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## **Pilot Comparative Case Study on Eco-innovation Dynamics at firm level**

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**Abstract:** This paper pays special attention to eco-innovations dynamics at firm level. Triple helix twins are employed to disclose the complex collaborations within and across the case companies, as it provides us the possibilities of looking beyond the simpler, linear model of innovation and. Grundfos (Denmark) is characterized by a strong commitment towards sustainable development; flexible organizational culture; high rate of employee participation; proactive strategies and practices regarding collaborations with external stakeholders such as suppliers, customers; its lobbying for tighter policies and environmental regulations. Dong Fang (China) is identified as a company at the very beginning of eco-innovation, as its compliance with environmental standards such as ISO 9001, ISO14001, OHSAS 18001 is absent at present; its collaborations with government and universities or research institutions are consistent with the context in which government plays a strong role in society to be the innovation organizer. The different environmental concepts and practices between Grundfos and Dong Fang are another findings based on comparative analysis. In the end, a discussion concerning the linkages between triple helix twins and eco-innovation dynamics is addressed.

**Key words:** eco-innovation dynamics, triple-helix twins, case study

**Subtheme:** S2.1 (The Triple-helix for sustainable development)

### **1. Introduction**

As the second largest energy consumption country to US, China has promised an aggressive plan to cut down its carbon density in Copenhagen Climate Conference in 2009. Given the fact that China is at the very beginning of its pursuing innovation (2006-2020), it is obvious to question how China takes on the challenges of integrating environmental concerns with innovations in the next 10 years. Industry (firms) as the main innovative subject in the process and according to M.M.Andersen(2008), the firms be the first important potential (eco-) innovator, rather than a polluter, what are the strategies and practices that firms taking environmental concerns into business operation?

Compared to China, Denmark has a long tradition concerning clean tech development to environmental problems. As early as 1990s, the greening of Danish industry has been the highlight of scholars with different backgrounds (see e.g. S.Georg, I.Røpke & U.Jørgensen,1992;A.Remmen,2000,2001;P.Cooke,2008). In recent years, Danish companies such as Grundfos, Danfoss are becoming famous for their environmental friendly products or services and deep commitment to sustainable development.

In this paper, comparative case study on a large power equipment manufacturing enterprise in China and one of the largest international pump manufacturing company in Denmark is carried out. The overarching objective is to disclose what is taking place at these two companies toward integrating environmental concerns into innovations. Triple helix twins are employed to disclose the complex collaborations within and across case companies in this study, as it provides the possibilities of looking beyond the simpler, linear model of innovation. The tentative use of triple helix twins as analytical tools for eco-innovation in this paper is a pilot endeavor to explore the possibility of triple helix as a powerful and helpful methodological approach to analyze eco-innovation dynamics. It is expected to add new knowledge to the theoretical and methodological study on eco-innovation process itself- on the one hand; on the other hand, it is expected to shed some lights on how companies in emerging economies tackle the challenges of taking both business development and environmental benefits into account.

### **2. Theoretical Understanding of Eco-innovation Dynamics**

If you type 'eco-innovation' into google scholar, there are only 1,790 references and references to 'environmental innovation' and 'green-innovation' which generally are the alternative terms of 'eco-innovation' separately are 4,660 pieces and 888 pieces hitherto. The study on eco-innovation is really poor compared to 'innovation' with 2140,000 references. Nevertheless, there is not

a consensus understanding toward eco-innovation. Furthermore, the extant study on eco-innovation dynamics are often more rooted in environmental policy than in innovation dynamics (see J.Hemmelskamp,1997;K.Green et al.,1998;Rennings,1998;J.A.delBrio&B.Junquera,2003;Andersen,2004; Rennings,2005;Cooke,2008; T.Cleff et al., 2008; J.Nill & R.Kemp,2009; S.Cantono & G.Silverberg,2009; D.Kammerer,2009).

### **2.1 Understanding of Eco-innovation**

The term 'Eco-innovation' is used with different understandings among scholars hitherto. Firstly the interpretations of innovation are somehow different. For example C.Fussler & P.James(1996) interpret innovation as 'outstanding implementation of radical ideas'(P.303); K.Rennings(2000) understands innovation as 'develop new ideas, behavior, products and processes, apply or introduce them'(P.321) in Europa INNOVA Thematic Workshop (2006) innovation is viewed as '...the creation of novel and competitively priced goods, processes, systems, services, and procedures...'; in M.Beise&K.Rennings(2005), innovation is defined as 'new or modified processes, techniques, practices, systems and products'(P.6); R.Kemp &T.Foxon(2007) underscores 'production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods that is novel to firm or user'; Secondly, the environmental benefits are defined differently, such as 'meet future needs' (C.Fussler & P.James,1996,P.303), 'a life-cycle minimal use of natural resources (materials including energy and surface area) per unit output, and a minimal release of toxic substances.' (Europa INNOVA Thematic Workshop,2006, Munich, Germany), 'significant and demonstrable process towards the goal of sustainable development through reducing impacts on the environment or achieving a more efficient and responsible use of natural resources, including energy' (Europe Commission,2007); 'throughout its life cycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resources use (including energy use)' (R.Kemp &T.Foxon,2007,P.8) and so on.

Another disputable point is whether 'environmentally beneficial normal innovations' (following R.Kemp &T.Foxon,2007) are categorized as eco-innovation (K.Rennings,2000; J.C.Hermosilla et al.,2010). In UNU-MERIT serial working-papers, both motivated and unintentional innovations offering environmental benefits are considered as eco-innovations and J.C.Hermosilla et al(2010) argue that it is difficult to identify an environmental motivation since in the evolutionary process of innovation, the environmental motivation for innovation probably become entangled with other motivations. Oppositely, the motivation of innovators are emphasized explicitly in Europa INNOVA Thematic Workshop(2006),Europe Commission (2007) and OECD (2009a).

### **2.2 Understanding of Eco-innovation Dynamics**

Andersen (2004) indicates dynamics as the interaction among different elements and synergy effect in term of national innovation system; R.Kemp &T.Foxon(2007) understand eco-innovation as a dynamic process, in which learning and changes within social and economic spheres are involved; A.Bergek, M.Hekkert &S.Jacobsson (2006,2008) identify three key processes at structural level concerning innovation dynamics : entry of organizations, formation of networks and alignment of institutions; V.Oltra(2008) interprets environmental innovation dynamics from the perspective of evolutionary economics as the interplay between the properties of technological regimes , the sectoral patterns of innovation and the evolution of market structure. Moreover, network activities are identified as influencing eco-innovation positively in M. Mazzanti &R.Zoboli(2006) based on the econometric analysis of the panel data set of Italian firms in 2002 and 2004. Other quantitative studies on the determinants of eco-innovation help the further understanding of eco-innovation dynamics :R&D(J.Horbach,2008; K.Rennings et al.,2006), environmental regulation (J.Horbach,2008),environmental management systems and tools (J.Horbach,2008; K.Rehfeld, K.Rennings& A.Ziegler,2007), organizational changes ( J.Horbach,2008; K.Rehfeld, K.Rennings& A.Ziegler,2007) are identified as important in eco-innovation by econometric evaluation.

Determinants of eco-innovation are also analyzed from an extensive study focusing on policy and regulation. S.Cantono & G.Silverberg (2009) develop a network model of new technology to simulate the diffusion process and come to a conclusion that the subsidy policy would be highly effective only for learning economies in a certain range; The empirical study of German manufactures of electrical and electronic appliances with logit regression analysis (D.Kammerer,2009) shows both customer benefit and regulation play a key role in eco-innovation; Case studies on transnational diffusion of innovations within wind energy (wind turbine generators in Denmark, Germany, Spain, Italy and Austria)and fuel efficient passenger cars are described and analyzed in Rennings (2005) and a conclusion is drawn that strict regulation results in the creation of lead markets when supported by global demand or regulatory trends.

However, they are somehow limited and separated from mainstream innovation study (Andersen,2008) excluding V. D. Marchi (2010) . V. D. Marchi (2010) highlights the high interdependencies with external partners in eco-innovation and based on the econometric analysis on a sample of Spanish manufacturing firms , he comes to following conclusions: 'cooperation boosts green innovation to an higher degree than other innovations' (P.17); the negative coefficient for users; the scientific agents are identified important in the development of knowledge for eco-innovations, in particular in the product innovation and universities, research institutions are stressed more important than other innovators in eco-innovations, as eco-innovations in relations to reduce environmental problems leading to highly knowledge-intensive; 'green innovators are involved in cooperation with foreign partners to an higher extent than other innovators'(P.18).

### **2.3 Triple-helix twins and Eco-innovation dynamics**

Triple helix is mainly a model for analyzing innovation in a knowledge-based economy (L.Leydesdorff &H.Etzkowitz,1998; L.Leydesdorff,2000 ). Universities or other knowledge-producing institutions, industry and government at various levels (local, regional, national, and transnational) are the main spheres involved in the innovation system by innovatively adapting themselves to changes(L.Leydesdorff &H.Etzkowitz,2001). It provides a theoretical framework to disclose what is going on in the innovation

system and how innovations are generated by analyzing university-industry-government interactions (L.Leydesdorff & H.Etzkowitz, 1998, 2001).

'Innovation, involving changes in physical and social environment, inevitably raises issues of sustainability.....' (H.Etzkowitz & C.Zhou, 2006, P.78). In recent years, the concept of sustainability triple helix of university-public-government is proposed as a complement to the Innovation triple helix of university-industry-government (see H.Etzkowitz & C.Zhou, 2006): the university-industry-government triple helix works to promote innovation and economic growth, while the university-government-public one serves as a balance wheel to insure that innovation and growth take place in ways that will not be harmful to the environment and health. The classical triangles of sustainability are indicated explicitly in triple helix twins. This might be the earliest linkages between triple helix and eco-innovation dynamics.

According to H.Etzkowitz & C.Zhou (2006), the two helices work in tandem to drive innovation and sustainability forward. The sustainability triple helix plays a role of insuring the innovation triple helix take place in ways that will not be harmful to environment and health and also the sustainable economic growth. Public is the new element which is expected to push the formation and evolution of helix. In innovation triple helix, the implementation of new ideas and the creation of business value are mainly in industry (firms) while universities or research institutions provide knowledge resources to help incremental or radical innovations come true; government is supposed to support the process of creation and carrying it out to market by policy, regulation, financial support or other approaches. Sometimes, the triple helix twins work together as a dynamic that advances sustainable economic and social development, which is called 'a fourth helix' (H.Etzkowitz & C.Zhou, 2006, P.80).

## 2.4 Summary

Given the fact that 60% of innovations offer environmental benefits (R.Kemp & T.Foxon, 2007, 2008) and about 80% of all innovating firms in the survey of German industry are involved in environmental-friendly innovation projects (Cleff & Rennings, 1999a), it is important to distinguish 'environmentally motivated innovations' and 'environmentally beneficial normal innovations' (following R.Kemp & T.Foxon, 2007). If the innovations with unintentional environmental benefits are categorized as eco-innovations, the majority of innovators would be eco-innovators. This may lead to a fuzzy borderline between innovations aiming environmental benefits and innovations in general on the one hand, and on the other hand, this probably would slow down the process of understanding 'environmentally motivated innovations' which are highlighted in EU policies.

Based on the existing understanding of eco-innovation, in this paper eco-innovation is interpreted as 'any form of innovation toward environmental benefits and business value, in which the development of novel products, productions, services or organizational structure and management that can avoid or reduce environmental harms compared to the alternative approaches'. Innovations aiming environmental benefits are the focus. This understanding helps to make empirical design and theoretical development away from a blurred borderline and avoid the duplicating work toward innovations in general, furthermore it provides the possibility of answering 'whether innovations towards sustainable development can be treated as normal innovations or if a specific policy are needed' (K.Rennings 2000, P.320).

With regard to understanding eco-innovation dynamics, it seems scholars can come to a consensus that eco-innovation dynamics are featured with complex interactions among different actors, the synergy effect induced by the interplays (technological, environmental, social and economic), learning process, networks of innovator, etc.. Considering the complex and rapid changing world, evolutionary perspective would be the most indisputable approach to eco-innovation study at present. In view of evolutionary approach, agents' history and situated context are considered into analysis of a process or phenomena. Actually, innovation system approach follows the evolutionary economics way too (see e.g. Freeman, 1987, 1995; Lundvall, 1988, 1992, 1999, 2005; Nelson, 1993; OECD 2001a, 2001b, 2005 et al.) and triple helix model is no exception.

The triple helix twins are identified as a theoretical framework to analyze eco-innovation dynamics, as sustainability triple helix of university-public-government provides the possibility of investigating the concept and practices of sustainability and the innovation triple helix of university-industry-government offers a framework to disclose the complex collaborations within and across organizations. The process that generates a balance of development in the interplays between sustainability triple helix and innovation triple helix is eco-innovation dynamics.

## 3. Research Focus

The study of eco-innovation dynamics is at the very beginning. Both theoretical and methodological approaches to analyze these processes are poorly developed (K.Rennings, 2000; M.M.Andersen, 2010). Taking Myrdal's (1957) suggestion into consideration, which concerns the understanding of the interplay between internal and external sources of dynamics (see below), this paper intends to employ triple helix twins to disclose what is going on in eco-innovation within companies strategically and practically.

*'... the main scientific task is... to analyze the causal inter-relations within the system itself as it moves under the influence of outside pushes and pulls and the momentum of its own internal processes.'* Myrdal (1957, P.18)

## 4. Methodology

Given the research focus is in terms of 'what', case study strategy is chosen (Yin, 1994). Cross-case study is conducted as it gives the possibilities to look into eco-innovation dynamics in different contexts and the conclusions induced is considered to be more convincing than the ones from single case (Herriott & Firestone, 1983). The approach of comparative case study is employed to explore the complex interactions, as comparative case study strategy is likely with more fruitful outcomes for cross-case analysis (Yin, 1981).

Grundfos A/S in Denmark and Dong Fang Turbine Co.ltd in China are selected since both of them are large firms (more than 5000 employees); they are both leading players in manufacturing industry in each country; both of them highlight environmental concerns strategically.

The data collection is mainly based on the previous study on samples, public documents and key contactors in case companies. Considering the complex and rapid changing world, an evolutionary perspective is the most indisputable approach to eco-innovation study at present (see Rennings,2000; Andersen,2010).

Coming to the data analysis, each case company is a unit of analysis firstly. An evolutionary perspective is employed to look into case companies' history and path-dependencies, transition processes. Furthermore, triple helix twins (see L.Leydesdorff & H. Etzkowitz,1996; H.Etzkowitz &L.Leydesdorff,1998) are employed to analyze data, since it provides us the possibilities of investigating and explaining how the sophisticated interactions within and across organizations in eco-innovation are going on.

## 5. Case Company Description

**Grundfos A/S** Grundfos is a pump manufacturing firm with representative companies in a large number of countries and more than 14,000 employees (Grundfos,2007). Circular pumps, submersible pumps and centrifugal pumps are the three major product groups of the company, which annually produces more than 10 million pumps (Grundfos,2006a). Grundfos White Paper on its perspectives toward climate change implies that innovation is the core of the company and sustainability will be the first concerns in the next 20 years.

**Dong Fang Turbine Co.ltd** Dong Fang is a state-owned enterprise with 9000 employees and it has grown to be one of the top three power equipment manufacturing bases within the past 44 years. Since 2006, Dong Fang takes 'Green Power Benefits Human Being' as its mission and new products of thermal power, wind turbine and solar power are launched successively. In 2008, Dong Fang had 13% market share of Installed Wind Turbine Capacity in China (see fig.1).

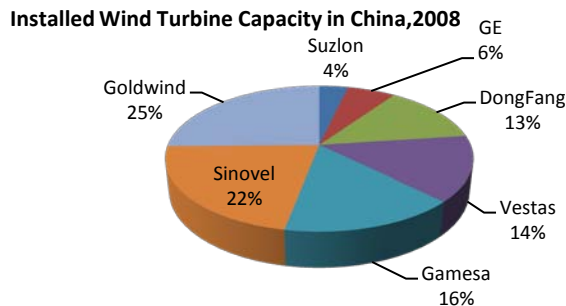


Fig.1 Installed wind turbine capacity share in China,2008

Source: CWEA (Chinese Wind Energy Association), *Statistics on Chinese Wind Power Equipment Capacity in 2008* (2009).

## 6. Findings

Complex interactions among different stakeholders in the eco-innovation dynamics include both inside and external collaborations. What is going on within and across case companies are analyzed in this part. The departure points toward eco-innovation, the organizational endeavors and the implementation at grass-roots level are chosen to disclose 'what is going on within companies'. The external linkages with product chain, university or research institution, government and public are analyzed to show 'what is going on across the borders of companies'.

### 6.1 What is going on within companies?

#### (1) Grundfos

##### *Self-Regulation - Departure Point toward Eco-innovation*

'Self regulation refers to a firm's adoption of environmental performance standards or environmental management systems (EMS) beyond the requirements of government regulations' (P.Christmann & G.Taylor ,2001,P.440), which is generally connected to the term 'Voluntary'(see A.Gouldson &J.Murphy,1998,Chapter 4) meaning 'all those actions unforced by law and un-persuaded by financial incentives, which individuals, groups and firms take to protect the environment' (Jacobs,1991,P.134). It was identified as an essential in achieving sustainable development in the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992(UNCTAD,1993) and there is a growing study on firms' voluntary measures to improve their environmental performance (see survey in M. Khanna(2001)).

At Grundfos, self-regulation can be detected remarkably with its deep commitment to sustainability. Due to the fact that its business is largely relevant to the world's water resources, Corporate Social Responsibility (CSR) is stressed in Grundfos White Paper (2010). They promise to reduce their carbon footprint, investigate and reduce carbon emissions over the entire life cycle of their products and services, reduce the water consumption through their value chain, facilitate a growing market of energy-efficient pumps, systems and solutions, help the world adapt to climate change, water scarcity and a low carbon economy and try their best to raise global awareness of the link between water, energy and climate change. Furthermore, programs such as 'Walk-to-Work' in UK, 'Lunch and Learn' sessions about environmental issues in US and the initiatives for employees saving paper, water and electricity in China and are implemented throughout the world, which indicate Grundfos' commitment towards new sustainable products and services at present and in the future; Life Cycle Management (LCM), Product Oriented Environment System (POEMS), Integrated Management System (IMS) (see J.E.Holgaard,A.Remmen,T.H.Jørgensen,2007a), Environmental Communication (see J.E.Holgaard,A.Remmen,T.H.Jørgensen,2007b) are implemented partly within Grundfos, such as suppliers' performance toward environmental issues are evaluated through assessment systems; Moreover, Grundfos has a traditional proactive participation in the global environmental issues, such as lobbying new European regulations to reduce the electricity

consumption of industrial motors; Being a proponent of establishing a voluntary A to G energy labeling for circulator pumps; Producing educational materials, publishing research, and running campaigns in the media.

#### *Well-developed Organizational Culture –Organizational Endeavors*

Coupled with the implementation of these environmental management systems, organizational adjustments and endeavors are carried out one after another. Central Service Department is established to coordinate activities concerning environmental issues and manage the external collaborations. Environmental management of production, environmental product chain management and corporate social responsibility are all involved as part of responsibilities of Central Service Department (J.E.Holgaard,A.Remmen,T.H.Jørgensen,2007a);In 2005, the intra-organizational link between the product-oriented work and the environmental management of production was strengthened and it provides employees the possibilities of spending part time in different departments when needed; Environmental teams are formed to be a forum exchanging ideas connected to specific issues and facilitating the generation of new environmental initiatives toward the existing environmental practices. In this process, environmental communication among different departments or sections within and across Grundfos is underscored and analyzed in J.E.Holgaard,A.Remmen,T.H.Jørgensen(2007b).

In the past 20 years, Grundfos has developed a flexible organizational culture, in which the annual environmental goals and how to make it come true are generally considerably dependent on each units and employees' central part of the development of most new sustainability initiatives(White paper2010). The statement from an environmental coordinator at the production site provides a vivid description toward the organization culture at Grundfos.

*"I think Grundfos has organized the work in a great way with production teams and so on, and the principle that those who work with the things on a daily basis are also involved when more exciting things happen and get the opportunity to feel your own influence. This also means that the mill is running by it self – because you get the chance to do what you are dying to do."*  
(J.E.Holgaard,A.Remmen,T.H.Jørgensen, 2007b)

#### *Employee Participation-Implementation Practices at grass-roots level*

A lot of work has been done to motivate employee participation at Grundfos hitherto. As early as in 2000-2003,series of personal interviews with Environmental Manager Christina Monrad Andersen, the head of the communication division Sune Salling Mortensen and person responsible for environment in the electronic production unit Peter Ellekjær Hansen at Grundfos have stressed the ongoing and visible commitment from top-management had motivated the employees to continuous environmental improvements (C J.E.Holgaard,A.Remmen,T.H.Jørgensen, 2007a,2007b ). In recent years, environmental teams, workshops, innovation camps and the design of creative toolboxes are the most used bottom-up approaches to get employees involved in the problem solving. At Grundfos, the employees are not only suggesting possibilities for change, but also they are authorized to give their ideas concerning the daily routines. Coupled with this, a data base with employees' ideas of environmental improvements has been established to provide an easy access to feedback. In 2008 alone, 4000 suggestions concerning eco-innovation was submitted by employees and more than 3,000 were implemented. In this process, participation gave the employees a relatively high degree of influence on the activities and the improvement of themselves toward understanding environmental problems and figuring out these problems, as environmental teams, workshops have been forums to discuss the potentials and problems that arose in the process (see also observations in A.Remmen et al(2000))and innovative toolbox, innovation camps have been tools helping their capabilities of solving problems.

## **(2) Dong Fang**

### *Pressures induced by Product life cycle - Departure Point toward Eco-innovation*

According to Dong Fang's practices, there are four stages in thermal power turbines' life cycle. The first stage (1st year): installation and grinding-in; the second stage (2nd-3rd year): reliable and efficient operation period; the third stage (4th-8th year): mass maintenance and renewals; the last stage (9th--): products are abandoned or reusing their scrap value. Fig.2 shows Dong Fang's products distribution during life cycles (8 year is a life cycle) from 1970 to 2005. Till 2001, its production kept increasing since 1970. From 2002, there is a reduction. It implies a decline of thermal power turbines in China.

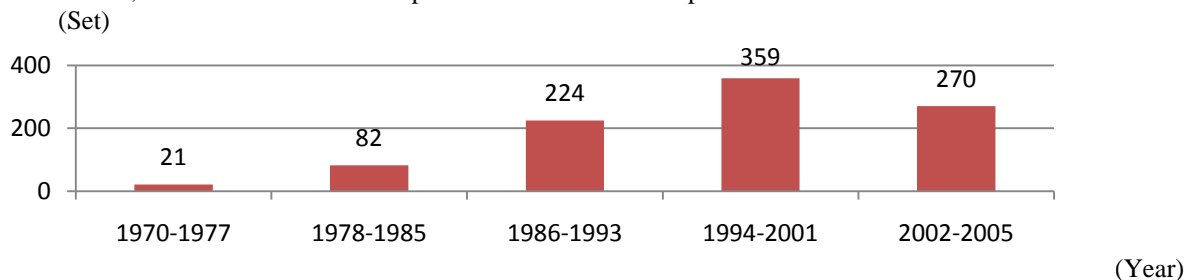


Fig.2 Dong Fang Production distribution in different Life Cycles

Source: reorganizing based on the data in Guang-ping Lin(2008),P.105

In late 1990s, power industry was facing the lowest business growth. Dong Fang propelled renovation business toward the old equipment nationally. In recent years, business toward renewable energy such as wind turbine and solar power industry has been developed rapidly. Based on the analysis of value chain of wind turbine and its competitive advantages, Dong Fang takes blades, gears, the control system and fabrication as the main business; Related to the solar industry, the production of high purity

silicon is the basic procedure the industry chain, in which polycrystalline silicon is the main resources. In the global market it is generally dominated (95% of global output) by Hemlock, Wacker, Tokuyama, REC, MEMC, Mitsubishi and Sumitomo. Under this background, Dong Fang took over the only company that has developed its own R&D and the production line toward polycrystalline silicon.

#### *Customer-centered Management Procedure-Organizational Endeavor*

Take an example to show the problems before 2008. When customers come to ask for documents concerning the ordered products, marketing department, customer services department, planning office, product development department, archive office, purchasing department, even top management and suppliers would be involved in. As when the ordered products are in production, it is the planning department that is responsible of communicating with customers. However, the documents concerning production technologies are in the charge of archive office while the core technologies documents are kept in technical office. In some situations, the documents are kept by suppliers because some accessories and assorted illustration or instruction documents are purchased from external suppliers and then purchasing department is involved in. In case the documents required by customers are not kept in purchasing department, the suppliers are involved in. The responsibility of each department is explicit in the internal communication process, however, the collaborations between different departments are absent, which makes a simple response to customers' requirements a tough way.

Fig.3 shows the complex communication process with direct or indirect linkages between different departments.

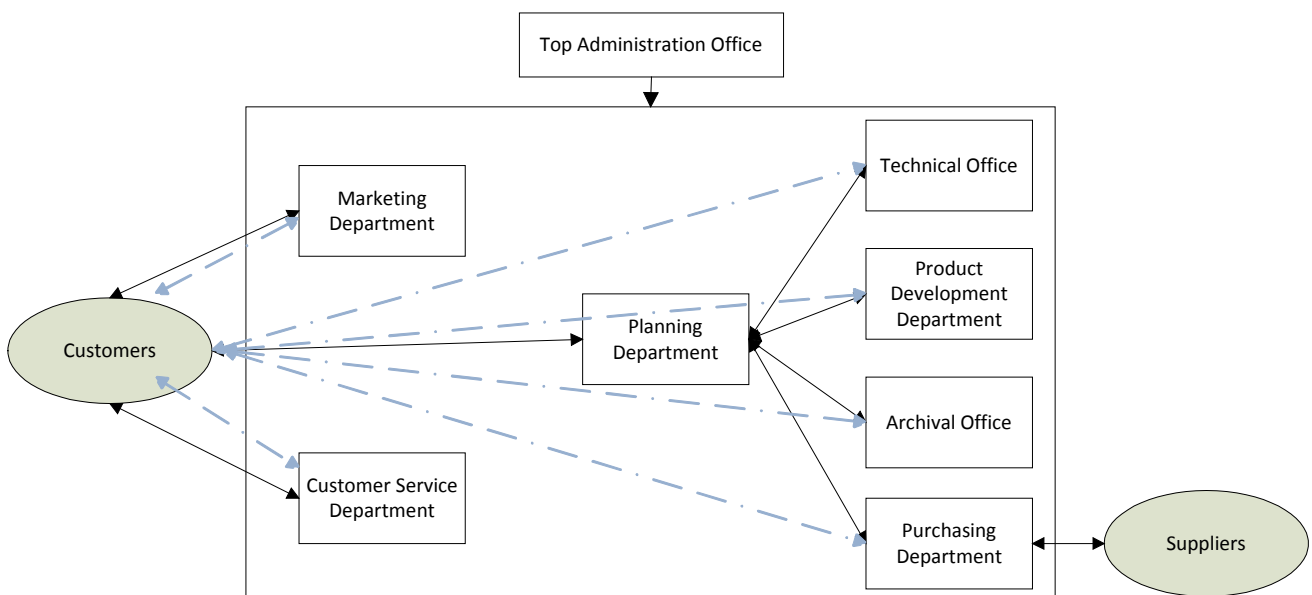


Fig.3 The Internal Communication Process of Responding to Customers' Requirements  
Source: Guang-ping Lin(2008)

In the following, project management system is constructed to eliminate the barriers between manufacturing and services. It provides project manager a convenient tool to collect data from manufacturing system, which makes a rapid response to customers and market possible. Meanwhile, the planning department categorized as manufacturing system knows well about the changes of customers and markets' changes and adjust its planning in time. The application of project management system makes different departments in service system and manufacturing system collaborate better.

Moreover, the departments which are not highly related with customers and markets are also required to be proactive to serve the manufacturing departments and marketing departments on human resource requirements, financial or law support.

#### *Highlight Employee Satisfaction-Implementation Practices at Grass-roots level*

At Dong Fang, the linkages between employee satisfaction, employee loyalty, productivity and customer satisfaction, customer loyalty, the rate of return are constructed in the manufacturing and service value chain(see fig.4). It is underscored that employee satisfaction is served for customer satisfaction and loyalty. How to achieve employee satisfaction is not observed yet.

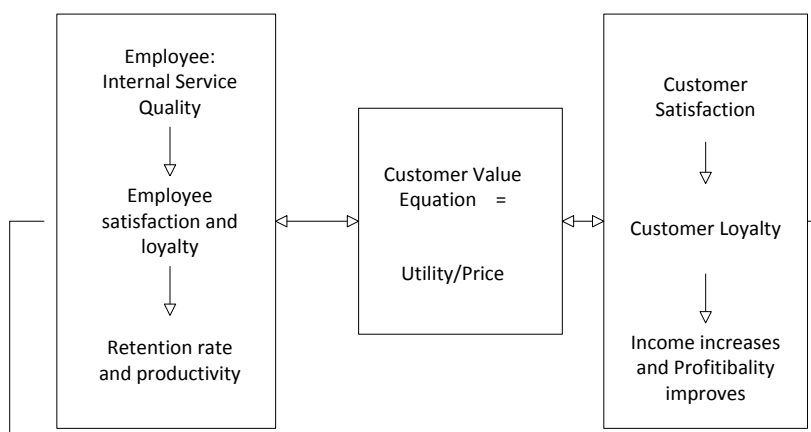


Fig.4 Customer-centered service value chain at Dong Fang  
Source: Guang-ping Lin(2008)

## 6.2 What is going on across companies?

### (1) Grundfos

#### *Grundfos-Product Chain*

Coming to collaborations with suppliers, Grundfos takes suppliers' environmental performance into evaluation system on the one hand and it tries to educate suppliers by providing environmental information on the other hand. Furthermore, the Future Now Award is established to be an added incentive to encourage the companies that has implemented the best green initiatives.

With regard to its interactions with customers, R&T department at Grundfos can be an example. Technology scans and close contact with end-customers are the general approaches to be informed of customers' requirements in R&T department. Communications with customers and markets are also the approach to obtain knowledge concerning developing incremental and radical innovations.

#### *Grundfos-Government-Public*

EU, NGOs, Environmental Protection Agency, local authorities and so on are also the important partners for Grundfos and it keeps proactive strategies toward collaborations with them, since Grundfos is always trying to influence policy and regulations in relations to energy-efficient pumps and water conservation. In Denmark, Grundfos is Chairman of The Danish Council for Sustainable Business Development and it takes part in the formulation of the Danish governments' action plan on corporate social engagement. The case mentioned above concerning Grundfos' endeavor of combining partners influencing the political agenda of the UN COP15 in Copenhagen Climate Conference.

#### *Grundfos-University*

In early 1990s, four universities are organized as partners to elaborate the requirements for 'intelligent' pump, which is first presented by Grundfos' former Present Niels Due Jensen(World Pump, January 2004,PP.36-39. www.worldpumps.com). In 2002 alone, Grundfos R&T engaged in 52 formalized cooperation agreements with universities regarding development projects. Industrial Masters or Ph.ds, cooperation with Professors with background in innovation or environmental management and pump technologies are the approaches. However, there is no further information disclosing its collaborations with university in recent years.

### (2)Dong Fang

#### *Dong Fang-Product Chain*

Dong Fang has a long tradition of keeping proactive interactions with international power equipment manufacturing companies for technology import and business corporations. In 1990s, Siemens (Germany), GE(USA), Alstom(France), Mitsubishi(Japan) were the main partners; in recent years, the collaborations are mainly on technology import on renewable energy.

Additionally, Dong Fang has a strong focus on customers. Marketing department keeps close interactions with customers on customers' demands; The project managers in Planning department are in charge of collaborations with customers on purchasing of raw material, the planning of various accessories, the implementation of planning, the production procedure and the delivery of products; Customer service department is responsible for after-sale service.

#### *Dong Fang-Government*

Referring to the collaborations between Dong Fang and government, marketing department within Dong Fang has the only connections with local government. Surprisingly, the related managers all attributed company's sustainable development and excellent innovation performance to government's policy support. The vice president of Dong Fang Xing-gui LIU said that, as a state-owned company, the support from local government is limited, while the central government helps much. For example, the bundling bidding policy on national power station project makes the cooperation of Dong Fang and GE (US), Hitachi(Japan), Siemens(Germany), Alstom(France) come true (JuLIU,2010). Another fact is that during 2004-2008, Chinese companies have increased their share of cumulative installed wind power equipment capacity from 18 percent to 62 percent (see Fig.4).



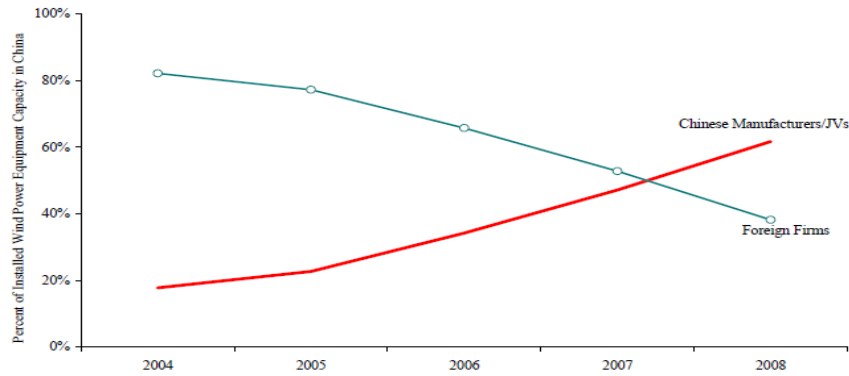


Fig.4 Share of Cumulative Installed Wind Power Equipment Capacity in China (2004-2008)

Source: Dewey & LeBoeuf (2010). *China's Promotion of the Renewable Electric Power Equipment Industry--Hydro, Wind, Solar, Biomass*. Report for the National Foreign Trade

### *Dong Fang-University*

The approaches that Dong Fang collaborates with universities are categorized as follows. The first one is joint labs. Unfortunately, it was always end with failure and this induces a situation that there is usually small and short-term projects corporate with research institutions and universities while the core R&D is within company (Ju Liu,2010). The second approach is serving as the internship place for bachelor or master students from corporate universities. This approach helps Dong Fang build close relationships with professors and universities, at the same time, having bachelor or master students for a certain time in company helps HR make an in-depth assessment of the students before a possible recruitment; Donation is also the usual collaboration way and scholarship and donation on buildings and teaching facilities are the main channels; Employees who pursue industrial Ph.d degree are serving as vehicles between Dong Fang and universities' collaboration. R&D department, Human Resource Management Department (HR) and Innovation Management Department (IM) are most related department involved in interactions between Dong Fang and universities or research institutions.

### 6.3 Comparisons

Grundfos (Denmark) is firstly characterized by its strong self regulation toward sustainable development, which is reflected by its commitment to environmental improvements and well-implemented environmental management systems; the loose-fitting organizational culture which makes a flexible communications among different departments and high rate of employee participation is another highlight; its strategies toward collaborations with external stakeholders such as suppliers, customers, in particular its trying to influence the policies and environmental regulations are proactive. All of these make it a responsible company in customers (White Paper,2010) and outstanding performances in world pump markets.

Compared to Grundfos (Denmark), Dong Fang (China) is identified as a company at the very beginning of eco-innovation, as its complying with internal environmental standards such as ISO 9001, ISO14001, OHSAS 18001 which are categorized as self-regulation is totally absent at present; its collaborations with government and universities or research institutions are consistent with the standpoint that China is still at the early stage of a triple helix development: through a government-pulled + industry-university collaboration.' (Zhou, 2008).

Coming to the triple helix twins at Grundfos and Dong Fang, universities are playing a peripheral role in innovation at Dong Fang while the data is absent coming to Grundfos. Furthermore, although both of them are proactive to collaborate with external stakeholders on the product chain, such as suppliers, customers, Grundfos takes environmental concerns into account remarkably while renewable energy business is at the very beginning at Dong Fang. Their collaborations with government is different, as Grundfos is proactive to influence the political agenda on sustainable development to propel its global business while in Dong Fang case , the central government plays a strong role of pushing and protecting on the concepts and practices of renewable energy. Compared to Grundfos' proactive interactions with NGOs, EPAs, Dong Fang's collaboration with them are not investigated at present.

Table1 Findings from two case companies.

Case Company	Triple helix twins				
	What is going on within companies			External Collaborations	
	<i>Departure Point</i>	<i>Organizational Endeavor</i>	<i>Implementation Practices at Grass-roots level</i>	<i>Sustainability (I-G-P)</i>	<i>Innovation (I-U-G)</i>

Grundfos (Denmark)	Self-Regulation	Cross-functional teams; Coordinators; Development of flexible organizational culture	High rate of employee participation	<u>Grundfos-Public-Government</u> : proactive to push the political agenda on sustainable development concerning its business strategy	<u>Grundfos-product chain</u> : proactive to push suppliers, customers and even competitors to a raised environmental awareness <u>Grundfos-University</u> : recent data is absent <u>Grundfos-university-government</u> : not investigated yet
Dong Fang (China)	Pressures induced by Product Life Cycle	Project Management System	Highlight employee participation, however 'how' is not investigated yet	<u>Dong Fang-government</u> Dong Fang is pushed and supported by central government and local government <u>Dong Fang-public</u> : NGOs, EPAs, WBCSD and so on are absent Dong-Government-Public	<u>Dong Fang-Product chain</u> : proactive to collaborate with customers, suppliers, however it is mainly on traditional business while renewable energy business is at the very beginning <u>Dong Fang-University</u> : peripheral role <u>Dong Fang-Government</u> : <u>Dong Fang-University-Government</u>

Based on the analysis of their strategies and practices toward collaborations in eco-innovation process, another two findings are identified: the huge gap between Grundfos and Dong Fang on eco-innovation; the different paths to eco-innovation. Grundfos(Denmark) and Dong Fang (China) are both the outstanding companies in each country. Dong Fang started to focus on renewable energy since 2006, compared to Grundfos' starting its way to eco-innovation since 1990s, there is a totally 16 years' lagging behind Grundfos on concepts and practices toward eco-innovation; Coming to the paths to eco-innovation, Grundfos is identified as induced by its strong self-regulation while Dong Fang is somehow pushed by the market pressure and pulled by central government. According to Christensen & Lundvall (2004), the process innovation actors collaborate within and across organizational boundaries are high context dependent, it may be in relations to their different national contexts and industry contexts—'environmental sensitivity' in different types of firms and sectors (Malaman,1996) ; it may also be connected with the gap of their R&D capabilities (see conclusions in J.Horbach,2008; Rennings et al.,2006). Anyway, the factors hiding behind the phenomena can be studied in the future but not the focus in this paper. Coming to the paths to sustainability, the departure points within both companies are analyzed, however, it is more reasonable to consider them as part of driving forces but not the whole. The further study is expected to focus on the sustainability triple helix of university-industry-public and how environmental concerns are considered into innovation triple helix of university-industry-government to generate a balance of development—eco-innovation.

## 7. Conclusions and Discussions

In this paper, triple helix twins are employed to capture eco-innovation dynamics. Different concepts and practices towards eco-innovation are identified. In sustainability triple helix of industry-government-public, Grundfos is the main impetus. Its endeavors toward sustainability are embodied in the whole process: strong self-regulation, new position of environmental coordinator, commitment to raise higher environmental concerns among employees and public, proactive strategies and collaborations with government and public toward tighter environmental regulations. Compared to Grundfos, Dong Fang has a commitment to sustainability while environmental concerns are rare considered into its practices. Even though it has organizational adjustments and highlights employee satisfaction by application of project management system and customer-centered evaluation system, environmental concerns are not implied at all. It is the same situation within its collaborations with customers and suppliers, university and government. In innovation triple helix of industry-university-government, Grundfos keeps a close interaction with stakeholders on product chain to collect new ideas about production, products or services and raise the environmental consciousness of customer, supplier. Its collaboration with university can be traced back to early 1990s whereas there is no further information disclosing its collaborations with university in recent years. Furthermore the role of government in supporting innovation at Grundfos is not investigated yet. In Dong Fang case, universities or research institutions are playing a peripheral role, as the core R&D is implemented in company although it keeps collaborations with universities on internship, consultancy and small short term testing projects. Regarding to the government role in the innovation triple helix, central government plays a strong role facilitating industry-university cooperation at national level and the role of local government is not investigated yet.

Triple helix twins are tentatively connected to eco-innovation dynamics in this paper. The interplays between sustainability triple helix and innovation triple helix in generating a balance of environmental, social and economic concerns are thought to be the concrete analytical framework of eco-innovation dynamics. According to (H.Etzkowitz & C.Zhou,2006) 'Everyone should feel free to modify this analytical and normative framework, to take local circumstances better into account'(P.79). In this paper, the triple helix twins are adjusted to industry centered as 'industry-government-public' and 'industry-university-government'. However, there are some topics in need of further discussion.

Firstly, it is about to what extent 'Everyone should feel free to modify this analytical and normative framework, to take local circumstances better into account' (H.Etzkowitz & C.Zhou,2006, P.79). In this paper, university-centered triple helix twins in (H.Etzkowitz & C.Zhou,2006) are modified to industry-centered triple helix twins. Disregarding industry-centered, university-centered or government-centered, is it reasonable to add another triple helix 'industry-university-public' to 'industry-government-public' concerning sustainability triple helix? In recent years, education for sustainable development (ESD) is underscored for its potential contribution to industry by training graduates with sustainable knowledge, skills and competences figuring out

environmental problems by production or products or service innovations (see S.Sterling,2001;S.Cough&W.Scott,2007; M.Barth et al.,2007 ).

Secondly, coming to the analytical framework of eco-innovation dynamics, is it reasonable to expand triple helix to quadro-helix instead of triple helix twins? In the past 25-60 years, the need for public intervention and its nature has changed remarkably (Andersen,2010) and a collective endeavor is in need but not only depends on government or industry or university to tackle the global climate change. All stakeholders work together in pursuing eco-innovation, in which a win-win-win (social-environmental-economic) model is achieved.

Thirdly, in (H.Etzkowitz &C.Zhou,2006), triple helix twins are introduced at a conceptual level while the boundary of the term ‘public’ is in need of further clarification, although public concern is discussed with sentences such as ‘Questioning the unintended consequences of industrialization has spread from West to East, North and South.....’ , and then environmental movement is used as an example to show the ‘public concern’. In this paper, public is concerning organizations like NGOs, Environmental Protection Associations (EPAs), World Business Council for Sustainable Development (WBCSD) and so on.

This paper is a pilot study based on previous study on Grundfos and Dong Fang and a tentative connection between triple helix twins and eco-innovation dynamics are proposed. This study adds new knowledge to the extant study on eco-innovation process at firm level on the one hand , and on the other hand, it makes the concept of triple helix twins relatively concrete. Furthermore, coupled with the topics in need of discussion above, this paper gives rise to a further thinking toward s the role of national contexts, industry contexts in eco-innovations. As a pilot study, it points out the possible empirical research focus in the coming investigations.

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