aspects. This paper has tri-fold contributions. Firstly, we develop an analytical framework integrating multi-perspective of learning, stakeholder relations and path dependence. It enables us to catch a relatively comprehensive understanding of eco-innovation dynamics. Secondly, this is an empirical study of a large, heavy power equipment manufacture, which is different from the existing innovation studies mainly focusing on ICT firms. Thirdly, it is an empirical study of eco-innovation practices in China. It opens us a window to know green transition and eco-innovation practices in an emerging economy entities while 'the field of eco-innovation studies is dominated be contributions from especially USA and Europe.' (Kemp&Oltra,2011:252)

The remainder of this paper is structured as follows. In section 2, we present an understanding and analytical framework of eco-innovation dynamics at firm level. In section 3, 4, we explain why the state-owned wind turbine manufacture is selected as case company (outset) and how this study is to be carried out (methodology). Then we carry out the case study by presenting findings in section 5. Finally, it comes to concluding remarks.

2. Understanding of Eco-innovation Dynamics and Analytical Framework

As the definition of eco-innovation depends on context and perspective, it is difficult to give a general delimitation of the concept (Carrillo-Hermosilla et al, 2010). Instead, we present an understanding of eco-innovation dynamics from an innovative firm' standpoint in terms of intents, resources, eco-innovation activities (types, what was done and how was it done), actors/stakeholders involved and the industry environment in which firm developed eco-innovation activities. Based on this understanding, we propose an analytical framework focusing on stakeholder relations, learning and path dependence in eco-innovation dynamics.

2.1. Understanding of Eco-innovation Dynamics

(1)Intents of Eco-innovation

Focusing on the intents of eco-innovation enables us to tell why eco-innovations are developed in specific case company (motivations) at two dimensions. The first dimension is about the direction of innovation and the content of progress (Rennings,2000). The majority of existing studies on eco-innovation stress the environmental benefits generated from eco-innovation while economic and social benefits are implicit except Fussler & James (1996), Andersen (2008a), Huppes et al. (2008). They have an explicit emphasis on economic value creation in their view on eco-innovation. The second dimension is about the innovators' intents when they develop eco-innovation. With regard to this topic, there is still a debate on whether 'environmentally beneficial normal innovations' (following Kemp &Foxon,2007:4) are to be considered as eco-innovations or not. In UNU-MERIT serial working papers, Beise&Rennings(2005), Carrillo-Hermosilla et al(2010) and Machiba(2010), both motivated and unintentional innovations offering environmental benefits are considered as eco-innovations, due to difficulties to distinguish environmental motivation from other motivations in the evolutionary process of innovation. In contrast, the motivation of innovators is emphasized explicitly in Europa INNOVA Thematic Workshop (2006), European Parliament and Council (2006), stressing the intended environmental benefits.

In this paper, we underline eco-innovation as a carrier of both economic and environmental benefits, as economic benefits are the momentum of industry to invest in innovation. Furthermore, we exclude the 'environmentally beneficial normal innovations' from the concept of eco-innovation but focus on the intended innovations toward environmental benefits following Europa INNOVA Thematic Workshop (2006), European Parliament and Council (2006). Policies and regulations are implemented intentionally to spur the industries on the environmentally friendly track. Specific studies on the emerging practices of intended eco-innovations would not only provide experiences of how a company can work systematically to foster eco-innovation, but also contribute to the future policy making for eco-innovation. Conscious decisions and an envisioned greening strategy are vital to innovative firms committing to sustainability.

(2) Resources

Traditionally resources are focused to explain why some firms outperform in resource-based view studies from perspectives of strategy management, neo-classical microeconomics and evolutionary economics (Barney, 2001), as resources constitute of the essentials of firms competitive advantage building (Barney,1991). A firm's resources can be categorized into two groups: tangible resources of plant, geographic location as well as its access to raw materials and intangible resources of human capital, organizational capital, technological capital and relational capital (Barney,1991;Ferna´ndez et al.,2000).

Given firms rely more and more heavily on the intangible experience and knowledge to build competitive advantages in knowledge-based economy (Cohen&Levinthal,1990;Zahra&George,2002), we choose to dismiss the tangible resources but underscore firms previous experiences and knowledge of developing new products, procedures, organizational management and marketing strategy as essentials and internal factors affecting firms innovation path focusing on how these experiences and knowledge influenced the on-going innovation activities.

(3)Eco-innovation Activities

●What Was Done? –Types of Eco-innovation Activities

Several typologies of eco-innovation are proposed due to different perspectives and purposes. For example, Andersen (2008a,2008b) categorizes eco-innovation into 5 groups of 'Add-on eco-innovations', 'Integrated eco-innovations', 'Alternative product eco-innovations', 'Macro-organizational eco-innovations' and 'General purpose eco-innovations' to stress the role different types of innovation play in the economic organization of green knowledge. Combining Schumpeter's classification of innovation (product, production & source of supply) and innovation modes of component-radical, component-incremental, architectural-radical, architectural-incremental, Hellström (2006) presents another understanding of eco-innovation types to stress radical–architectural eco-innovations.

In this paper, we neither intend to distinguish the eco-innovation activities in terms of the role they play in the market nor try to characterize each innovation in terms of radical-incremental and architectural-component. We would rather generalize innovations into different groups following OECD(2005), where four types of eco-innovation are distinguished:

◇product innovation of material product and services

◇process innovation of production procedures and systems as well as process management and delivery

◇organizational innovation in business practices, workplace

◇market innovation in product design, packaging and new methods of pricing

●How Was It Done? - Learning and External Collaboration

Focusing on learning enables us to disclose the internal dynamic of new knowledge creation. Jensen et al.(2007) connects learning to two modes of innovation in terms of knowledge creation: Do-Use-Interact mode (DUI) and Science-Technology-Innovation mode (STI). In DUI mode, innovation is the process that employees learn by doing, experiencing, communicating and interacting with other colleagues, customers and other external stakeholders. It is a dynamic process that employees and organizations learn to integrate knowledge of 'know-how' and 'know-who' and then form collective meaning structures. STI mode emphasizes that knowledge is created by professional research institutions under large firms. It is a process researchers or scientists integrate knowledge of 'know-why' and 'know-how'. Learning in STI innovation mode is organized formally and characterized by exchanges of codified knowledge while the learning in DUI innovation mode is generally organized informally and characterized by exchanges of tacit knowledge. In this paper, we understand firms' developing eco-innovation as a process of learning by DUI mode or STI mode at both individual and collective level.

Besides learning perspective, in mainstream innovation study, multi-stakeholder engagement and collaboration across organizational boundaries are underscored. National system of innovation, regional system of innovation and triple helix of innovation are the examples (see Lundvall, 1992; Cooke et al.,1998; Leydesdorff&Etzkowitz,1996). Collaboration network of multi-stakeholder engagement enables firms to pool or exchange resources, create novel ideas and develop new skills jointly as well as expose firms to richer experiences, different competencies and added opportunities (Powell&Grodal,2005). Collaboration with other stakeholders is especially important for firms in industry with rapid development and diffusion of science and technology, as they contribute to a turbulent and unpredictable industry environment. In this paper, we take triple helix framework of innovation as a departure point of explaining the multi-stakeholder relations in eco-innovation dynamics at firm level. The metaphor of triple helix is formulated as a methodological tool that generalizes innovation dynamics to a non-linear interactive and reflective process among stakeholders (Leydesdorff&Etzkowitz,1996). Different from national system of innovation and regional system of innovation, which tries to take a real-life picture of certain innovation process avoiding any generalization, triple helix generalizes the non-linear dynamics of innovation to university-industry-government interactions at diverse levels of national ,regional, industrial and firm (Etzkowitz & Leydesdorff, 2000).

(4) Actors/Stakeholders of Eco-innovation

Focusing on actors/stakeholders has twofold contributions. It enables us to disclose by whom eco-innovation Is developed as well as the complex stakeholder relations in firms developing eco-innovation. An explicit illustration of the actors involved in eco-innovation can be found in Rennings(2000) and Beise&Rennings(2005). According to these publications, eco-innovations can be developed by firms, politicians, unions, associations, churches and private households. Under a general definition of eco-innovation, this understanding stresses the variety of actors involved in eco-innovation. In this paper, we take a firm's perspective and consider other actors as its stakeholders covering the product chain, NGOs/local communities, governments and research institutions. They inter-depend for information sharing, knowledge acquiring, and business developing by co-R&D or strategic alliance.

Eco-innovation highlights environmental protection as a common benefit. Concerns for the commons imply an explicit focus on civil society/NGOs/local community. When there are market failures or government failures resulting in environmental damages, a party representing public interests and a long-term perspective is particularly in need. NGOs & local communities are the non-profit entities representing public and particular groups' interest towards decision-makers, channeling concerns, viewpoints and values within political process (Platform of European Social NGOs,2001). 'In cases where important services, representation, and/or social cohesion are lacking, NGOs play critical roles in governance and value creation for social ends' (Teegen et al.,2004:.467). From this perspective, we add NGOs/local community besides university, industry and government. NGOs/local communities are not stressed in the triple helix framework, as three spheres are sufficiently complex to accommodate various forms of chaotic behavior toward business value creation and economy growth (Leydesdorff&Etzkowitz,1996).

(5) Industry Environment

Innovation process is contingent (Pavitt,2005). Focusing on industry environment enables us to further explain the path dependency embedded in firm's eco-innovation activities besides resource-based perspective, as industry environment of an organization is one of the distinct intertwined factors contributing to the critical contingencies that an organization faces (Hambrick,1981). Concerning the elements comprising industry environment and how to analyze it, Lawrence &Lorsch (1967) takes both internal and external environment of an organization into consideration and divide it into sub-environments of science, market and technical-economic. Michael Porter's Five Forces Model provides us an analytical framework of industry environment constituting competitors, suppliers, potential entrants, substitutes and customers (Porter,1980). Duncan(1972) develops a similar set of components to analyze the relationships between industry environment and management of uncertainty including customer, supplier, competitor, sociopolitical and technological dimensions. Based on Duncan(1972), Gordon(1991) simplifies the components of industry environment into competitive environment, customer requirements and societal expectations. In these literatures, they share commons on underlining market actors (customers, suppliers and competitors).

In this paper, we do not pre-assume innovative firm and its competitors are only competitive relations as Porter(1980) and we focus on the market actors to disclose the market demand. To tackle the challenges of global climate change and other environmental problems, it is not sufficient to develop cleaner technology, as the problems emerged are not only technological problems but also problems in relations to the social and institutional contexts. Life styles, purchasing and consumption behaviors, public's perceptions and attitudes toward environmental problems, industrial ecology, which are under the concept of social innovation, all matter (Rennings,2000;Remmen,2001). Thereby, We tend to follow Dunan(1972) and Gordon(1991) taking both sociopolitical and technological factors into consideration and further focus on policies& regulations, industry standard as well as technical viability and economic feasibility, in which policies& regulations together with industry standard constitute the important indicators of diverse sociopolitical factors while technical viability and economic feasibility is to disclose technical and economic base (Etzkowitz,1984).

2.2. Analytical Framework

Based on elaborations above, we propose an analytical framework of eco-innovation dynamics covering intents, resources, actors /stakeholders and activities. Firms' intents toward green benefits are to be affected by its previous experiences and knowledge of business development and the industry environment at a strategic level. Industry environment comes together with resources to disclose the path dependence in eco-innovation externally and internally. Actors/stakeholders are mediators bridging resources, intents and innovation activities, by whom eco-innovations are developed. They are supposed to be part of eco-innovation activities. But to stress their role of actors and mediators between intents, resources and activities, we separate 'Actors/Stakeholders' from 'Activities' in this framework.

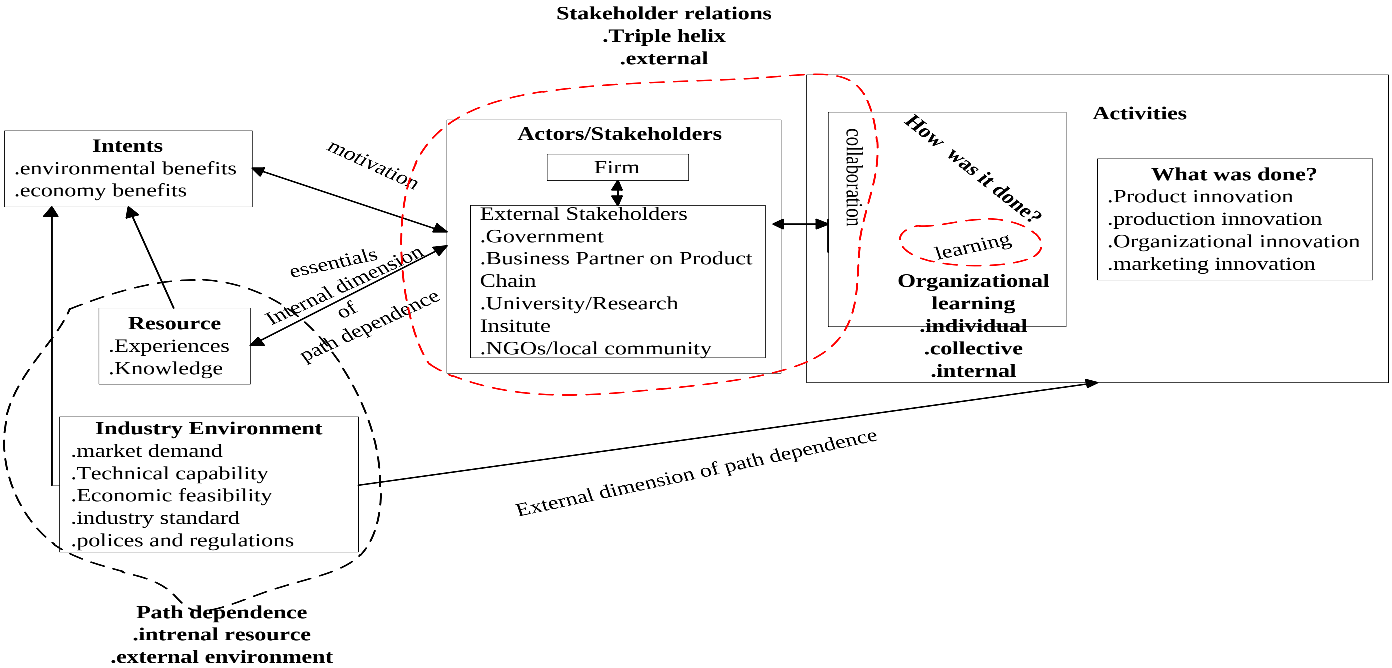


Fig.1 Analytical framework of eco-innovation dynamics at firm level

In the following case study, this framework is further divided into three parts: analysis of stakeholder relations from triple helix perspective, covering 'Actors/Stakeholders' and 'How was it done? -Collaborations', analysis of internal learning process at individual and collective level and the path dependence in terms of resource and industry environment (see the three circles with dotted line in fig.1). Given the article length limitation, in this paper we choose to focus on learning and stakeholders (the dotted circles in red). The intents and 'what was done' are presented together in the following case study.

3. Outset and Methodology

In recent years, Chinese wind power industry experienced an explosion and surpassed US to be NO.1 in terms of both cumulative capacity and new installed capacity (GWEC, 2010,2011). Behind this fact, it is the rapid development of Chinese domestic wind turbine manufactures. Sinovel, Goldwind and Dong Fang Electric (DEC for short in the following) shared more than half of the China wind turbine manufacturing market (CWEA,2010,2011). Among these three companies, DEC is the only one with pure state-owned background. It is also the only one that has a green transition on products. Under the value and vision of 'Green Power Benefits Human Beings', DEC turned to clean energy business from thermal turbine manufacturing with heavy energy consumption and intensive CO_2 emission intentionally (see table 2). Thereby we select DEC as the case. It is expected to shed some lights on understanding of eco-innovation dynamics at firm level as well as be a window for the westerners to know how Chinese manufactures are turning green.

This case study was conducted in four stages during Spring 2010 and Autumn,2011. We first started an overview of the facts at DEC in Spring 2010. The data was based on an intensive study of 3 Ph.D thesis on DEC's innovation practices (Lin,2008; Chen,2009; Liu,2010), DEC's online electronic newspaper and news, annual reports of wind power industry from China Wind Energy Association and Global Wind Energy Commission as well as other information gathered from its website and other industrial websites. Multi approaches to gathering data reduced our impartial understanding of the facts (Yin, 1994). This is the first stage. Based on this and following the proposed analytical framework, a set of semi-structured interview guideline was figured out in the second stage during November, 2010 and February, 2011. In the third stage, we carried out the field investigation during March,2011. Before the formal face to face interview, the first author had an informal discussion with the top management at DEC. Through this personal conversation, DEC was confirmed as a suitable case company and information collected from its top management enabled us to catch a more actual and comprehensive picture of DEC. After this personal conversation and before the formal face to face interview, the first author visited DEC. Informal face to face interviews with the secretary of the abovementioned top management at DEC and the vice director of Safety and Environment Management Mr. ZHU were carried out during this field visit. This informal interview and on-site observation provided a better understanding of the possible difficulties and available data during the upcoming formal face to face interviews. The interview guides were revised again after this short field visit and finally we carried out the formal interviews. Finally, 14 individuals were interviewed. Table 1 outlines the specific interviewees and the purpose. The fourth stage is transcription and data analysis. All were done strictly following Yin (1994).

Table 1 Information of Interviewees

Interviewees -Department	**Interviewees -Administrative Positions**	**Interviewees -( ) person(s)**	**Purpose**
Wind Power Division Top Management	vice-president of DEC and general manager of DEC Wind Power Division	1	.get a whole picture of DEC's wind power business: background , history, internal linkages among different functional departments, organizational management, external collaborations, innovation strategy in the upcoming 5 years, barriers and challenges in the past 7 years.
Wind Power Division R&D Center	.vice chief-engineer .administrative director .R&D engineers	1 1 7	.get a whole picture of its product innovation, procedure innovation and find out the very examples ; .dig the external collaborations and organizational learning within those very examples.

Department of Safety and Environment	.vice administrative director .chief engineer .functional group leader	1 1 1	.get a whole picture of its environmental work .find out how its environmental works was organized and the outcomes, barriers, challenges and strategy for future
Department of Energy	.administrative director	1	.get a whole picture of its energy planning and management and find out the differences and linkages between it and department of Safety and Environment.

Source: authors' own summary

4. The DEC Group

DEC is a large state-owned thermal turbine manufacture in China. It was one of the 39 ultra-large key enterprises listed by central government. It was set up in 1966 with main business on thermal turbine R&D and manufacturing. It is located at De'yang-a small city in Sichuan Province in the southwest of China. Its products are generally sold to China domestic market and other less developed countries in Asia, such as Indonesia, India, Iran, Bangladesh, Malaysia and so on.

With the changing global environmental agenda, its products turned from thermal turbine via nuclear turbine to wind turbine, solar power panel as well as seawater desalination since 2004. In 7 years, its wind power business has developed into a large division with 4 general assembly bases, 5 regional service centers and 6 subsidiaries all over China. Concerning its green transition, Mr. REN-Vice president of DEC group and general manager of Wind Power Division at DEC, explained:

"…our traditional products- thermal turbines are generally characterized by heavy consumption of coal and heavy pollution. We developed business on wind power, solar power in recent years to provide human beings green *energy."*

Table 2 is a brief overview of the facts at DEC in the past over 4 decades. We can see, imported technology used to be considerably important to DEC. It generally followed an 'Import-Imitate-Assimilate-Renovate-Innovate' innovation path (Chen,2009: 89).

Table 2 Facts of DEC

Properties	**Details**
Headquarters	De'yang, Sichuan Province, China
Property rights	State-Owned
No. of employees	12,000-13,000
Type of Industry	Large power equipment manufacturing
Main business	Product R&D, production and sales of thermal turbine, nuclear steam turbine, solar power panel, seawater desalination, wind turbine (blades, final assembly, wind field service)

Key Events	.1966, set up; .1974, produced the first set of 50MW high pressure thermal steam turbine; .1976, produced the first set of 200MW super high pressure thermal steam turbine .1990, started to cooperate with Alstom on co-R&D and production of 900MW nuclear steam turbine; .2001, bought the improved 600MW sub-critical steam turbine tech from Hitachi; .2002, cooperated with Alstom on 1080MW nuclear steam turbine on Ling'ao nuclear power plant; .2003, bought the improved 600MW super-critical steam turbine tech from Hitachi; .2004, set up wind power project team; Bought wind power tech from Repower Germany; .2005, the first 7 sets of 1.5MW wind turbine were sold; bought 1000MW super supper-critical steam turbine tech from Hitachi; bought F-gas steam turbine from MHI (Mitsubishi Heavy Industries); .2006, entered into solar power industry by merging with E'mei semiconductor Research Institute;33 sets of l MW wind turbine were put into operation in inner Mongolia; set up Wind power business division; began to implement EMS ISO14001 .2007, co-set up ZhongHe Seawater Desalination Engineering Co.Ltd with another two companies and one public research institution; .2009, set up Tianjin production base; set up DEC (Tongliao) Wind Power Technology Co.ltd .2010, pitch-controlled variable-speed double-fed constant frequency 2MW wind power generator set were put into market; set up Jiuquan production base

Source: authors' summary

5. Findings

As stressed in section 2, this section would focus on the internal learning process and external stakeholder relations in Wind Power Division at DEC. Before elaborations on these two focuses, it is a brief introduction of what was done in terms of eco-innovation types.

5.1. Eco-innovation Activities - What Was Done?

All the four types of eco-innovation activities defined following OECD (2005) are identified in Wind Power Division at DEC. Following its innovation path in thermal turbine R&D and manufacturing, DEC started its wind power business from importing 1.5MW wind turbine technology from Repower at a heavy cost. Based on imitation and assimilation, DEC produced the first set of renovated 1.5MW wind turbine which was able to run under -30℃as well as independent innovation of 1 MW, 2MW wind turbines fitting to the diverse landforms and climate zones in China. Blade, spindle, wheel hub, yaw system, hydraulic system (including brake system), general assembly, storage of the spare parts are produced and organized at DEC. These renovated and indigenous innovated wind turbines brought DEC another new business value creation arena. In 2008, they created 7.2 billion ￥- 50% of DEC's gross output value.[1]

1 Source: http://www.wp-forum.cn/ArticleShow.asp?nid=6D0C1D6F-160D-4C2C-8E6A-C973E13DC84F

Concerning the environmental intents, Mr. DENG- vice director of R&D center in DEC Wind Power Division[2], explained how they integrated environmental concerns into product development:

"To R&D center, it (Green Power Benefits Human Beings) means improvement of new products' energy consumption efficie*ncy, for both wind power and thermal power (product development)…for example, in the R&D of wind turbine,* we optimized blades, gear-boxes. We pushed motor manufactures to think of *motors'* energy efficiency. We check every possible parts and components and *procedure to improve our products' energy efficiency and reduce* consumption of energy and materials.*"*

Table 3 Innovation Activities at DEC Wind Power Division

Types of Eco-innovation Activity	**Eco-innovation activities at DEC**	**Descriptions**
Product Innovation	.1MW wind turbine .2MWwind turbine	.developed by DEC independently; .developed into several series that operate in diverse landforms and climate zones in China: low-temperature area, continental plateau area, typhoon area, offshore and mesolittoral zone.
	.2.5MW .3MW .5.5MW 1.5MW	.co-developed by DEC and Windtec .co-developed by DEC and Windtec .imported from Repower, renovated its blade materials and production procedure
Production Innovation	.assembly procedure	.a completely new assembly procedure; .innovation on assembly procedure made DEC able to assemble hundreds sets in month.
	.Wind Power Division	Wind Power Division is a highly-independent business unit at DEC while it also has close connections with resin division, material R&D center.
Organizational Innovation	.organizational structure	It has developed from a project team with less than 20 team members to a business division covering R&D centre, service centre, marketing department, strategy and planning department, quality management department, sub production and service base located throughout China.
Marketing Innovation	.quick response procedure to users	24-hour quick response procedure to users involved almost all of the departments and centers in.

Source: authors' own summary

5.2. Learning: How was it done?

Focusing on the learning process in its product development and production innovation, we find the learning process was organized mainly in a Do-Use-Interact (DUI) way. Followings are two examples of daily R&D activities and assembly procedure innovation.

(1)Learning in Daily R&D Activities

In Wind Power Division at DEC, the learning in its daily R&D activities was organized through diverse approaches in both formal and informal forms (see table 4).

Table 4 Learning Approaches in Daily R&D Activities

2 Mr. DENG was one of the pioneers starting up wind power business at DEC and he has worked at DEC for 14years. Before he came to Wind Power Division, he was with considerable experiences of thermal turbine R&D.

Collectively	Individually
.'experienced engineers mentor fresher'	.books
. informal on-spot communication and discussion with colleagues	. on-line BBS and QQ group
. formal/informal group meeting with specific technological focus	.industry conferences/forums
. internal and external training	.daily work logs
.work at partner companies located abroad	.summary and paper writing on work and technological reflections

●Collective Learning

All of its R&D engineers, engineers-in chief and administrative managers are located in a big office with several inter-dependent functional R&D groups while there are not distinctive borderlines between different groups. This office location provides its R&D engineers sufficient convenience to communicate with each other as well as experienced engineer taking on fresher. R&D engineer Mr. GAO said:

*"*Our office is not like others that different functional departments are not divided separately and we interact with each other conveniently. We can easily see each other when we stand up. When we have questions we go to our colleagues at once and figure it out on-spot.*"*

R&D engineer Mr. LIAO explained the benefits of 'experienced engineer mentoring fresher' as:

"Everybody is pleased to share his knowledge, as you can never get through the work by one's own. If you share your experiences with the fresher, they can probably be qualified in a shorter time than through trials and errors by themselves.*"*

He further supplemented:

"To me, informal communication with other colleagues is very popular. It is better that you figure out the problems/ questions as soon as possible…If colleagues are more experienced, they can suggest you a solution rapidly."

Formal and informal group meeting is a popular approach of learning in DEC wind power R&D center. Generally it is organized among colleagues within same R&D groups. The contents of group meetings can be discussing on specific technological issues or problems, sharing specific R&D experiences or summary of reflections. There used to be technological seminars every Friday which was open to the whole R&D center. There would be experienced engineers sharing basic knowledge of industry design standards, common problems in specific design, possible solutions and so on. R&D engineer Mr. LIAO understood this collective interpretation approach as:

*"Sharing my related (R&D) experiences with other colleagues makes I mys*elf further improved. Before sharing experiences you are supposed to know-how and then you should be able to present it and make it understood. By this knowledge diffusion process, I have intensive communications with my colleagues.*"*

●Individual Learning

Individually, R&D engineers themselves collected information from books, website and local library as well as conference and on-line peer communication platforms such as BBS and QQ group. Each engineer has a fund of several-hundred￥ to purchase books concerning wind turbine R&D. The amount varied according to DEC's annual business performance. Besides, DEC had local libraries in each division. In Wind Power Division, R&D engineer can easily get access to the previous project R&D archives in its local library. R&D engineer Mr GAO said:

"These archives provide us the possibility of learning from previous experiences and knowledge on some specific problems.*"*

Wind power industry conferences/forums, online BBS and QQ group provide DEC the platform of updating industrial policies, regulations, new technologies and even some of rivals' information. This contributes to DEC's more accurate strategy making on innovation and business development. Its vice director of R&D center in DEC Wind Power Division Mr. DENG explained:

"From the standpoint of company, we rarely talked with them (rivals). But from a personal perspective, we do. As we probably know somebody from rival companies in industry conference or forum. When we are familiar with each other, we would ask each other what kind of wind turbines they are developing or what kind of system is better. However, we would not refer to the detailed technology information. This kind of information only be useful to macro strategy making. *"*

Besides, individual learning was achieved also by writing daily work logs, irregular summary and writing technological papers. Each R&D engineers at DEC has a logbook to write down the key notes of daily work and reflections. Besides this, some R&D groups required the engineers to submit summaries once a month. Moreover, every year, Dong Qi Ke Yuan-an internal publication with specific focus on technologies would call for papers and organize competition among different divisions. R&D engineers are encouraged and required to submit papers. These papers on be academic ones, reflections and experience sharing. The only requirement is they should be concerning technology development.

(2)Learning in Assembly Procedure Innovation

As mentioned above, DEC started its wind turbine business from importing 1.5MW wind turbine technology from Repower. At the very beginning of assembling wind turbines, DEC has little knowledge on mass production and it applied the thermal turbine assembly procedure to wind turbine assembling tentatively. With the exploding increased orders of wind turbine[3], DEC found problems in its assembling procedure. First, the assembly procedure could not be applied any more as it took too much time to assemble hundreds of sets in one year. Second, there were differences on resource arrangement and management. About these two problems, Vice director of R&D center DENG Liang explained:

*"We manufacture*d thermal turbines in the past 40 years. Usually one set of thermal turbine would take around 1year.But now the wind turbine orders are generally with dozens of sets and they are required ready within 1-2

[3] And Within year of 2006, DEC produced its first set of 1.5MW wind turbine and it got order of 400 sets for 2007.

months. The available time is extremely short. It is not feasible to follow the old assembly procedure which is applied *to thermal turbine assembling any longer…* The foreign companies probably have well-appointed information system, such as ERP. But DEC has not made it, at least in Wind Power Division. All resource management and planning are dependent on manual approaches. Moreover, the parts and components supplied in China are also different from the ones from abroad on specifications and size.*"*

With these problems in mind, DEC employees began to think of assembling wind turbine in the way of car assembling. They disassembled the procedure into 3 parts: pedestal body, kinematical chain and impeller-hub. Following this initiative, numerous experiments, frequent and intensive communication among different departments were organized. Mr. DENG further explained:

"We just try to see how to assemble the parts and components is fastest and going well …Given the assembly procedure is highly complex and difficult to coordinate, take manufacturing shop for example, R&D center provides supportive technological platform on the one hand, on the other hand, we sit together and discuss how to make it best for a mass production with department of material purchasing, warehouse, planning, production *shop assembling."*

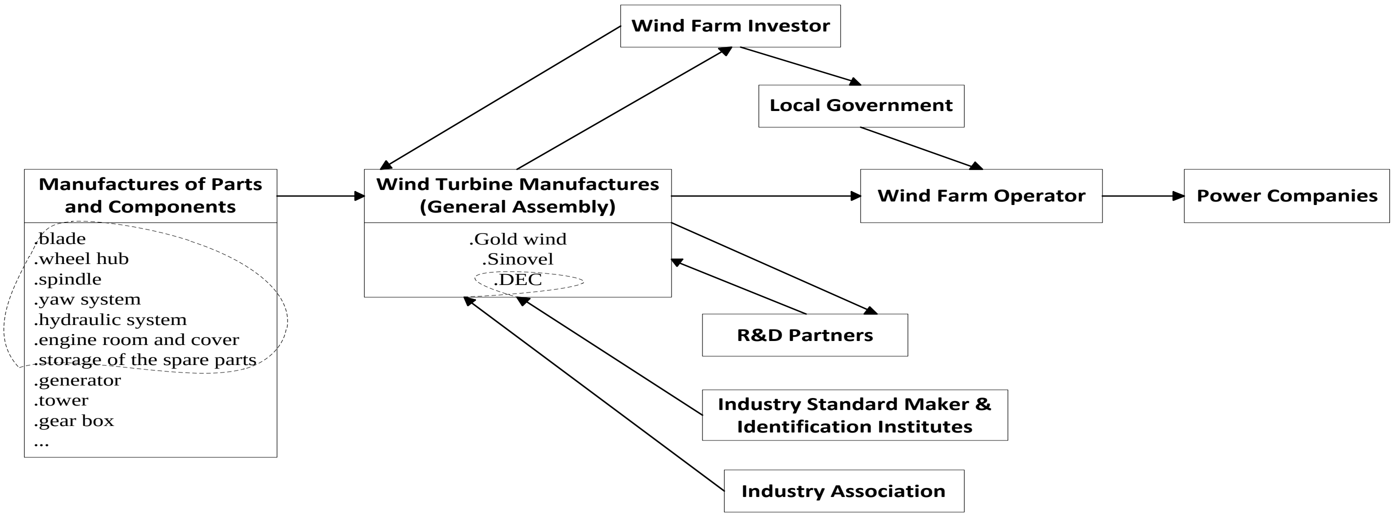
By experiments and communication, learning took place collectively. During this process codified knowledge was created and kept in mind. Mr. DENG said:

"After rounds of tests and communications, we know well about which parts and components would affect the assembling procedure and then we would store more in warehouse. We know when and by whom to order the components as well as how to guarantee the procedure implemented smoothly. This is the common experience and *understanding shared by all of the departments involved… It is kept in mind but without written documents"*

The assembly procedure innovation was a problem-based learning process and it was achieved exactly by employees' learning by doing, learning by using and learning by interacting. By this procedure innovation, DEC has improved its assembling capacity of 10 sets/ month to hundreds sets/ month. It contributes to DEC's wind turbine expansion to the top 3 manufacture in China greatly, particularly during 2006-2008, when it was still a seller's market in China wind turbine market.

5.3. Stakeholder relations: How was it done?

Fig.2 presents the wind power product chain in China and the position of DEC and the related stakeholders.



As pointed out above, DEC produces its own blade, wheel hub, spindle, yaw system and hydraulic system while motor, tower, gear box and other small parts and components are from suppliers. This makes DEC relatively independent and competitive with lower manufacturing cost. Given this, we choose to neglect suppliers in the following elaborations. Following the metaphor of triple helix, we categorize DEC Wind Power Division's external stakeholders into 4 groups: government, business partners on product chain, university/public research institute and NGOs.

(1)Government

●Central Government

Ministry of Finance (MOF), Ministry of Science and Technology (MOST), National Development and Reform Commission (NDRC) and its subordinate body National Energy Administration(NEA), Ministry of Industry and Information Technology(MIIT), State Oceanic Administration(SOA) are the main central governmental authorities that influence the development of wind power industry at strategic level and in an' up-down+ command-order' way. NDRC and NEA are in charge of renewable energy policy, regulation and strategy making while MOF acts as a partner concerning subsidies. MOST generally contributeS to wind power industry by providing research project foundation for innovative firms.

Since Sept. 2003, NDRC, NEA, MOF and SOA have jointly issued series of laws/directives/plans/regulations concerning the development of wind power (see table 5). These directives and regulations are characterized by domestic preferences and top priority of developing renewable energy, which created a vast market niche for Chinese domestic power generating equipment manufactures and spurred a veritable explosion of new investment in wind power industry. In 2007, there were 25 estimated wind turbine manufactures while another 40-50 manufactures were planning to add facilities; by 2009, the number of wind turbine manufactures had grown to 100 plus(Howell et al.,2010).

DEC is one of the first movers entering into wind power industry in2004. Under these directives, incentives, DEC experienced a rapid growth during 2006-2008, when it was still a seller's market. To take care of the overwhelming orders, a mixed innovation strategy of combining independent R&D and co-R&D with Windtec was employed. Although DEC paid a lot for importing technologies from Repower and cooperating with Windtec, this strategy made it grow to top 3 wind turbine manufacture with 12.9% wind power market share in China in 2009(CWEA,2010), 5 years after its establishment. Since 2009 China government enacted some specific directives and standards to optimize wind power industry structure by encouraging several large wind turbine manufactures to grown bigger and stronger while enforcing stricter market admittance for small manufactures. From this point, as a large state-owned manufacture, DEC is expected to benefit more from these directives and regulations in the future.

●Local Government

'Local' here is mainly referred to where wind farms are located. In China, wind farm project is decided by government: for projects larger than 50MW, the NDRC is responsible for decision-making while local government can approve projects smaller than 50MW without approval from NDRC. Besides this administrative approval right, similar to central government, local government has the administrative right of enacting local wind turbine purchasing requirements, standards and various taxes for wind farm operators. Under this background, local government became a marked external stakeholder to wind turbine manufactures since 2009.

On the one hand, after a surge, central government began to reflect the problems emerged in 2009 and slowed down the development of wind power industry in China. This resulted in an important turn of suppliers and buyers from a seller's market to a buyer's market, which further led to an ill industry environment: flooded with hostile competitions by price war and blind expansion of wind turbine power. DEC was also involved. One interviewee complained[4]:

*"We did develop 1MW wind turbines. It would fit the mountainous region*s perfectly. But local governments and power companies think it is too low-powered, as it (1MW wind turbine) does not make sense to their administration *achievements. Now we have to send it to archives even if we have not sold it to market!"*

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[4] According to the interviewee's requirement, we keep this citation anonymously.

On the other hand, after several years' rapid development, local government began to think of its cost (land, resources, supporting infrastructure) and yield (compensation for land occupation, soil and water conservation fee, compensation for forestry). To increase income, these compensation and fees were increased greatly. Moreover, more and more administrative fee in relation or not such as Lightning Protection and Checking fee, wind resource taxes are imposed on investors and wind farm operators. This indirectly affects wind turbine manufactures such as DEC.

Table 5 Laws/Directives/Plans/Regulations Concerning Wind Power Industry

Time	Governmental Authorities	Laws/Directives/ Plans/Regulations	Key Points
Sept,2003	NDRC	Call for Bids on Wind Power Concession Project (1)	wind turbine must be assembled in China; .domestically-made rate is ≥50%
Sept,2004	NDRC	Call for Bids on Wind Power Concession Project (2)	wind turbine must be assembled in China; domestically-made rate is ≥70%
Feb,2005	Standing Committee of the NPC	Renewable Energy Law	full purchase of standard renewable power; preferential loans and tax incentives for renewable energy projects
Jan,2006	NDRC	Renewable Power Price and Cost Allocation Measures (Tentative)	the price of electricity generated from wind power is the original bid price; the extra cost caused by purchasing renewable power rather than thermal power is apportioned by provinces within the whole power grid.
Aug,2006	NDRC	Regulations and Requirements on Wind Farm Management	Wind farms are not illegal if the wind turbines imported rates are over 30%; Imported equipment should pay tax
Jul,2007	NDRC	Call for Bids on Wind Power Chartered Right (4)	tenderer should have one wind turbine manufacture engaged together; the wind turbine manufacture should promise its products are with a ≥ 70% domestically-made rate
Apr,2008	MOF	Adjustment of Import Tax Policy on high power wind turbine parts, components and materials	stop implementation of tax free policy for imported wind turbines(≤2.5MW); for the key parts, components and materials that need to be imported, the tax policy is 'first charge and then refund'
Aug,2008	MOF	Temperate Management Measure of Special Fund for Industrialization of Wind Power Generation Equipment	for the eligible manufactures, their first 50 sets of wind turbines (≥1MW) can get subsidies of 600￥/KW. The whole set manufacture and parts/components manufacture each share 50% of this subsidy; the subsidy is expected to be invested on new product R&D
Aug,2009	NDRC	Directives on problems of duplication of similar projects in some industry (wind power industry)	encourage a small amount of large wind turbine manufactures grow bigger and be more innovative; new wind turbine manufactures will not be permitted principally
Mar,2010	MIIT	Wind Power Equipment Manufacturing Industry Admittance Standard (calling for Suggestions)	.manufactures of wind turbines are required to have production capacity of ≥2.5MW (single set) , ≥100MKW (annual output)

Source: Report on the development of China wind power industry (2011), pp.4-5.

(2)University/Research Institute

According to Mr. QIAN , the vice chief R&D engineer who is one of the pioneers involved in starting up wind power business at DEC in 2004, DEC generally cooperated with universities through co-R&D projects in which universities contributed on some specific parts while the core tech was carried out within R&D center at DEC:

*"*We cooperate with universities generally on only small parts such as strength calculation, calculation of design load, structure calculation. We do not cooperate with universities on foundation design.*"*

The R&D engineer LIAO, who participated in all wind turbines R&D activities at DEC, explained how partnerships between DEC and universities were developed and expanded.

*"because some rese*archers in these universities conduct *research concerning wind turbine manufacturing… they are probably found by our leaders…or these researcher* know we are developing the similar projects and they contact us actively by dialoging with our leaders or giving a self-introduction .When we find they dig deeper on some technical aspects which we are interested in, we would cooperate with them tentatively. After several rounds of intensive cooperation, we develop close and steady partnerships with them now.*"*

R&D engineer SONG further exposed another collaboration approach of 'co-R&D-internship-possible recruitment', which is derived from co-R&D between DEC and universities. It further explains how and why the partnership between DEC and these universities are becoming closer and closer. SONG himself is the beneficiary through 'co-R&D-internship-possible recruitment' approach. He said:

*"*When I was still an undergraduate, I participated in a co-*R&D project between my supervisors'* research team and DEC. Through this kind of involvement, I acquired skills and knowledge of wind turbine R&D. So when my supervisor recommended me to the R&D department at DEC, *I was a qualified and well prepared candidate…As I know, there* are also some other colleagues recruited by recommendations from their supervisors who have co-R&D projects with DEC. This kind of collaboration approach benefits DEC with qualified and well-prepared employees and closer *partnerships between DEC and the research groups in these universities."*

(3)Business partners on product chain

According to the role the business partners on product played and their importance, we focus on 3 groups of them: investors & wind farm operator, industry standards maker and R&D partners.

Investors and wind farm operators are categorized in the same group, that is because, usually wind power investors are also wind farm operators in China, at least the investors that DEC collaborated with were in this situation. They include Hua'neng Group, China Longyuan Power Group, Shenhua Guohua Energy Investment Co.ltd, China National Offshore Oil Renewable Energy Investment Co.ltd, Huadian New Energy Development Co.ltd. The surge of investors was spurred by the positive policy signal sent by central government. After the announcement of 《Call for Bids on Wind Power Chartered Right (4)》, investors and wind turbine manufactures are bundled tightly. NDRC required that all tenderers must have an eligible wind turbine manufacture engaged together. With this requirement, these investors became the important cooperate partners strategically. Every year, DEC would organize annual expert consulting meeting. These investors are invited there to give feedback and advice on product/ service promotion and marketing strategy.

Among the industry standards makers & certification institutes, China Electric Power Research Institute (CEPRI) and State Grid Corporation of China (SGCC) are the most important external stakeholders to DEC. CERI is a large research institute under SGCC. Industry standards on Low Voltage Ride-through is made by CERI, according to which wind turbines need to be tested qualified before being sold to wind farm. Furthermore, SGCC's load capacity toward unstable electricity generated from wind energy affects the development of wind power industry considerably in China. The stagnation of wind power industry in China today is the evidence (Luo,2011; Han et al.,2009).

Besides universities and public research institutes, Windtec and FEA on line are another important R&D partners to DEC. They served as DEC's external brains which greatly helped its product development. DEC sends groups of R&D engineers to Windtec in Hunagry every year for co-R&D. By this approach, DEC learned the advanced knowledge and R&D experiences. FEA online is another important consulting company to DEC. They collaborated on R&D engineer training, consultation and software on professional software for tower analysis, main frame analysis, wheel hub analysis and leaf blade analysis.

(4)NGOs

DEC is the member of many domestic industrial associations, such as Chinese Renewable Energy Industries Association, Chinese Wind Energy Association, China Association of Agriculture Machine Manufacture and so on. There are mainly two collaboration approaches between DEC and these NGOs. The first one is, DEC organizes annual external expert consulting meeting. The directors or chief engineers in these industry associations used to be invited to the meeting as experts to provide professional suggestions on DEC's product development and market strategy. The second one is, these industry associations would organize some product exhibition and sale fair every year. It provides DEC the platform of expanding enterprise image, promoting product as well as getting access to potential sales and co-operations. However, to what extent these industry associations are helpful? The interviewees did not answer this explicitly[5]:

"These associations organize two fairs every year and the expense is more and more expensive. We have no choice but to participate in these fairs, as the experts in these associations usually occupy important positions in related government authorities... These associations publish an annual report, organize some fairs, run some internal publications, organize annual conferences and collect the dues. Then they call it a year. "

China General Certification Center (CGC) is an important certification NGO that DEC collaborated with. CGC is backed by the National Institute of Metrology, which is subordinate to the State General Administration of Quality Supervision and Inspection & Quarantine of the People's Republic of China. It is kind of government operated NGOs (GO-NGO). DEC collaborated with it was generally on series of certifications required by CEPRI and SGCC and their collaborations were also characterized by an up-down communication approach as government.

Table 6 is a summary of stakeholder relations at DEC's wind power business development outlined it in terms of 'on what knowledge', 'at what stage', 'for what innovation' and 'characteristics of collaboration'. We find that these external stakeholders are important to DEC for generally product innovation and marketing development. Government, local government and government-organized NGOs are important to DEC, because they are in charge of enacting industry policies, directives and standards. The communication was characterized by up-down and command-order single way while bottom-up feedback was absent. Investors are important to DEC. That is due to government's policy directions and signals. What is ridiculous is, the majority of these investors have state-owned background. About its R&D partners, it seems foreign wind turbine companies are more important than local universities and research institutes in China, although these universities are becoming more active in collaborating with firms.

[5] According to the interviewee's requirement, we keep this citation anonymously.

Table 6 Collaborations with External Stakeholder

		.on what knowledge	.at what stage	.for what innovation	. characteristics of collaboration
Government	.Central government	.industry laws, directives and regulations	.innovation strategy making (product & marketing)	.product innovation .marketing innovation	.up-down .command-order
	.Local government	.Local public procurement	.sales of innovative product	.marketing innovation	.up-down
University& Public Research Institute		.basic knowledge of parts strength calculation, calculation of design load, structure calculation.	.product development	.product innovation	.peripheral R&D partner
Business Partner on Product Chain	.Investors & Wind Farm Operator	.industry information .market information .wind turbine operation requirements and feedbacks	.bid .sales, use and maintenance	.marketing innovation .product innovation	.inter-dependent partner
	.Industry Standard makers	.industry standard	.after R&D and before selling to market	.product innovation	.up-down
	.R&D partner	.professional and specific knowledge concerning product R&D	.product development	.product innovation	.R&D partner
NGOs	.Industry Association .Identification Institute	.industry information .marketing information	.innovation strategy making (product & marketing)	.product innovation .marketing innovation	.up-down

Source: authors' summary

6. Conclusions and Perspectives

"Although the application of wind turbine is very early in China, the widely application of high power wind turbines was started from 2005. With more and more products brought to market, more and more problems would emerge, as it is an emerging industry in China. Given the majority of wind turbine tech is imported from foreign companies, we need time to understand it and find out solutions for the emerged problems." Mr. REN, General Manager of Wind Power Division at DEC

Although the long existed technological and qualitative gap between Chinese and foreign wind turbines still exists, DEC is narrowing the gap and reducing its dependency on imported parts and components. Its wind power business was developed in a problem-oriented Do-Use-Interact learning way and external collaborations with government, universities, business partners on product chain and NGOs contributed to innovation activities on different knowledge at different stages and in different approaches .

From triple helix perspective, the triple helix mode at DEC case is characterized by a government-pulled triple helix in which there is a strong government playing a critical role in which government affect market and industry development by enacting laws, policies and organizing innovation agents including universities, science parks and innovative firms together(Etzkowitz&Zhou,2007) . Coming to the tri-spheres, it seems universities and domestic technology consulting companies played a peripheral role in DEC's product development while the foreign partners meant more on advanced knowledge acquiring and R&D experiences. We see the universities involved in this case are active to collaborate with firms, which is line with argument that the linkages between university and industry in China is changing from 'industry-university' to 'university-industry' (Zhou&Peng,2008). However, it seems Chinese universities' ability of connecting theory to reality is still in need to be improved to fulfill firms' demand and be an important external knowledge source to innovative firms. Moreover, although Chinese companies have made significant efforts in international communication and cooperation, this can be further enhanced to improve its R&D capacity and globalized vision.

Undoubtedly, the rapid development of wind power business at DEC has benefited dramatically from government measures which are characterized by domestic-made preference toward wind power equipment procurement and top priority of developing renewable energy. These ensured manufactures as DEC a large and growing market for their products. That is also why DEC chose a mixed innovation strategy of independent R&D and co-R&D with foreign companies. It is to catch the market opportunity. However, our concern is wind power industry in China is heavily affected by government-central government, local government and government-organized/government-operated NGO (GO-NGO). Under this situation, the force of market is weakened. It is not good for Chinese firms in a long term, especially the state-owned ones which are backed by government, to build competitive advantages. For the state-owned enterprises as DEC, it would be helpful to realize this point and to build their technology-based innovation capacity to ensure when the umbrella of government does not help so much, they can still survive and develop very well. The case of Huawei proves that Chinese companies have the ability to transit from 'China-Made' to 'China-Innovate'.

Our findings from this case study have some theoretical, policy and practical implications for governmental authorities, industrial practitioners and future research. Practically, China government is to pay a special attention to renewable energy in the following 5-10 years. Probably the related policy and regulation would be made in a trial-error way. It indicates the renewable market would be with high uncertainty. Besides this, China government probably needs rethinking of how to make these semi-governmental NGOs helpful indeed? Theoretically, when mass attentions are paid to the traditional tri-spheres of government, university, research institute, now it seems to be a need for moving to the practical level to elaborate on the triple helix frameworks from different contextual and institutional perspectives and also to continuously construct and re-construct the understanding of eco-innovation dynamics. To firms that have turned to green business or plan to develop renewable energy business, take this macro national context into consideration might be helpful in terms of strategy making, as the innovation decisions of firms were found mainly driven by national regulation (Popp,2006). In industries concerning large-scale political and ecological problems, intervention from government is expected, although the style and level vary spatially and temporally (Gee&Mcmeekin,2011). Finally, it would be interesting to focus on the path dependency and 'lock-in' effect by focusing on its intangible resources of knowledge and experiences and industry environment.

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