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THE DANISH WIND CLUSTER:

STRATEGIES, TRAJECTORIES AND FUTURE DEVELOPMENT

SUMMARY

ABSTRACT

This thesis is concerned with the origins and dynamics of the Danish wind power cluster, focusing on the competitive and technological dynamics of its formation and operation. The thesis thus spans two of the most interesting and challenging issues in International Business, namely (1) the rise of industrial clusters as a means of focusing and concentrating regional competitiveness; and (2) the rise of renewable energy systems as sustainable successors to fossil fuel systems. Denmark is one of the few countries in the world to have a stated national goal of transforming its energy systems to become independent of fossil fuel inputs, and its Jutland wind cluster is the principal means for achieving this goal.

The Thesis is aimed at demonstrating the complementarity between clusters and renewable energy industries, drawing out the means through which a cluster can trigger and enhance the development of an efficient and successful wind turbine industry. The Thesis provides a description of the Danish wind cluster as a successful model of operating cluster, together with the demonstration of the structurally fundamental role that the government policies can play in bringing about such a result. The thesis provides an analysis of the future trajectories and developments for the Danish wind cluster with reference to such macro-issues as the supply chain and the productive system; the R&D system; the financing system and the strategies of political intervention.

The thesis moves its argument through four stages, grouped as four chapters. The first expounds the notion of industrial cluster, bringing into focus clusters' role in enhancing productivity, innovation and the formation of new businesses; the role that coopetition and economic dynamics play within a cluster; and the relation between clusters and government. The second chapter provides an analysis of wind power as a proficient answer to the problem of developing sustainable energy systems that effect a rupture with fossil fuels systems, where the focus is on three main topics: the

energy problem in the globalized economy, renewable energies as a solution and the case of wind power and how the technology of wind power provides a credible and efficient solution. The third chapter describes the successful model of the Danish wind cluster while the fourth deals with the forecasting of the expansion paths of the Danish wind cluster in the next future in terms of supply chain, R&D and financing system transformations.

Methodology

The first two chapters of the thesis develop a synthesis of the views expressed in a wide and growing literature, with a focus on the ideas and concepts of the cluster as an economic phenomenon and the energy problem. In the third chapter, an original analysis of the Danish wind cluster is developed, applying several research frameworks, such path creation and path dependence; the switching point and first-mover analysis; analysis of spillover effects and the Porter diamond of national competitive advantage. Finally, in the fourth part the thesis elaborates a three-channel analysis on the trajectories and the future development of the Danish wind cluster, based on five interviews conducted by the author with academics and managers directly operating within the cluster, and representing some of the leading firms found in the cluster.

Findings

The following conclusions emerge from the analysis conducted:

- Cluster are one of the most successful development models when it comes to enhancing the impact of such a growing and innovative product as wind turbines and the supply chain providing all the components related to this product. The Danish wind cluster is a clear demonstration of how effective this model is.
- Once a product has reached its industrial maturity, and a specific level of mass production, its supply chain will start to move towards countries where

the production models are dominated by lower costs. This is what is happening within the Danish wind cluster's supply chain system.

- The development of the Danish wind cluster shows that, once it has developed a powerful technology advantage, this will endure in time, and it will actually attract foreign investors who are looking to enjoy the spillover effects arising from the district.

The government policies and public financing mechanisms can be a powerful tool in order to augment the growth and the improvement of such an industry. In order to do so, feed-in tariffs are an effective policy tool to use in the expansion stage, while market-based mechanism tend to be more effective once the industry reaches maturity.

I. THE CLUSTER PHENOMENON

1.1. Defining clusters: some history

There are some phenomena that have been often studied with insufficient attention, although having a primary importance in the global economic dynamics. The emergence of clusters is one of those. Few people really know what clusters are and what they represent for the modern, highly globalized world economy. Therefore, it is crucial to clarify how they work and which are the main forces that influence their trends and their functioning.

In the modern world the concept of geographic proximity has been rapidly losing its importance. Internet, strikingly rapid means of communication and transportation, satellites, have encountered the atavist need of human kind to narrow the world distances and to connect people from all over the planet.

However, even in such a modernized and interconnected world-wide environment, the role of propinquity is far to be exhausted. Overall in the industrial macro-environment, clusters and geographic conglomerates of economic actors, companies and institutions have emerged as one of the most fascinating events of the last 50 years.

In "The Competitive Advantage of Nations", Michael Porter (1990) sets the guidelines for a more conscious and careful analysis on the trajectories of global competitiveness. His analysis focuses on the role of clusters as triggers for a new phenomenon which can be called *coopetition*. In fact, within industrial conglomerates, firms do not just compete for gaining a competitive advantage over another. This is a crucial aspect of their interactive relations. However, firms which operate in a geographically close environment, develop the tendency to cooperate as well. This process can be intentional or unintentional. In both cases, it generates positive effects that are going to be analyzed in this chapter.

Before focusing on the positive aspects that clusters are able to initiate, a more clear understanding of these is needed. Giving a precise definition to industrial districts has been the main concern for many important scholars since the early XX century. Indeed, the first to understand the complexity and the advantages arising from geographical proximity of firms within the same industry was one of the most inspiring economist of all time, Alfred Marshall.

Strongly influenced by the Marxist epistemological approach, according to which *praxis* has to necessary accompany the theoretical research, Marshall undertook a so-called "*Wanderjahre*[1] among factories" in the first decade of XX century. During this self-imposed trip among the English factories of the Lancashire District, he succeeded in deeply understanding some important dynamics standing behind the industrial agglomeration. Visiting a huge number of wool and cotton knitwear factories, he demonstrated that a clustering economy - such as the English one in the late XIX and beginning of XX century - can be as efficient as a strongly mechanized, standardized and labor based one - such as the American during the same period.

Starting from these practical findings, Marshall could provide a rather specific definition of industrial agglomerates, already in his "Principles of Economics" (1920). According to the English economist, an industrial district is an area in which a concentration of firms has developed. However, this concentration does not resolve in a mere localized industry. On the contrary, it refers to *"an industry concentrated in certain localities"*[2].

The agglomeration process can occur for different reasons: the demand for particularly high specialized and high quality goods; the necessity of connecting the economic activity to the natural resources; the presence of a close, industrial city which

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[1] "Internship" in German.

[2] A. MARSHALL, *Principles of Economics*, London: Macmillan. 1920. p. 268

works as benchmark for both the labor force and the services connected to the industrial activities[3].

Therefore, Marshall argued that when an industrial district is settled, then several positive effects can emerge: the creation of hereditary skill, the growth of subsidiary trades; the usage of highly specialized machinery; the creation of an internal labor market for highly specialized laborers; the strength of an industrial leadership, stimulated by the vitality of the district; the introduction of innovative means of production[4].

Anyway, all the first half of the XX century was dominated by the Ford-Taylor model of production. This system was based on the vertical integration of the firms, the production of highly standardized goods for a vast public of consumers and the usage of poorly skilled labor force. The industrial district model was just a theoretical remembrance which seemed not to be applicable in the dynamics of the remarkably growing capitalistic world, after World War II.

However, in the 1970s, the Fordist-Taylor model entered a deep crisis, driven by the profound changes of the global geopolitical and economic structure. The energetic crisis in 1973-1974; the saturation of many markets; the emergence of new global competitors being able to offer a great quantity of low skilled and underpaid labor force; the occupational saturation in the Western countries were just some of the main factors influencing the shift from a mass production model to others, much more involved in the quality and diversification research.

The emergence of the industrial districts has started in such a multifaceted environment. One of the first attempt to give a narrow notion of the phenomenon was made by Giacomo Becattini in “The Marshallian industrial district as a socio-economic notion” (1992). According to Becattini industrial districts *“are socio territorial entity*

[3] F. BELUSSI AND K. CALDARI, *At the origin of the Industrial District: Alfred Marshall and the Cambridge School.* Department of Economics, University of Padova. 2008. p. 2-3

[4] A. MARSHALL, *Principles of Economics*, London: Macmillan. 1920. p. 271

which are characterized by the active presence of both a community of people and a population of firms in one naturally and historically bounded area. In the district, community and firms tend to merge"[5]. Becattini's idea of an industrial district was strongly based on Marshall's studies. However, he makes an important step forward. Becattini's district is centered on the sociological concept of a local community, a socio-cultural *milieu*, in which the firms are nothing but one of the many actors. This was the milestone of the Italian concept of industrial district and it fit the history and the tradition of the Italian experience, overall in the textile industry of the Central Italy (in Toscana and Emilia Romagna)[6].

Starting from the studies of Becattini, and considering the evident emergence of the phenomenon, a vast literature has come out during the following two decades. The most important contributes were given by Paul Krugman in "Geography and Trade" (1991) - where the Marshallian influence is clear and undoubted - and overall by Michael Porter. In "The Competitive Advantage of Nations" (1990), he performed a study of the tile industrial district in Sassuolo, Italy, highlighting the importance of geographical proximity. Afterwards, in "On Competition" (1998), he first gave a distinction between clusters and industrial district, defining the latter as a particular case of the former.

Porter added a fundamental contribution to the theoretical consolidation of the industrial district notion. According to Porter, a cluster is a *''geographic concentrations of interconnected firms, specialized suppliers, service providers, firms in related industries, and associated institutions in particular fields that not only compete but also cooperate"*[7]*; "a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complemen-*

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[5] G. BECATTINI, *The Marshallian industrial district as a socio-economic notion*, International Institute of Labor Studies. Genova, 1992

[6] F. SFORZI, *Il distretto industriale: da Marshall a Becattini.* Il pensiero economico italiano, Università di Parma, Dipartimento di Economia. 2008. pp. 73-74

[7] M. PORTER, *On competition*. Boston: Harvard Business School Press. 1998. p. 197

tarities. The geographic scope of clusters ranges from a region, a state, or even a single city to span nearby or neighboring countries. […] The geographic scope of a cluster relates to the distance over which informational, transactional, incentive, and other efficiencies occur"[8].

Comparing this definition with Becattini's, we can easily capture the difference that separates the industrial districts from the clusters. Porter's idea of clusters focused on the economical and institutional macro-environment, whereas Becattini centered his attention on the set of socio-cultural aspects which the district was embedded in. As Porter points out, *"more than single industries, clusters encompass an array of linked industries and other entities important to competition. They include […] suppliers of specialized inputs such as components, machinery, and services as well as providers of specialized infrastructure. Clusters also often extend downstream to channels or customers and laterally to manufacturers of complementary products or companies related by skills, technologies, or common inputs. Many clusters include governmental and other […] associations and […] collective bodies. Finally, foreign firms can be and are part of clusters, but only if they make permanent investments in a significant local presence"*[9]. It is clear that a sort of interchangeability between the two concept exists. However, Porter's notion of clusters seems to include the Becattini's one.

In the following years, many scholars brought their share to the debate. For example, authors such as Markusen (1999), Martin and Sunley (2003) strongly criticized the lack of precise boundaries in the definition provided by Porter. However, we can still consider Porter's work as the theoretical benchmark, as the next pages will demonstrate.

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[8] M. PORTER, *Location, competition, and economic development: local clusters in a global economy,* Economic Development Quarterly, 2000. pp.15-20

[9] M. PORTER, *Clusters and the new economy of competition,* Economic Development Quarterly, 2000. p.78

1.2. The cluster classification

Going on with the description of clusters, it is particularly important to consider the contribution provided by Henry Wai-Chung Yeung, Weidong Liu and Peter Dicken (2005). As a matter of the fact, they proposed an important classification of the three different model of existing clusters.[10]

As seen in Figure 1.1, these authors, starting with the former categorization of Gordon and McCann (2000), distinguished among three typologies of how clusters can arise.

Model of clusters	Intellectual traditions	External economies accrued to firms in clusters	Territorial sources
Pure agglomeration economies model	Neoclassical economics after Alfred Marshall	—A local pool of specialized labor (lower search costs) —Local provision of non-traded inputs (economies of scale) —Maximum flow of information and ideas (product and market knowledge)	Within clusters
Industrial complex model	Location theory after Alfred Weber	—Lower transport and logistics costs —Greater certainty in transactions	Within clusters
Social network model	Embeddedness in new economic sociology	—Localized trust and inter-personal relationships (relational assets) —Institutionalized practices, for example, conventions and norms (institutional thickness)	Within clusters

Source: Adapted from text in Gordon and McCann (2000).

Figure 1.1: type of clusters[11]

The first is the so-called pure agglomeration economies model. These are the industrial districts which have grown due to a high degree of natural integration. This means that the firms in the agglomeration operate in the same industry. Therefore, they enjoy external economies deriving from the geographical proximity and the similarities among their production processes. This model does not enjoy any kind of

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[10] H. WAI-CHUNG YEUNG; W. LIU, P. DICKEN, *Transnational Corporations and Network Effects of a Local Manufacturing Cluster in Mobile Telecommunications Equipment in China*. World Development Vol. 34. 2005. p. 524

[11] I. R. GORDON, P. MCCANN, *Industrial clusters: Complexes, agglomeration and/or social networks?* Urban Studies. 2000. pp. 514–537.

traded interdependences - the external economies of collective bargaining and production capacity accumulated in the firms within the cluster. In fact, pure agglomerates are usually generated by the pooling of specialized labor force; the possibility of enjoying economies of scale; and the high spillovers in terms of technology and knowledge. Thus, they are basically "open systems" in which the firms have free entrance to the district[12].

The second model consists in the industrial complex. In this model the transaction costs among the firms are strongly reduced. This is possible because of the geographical proximity of the firms. These types of agglomerations strongly rely on the importance of inter-traded interdependences. Firms cooperate and compete one with another to achieve the external benefits deriving from the interdependencies. This can be translated also in common plans or decisions among the firms. The industrial complex model applies particularly well in those sectors where *"spatial proximity enhances inter-firm transactions along particular production chains via the formalization of just-in-time production and supply chain management practices"*[13] such as chemicals, oil, automobile, etc[14].

Finally, the third case considers the social network model. In this particular type of clusters, local networking and personal relations among the cluster's actors are fundamental for the efficiency of the industrial district. Thus, the trust among the participants in the economic activities enhances the linkages and makes professional relations more solid. Therefore, the companies trust one another and they are able to institutionalize cooperative practices, tacit knowledge and tradition spillovers. Corporations are highly localized, and the benefits of the clustering process derive from the

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[12] H. WAI-CHUNG YEUNG; W. LIU, P. DICKEN, *Transnational Corporations and Network Effects of a Local Manufacturing Cluster in Mobile Telecommunications Equipment in China*. World Development Vol. 34. 2005. p. 523

[13] H. WAI-CHUNG YEUNG; W. LIU, P. DICKEN, *Transnational Corporations and Network Effects of a Local Manufacturing Cluster in Mobile Telecommunications Equipment in China*. World Development Vol. 34. 2005. p. 525

[14] *Ibidem*. pp.523-525

services, productive activities and ancillary facilities the firms share. In the social network, the external economies derive principally from the knowledge transfers, which are strongly connected with the spatial and socio-cultural proximity.

However, these types of clusters are not only connections of local entities in "familiar" environments. In the social networks, some important connections with the global network exist as well. Often, the most productive firms in the regional district, are strongly related with large multinational enterprises, which provide them support and funds to keep on their activity. As a matter of the fact, in the last years, many firms producing within the social network, have adopted the global, modern way of production, or become part of a global value chain process[15].

1.3. How do clusters work?

This section will focus on the dynamics as a base of the success of the cluster model. A cluster is a winning model of an economic system as it triggers a sequence of important phenomena. First, in the cluster the presence of suppliers of specialized inputs makes the value chain more flexible and accessible. Moreover, clusters give the corporations access to accurate, pertinent and specialized information. This means that members have a privileged access to extensive market, technical and competitive information. Thirdly, in clusters, multinational enterprises may have an important role. In fact, they tend to supply sources of technology and innovation, modern managerial and learning-by-doing practices to the local firms. Furthermore, they generally furnish specific infrastructures to the firms' activity. Finally, they link the local firms to the global value chain, increasing their productivity and efficiency[16].

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[15] H. WAI-CHUNG YEUNG; W. LIU, P. DICKEN, *Transnational Corporations and Network Effects of a Local Manufacturing Cluster in Mobile Telecommunications Equipment in China*. World Development Vol. 34. 2005. pp. 525-526

[16] M. PORTER, *Clusters and competition: new agendas for companies, governments and institutions.* From, *On competition. Boston*: Harvard Business School Press. 1998. pp. 4-12

According to Porter, clusters are particularly efficient in creating a noticeably larger competitive advantage to the firms. This happens because the competition mechanisms are particularly sophisticated, the degree of personal relations is higher than standard industries, direct communications are widely available and networks are particularly interactive; finally, the organizational structure of the system tends to be informal and elastic.

1.3.1. How clusters affect productivity

Clusters influence the competitive advantage in three ways. In the first place, they have a strong impact on *productivity*. This can generate further typologies of benefits. For example, clustering of firms improves the *access to highly specialized labor force and inputs*. This fact derives maximally from the advantage of geographical proximity. In fact, in a cluster, the presence of specific suppliers renders the procurement of machinery, services, components and employees much easier than in a classical competitive environment. The high demand for specific assets encourages the formation of a locally-based supplier-pool and the entrance of new ones from outside[17].

Another important effect of clusters over productivity is represented by the *improved access to information*. Firms in the agglomerate enjoy a better flow of information given by the geographical closeness of the firms and their suppliers and technological spillovers. Moreover, the inter-firm relationships are oriented towards trust and cooperation. In this setting, information flows faster and more efficiently[18].

In clusters, is very likely to find *complementary activities*, which improve both the productivity and the efficiency of the overall system structure. This effect manifests in several ways. For example, through complementary products for the buyers, firms are able to create value for the customers. The particular conformation of the cluster

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[17] M. PORTER, *Clusters and competition: new agendas for companies, governments and institutions.* From, *On competition. Boston*: Harvard Business School Press. 1998. p.13

[18] *Ivi*, p. 14-15

can trigger a coordinating mechanism which will tend to improve the quality of the overall efficiency of the supply chain. Other kind of complementarities are the so-called marketing complementarities. These manifest in conjoint activities with the firms that operate in the same sector. Examples of this phenomenon can be the joint marketing actions. Moreover, this kind of complementarities can also create a positive effect on the location reputation of a particular industrial sector and consequently reduce the perceived risk of the customers. The final type of complementarities is represented by the ones rising from the better alignment of activities among cluster participants. This alignment generates from the strength of the linkages existing inside the cluster between the corporations and the suppliers, the distribution channels and the other downstream activities of the value chain[19].

The *access to institutions and public goods* is another very important issue. Within clusters, firms are able to manage public or quasi-public goods. For example, the access to specialized infrastructure in a cluster are cheaper, or the turnover expenses to replace high skilled labor force lower. Some public goods in clusters are actually created thanks to the healthy competition within them. It is the case of information, technology, reputation and so forth. Moreover, public or quasi-public goods can be managed also because of the funds of private investors, attracted by the possibility of the profit of being part of the cluster activity range[20].

Clusters also provide *incentives* to cope with the agency problem that is typical to the most vertically integrated industries. The most important effects are: pressure from the firm's competitors; pressure from the firm's peers - the firms operating in the cluster have similar levels of productivity. In the cluster the transaction costs are strongly reduced and managers can also use shared, more efficient tools for performance measurements.

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[19] M. PORTER, *Clusters and competition: new agendas for companies, governments and institutions.* From, *On competition. Boston*: Harvard Business School Press. 1998. p. 15-17

[20] M. PORTER, *Clusters and competition: new agendas for companies, governments and institutions.* From, *On competition. Boston*: Harvard Business School Press. 1998. p. 15-17

1.3.2. How clusters affect innovation

The second big macro-area which is strongly affected by a cluster model of development is the innovational one. In a cluster the high concentration of firms within the same industry or related ones, the fast flow of information and the trust and cooperative relationships render the technology and knowledge spillovers easier than what happens in an isolated location. Moreover, in a cluster, the high efficiency and coordination degree of the distribution channels, the average high rate of Research and Development (R&D) expenses, the high degree of competition and the possibility to have a face-to-face relation with both the competitors and the suppliers, facilitate the learning process.

This agility in capturing and managing innovation, is one of the most important features of the clustering phenomenon. Corporations operating in a cluster have a strong technological advantage over their external competitors. As a matter of the fact, they tend to be more preemptive to change, more flexible and adaptable to the continuously transforming global demand and exigencies. They are able to develop new technologies and supply faster their clients with new materials, activities, services and facilities required. Furthermore, the process of capturing innovation is implemented by the constructive presence of specific suppliers and complementarities within the cluster itself.

Moreover, the strong competition within the cluster implies that the firms ought to find alternative ways of competing. On one side, the pressure deriving from competitors and peers is like an engine triggering even further the tendency of the firms to innovate and generate creative, modern and always different managerial techniques, organizational structures or productive technologies. On the other hand, the imitational mechanisms are particularly active within a cluster. These render the competitive advantage deriving from such innovation, brief and volatile. Therefore, the seeking process towards more efficient technologies is constant and theoretically endless.

However, as Porter (1998) notices, in some cases, clusters can be also a hinder for the development of innovation. In fact, sometimes cluster are more embedded in traditional patterns in respect with isolated firm systems. Innovative production or managerial systems, in those cases, can be seen as a violation of socio-cultural and traditional patterns which have gone on for centuries. Another case can be a cluster model in which the competition is seen as a threat for the stability of the system and a sort of central controlling panel that sets some limits to the autonomy and independence of firms. Anyway, in general and under normal circumstances, clusters are a powerful booster of the degree of innovation in an economic system[21].

1.3.3. How cluster affect the formation of new businesses

It is universally recognized fact that clusters have been one of the most important sources of new businesses in the last decades. This trend is strongly influenced by the ability of a cluster to efficiently allocate information about new needs, exigencies and fashions of customers. This obviously tends to favor those firms which, operating in the cluster, have a direct access to updated indications and signals about the most appealing and promising businesses.

In addition, new business is very likely to develop in a cluster because of its tendentially low barriers to entry; the moderately reduced need of new assets or particularly costly facilities - many of the infrastructures are already settled in the cluster - the already strong presence of highly skilled employees; the facilitation of the financing system. Moreover, the inside-cluster market is an already significant sample testing of whether the new products or activities can provide an adequate amount of profits.

Sure enough, all these factors not only minimize the forecasted risk of entering a new business but also render the cluster as a magnet for enterprises willing to enter new businesses, and for firms located outside.

[21] M. PORTER, *Clusters and competition: new agendas for companies, governments and institutions.* From, *On competition. Boston*: Harvard Business School Press. 1998. pp. 17-18

Finally, clusters can also be incubators of new ideas and innovative businesses. In practice, large firms with impediments to innovate, may arrange alliances and contract with small, efficient and rapidly innovating firms within a cluster. As the business grows, the number of firms implanting their activities within the cluster, the dimension of the agglomerate tends to expand over time and to amortize and decelerate its openness. This, as a result, increase the level of barriers[22].

1.3.4. Coopetition and economic dynamics within a cluster

Finally the actual economic mechanisms which render a cluster such a profitable and interesting reality will be examined. In doing so, the fundamental references will be the works of Paul Krugman (1991, 1995) and Hubert Schmitz (1997).

Krugman recognizes that the economic benefits deriving from a cluster can be subsumed in a concept that he dubs as "Marshallian trinity". In practice, localization happens when there is a pooling of the labor market; when there is a presence of intermediate inputs – the presence of specialized suppliers within the cluster; and when technological spillover are very likely to happen.

Starting form this standpoint, Krugman indirectly introduces the concept of external economies which Schmitz will deepen in his own analysis. Marshall was the first to theorize what external economies are. In his view they are economic phenomena that happen when *"agents cannot capture in the price of their product all the benefits of their investment"*[23]. In brief, the effect of an external economy is an involuntary benefit to external economic actors. Therefore, the main characteristic of external economies is their being incidental[24].

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[22] M. PORTER, *Clusters and competition: new agendas for companies, governments and institutions.* From, *On competition. Boston*: Harvard Business School Press. 1998. pp. 17-18

[23] H. SCHMITZ, Collective efficiency and increasing returns, DS Working Paper 50. 1997. p.7

[24] E. J. MISHAN, *The postwar literature on externalities: an interpretative essay.* Journal of Economic Literature, Vol. 9 No 1. 1971. pp. 1-28

These kind of economies are particularly important when it comes to explain the widespread of clusters throughout the world. However, it is important to notice that within a cluster the incidental external economies are not the only force in play. In a cluster there is also a completely voluntary component which operates. Schmitz calls this second component “joint action” which can be categorized in two different ways: cooperation of single enterprises or association of firms’ groups.

From the fusion of external economies and joint actions we can finally derive the concept of collective efficiency. Schmitz defines this entity as the actual competitive advantage which arises from a cluster. The collective efficiency can be unplanned or planned. In the former case, the benefits of the cluster are related with the unintentional activities and dynamics developing within the cluster. Instead, the latter refer to the joint measures and deliberate actions being voluntarily undertaken by the firms.

Another central issue, when analyzing clusters, is the concept of increasing returns. This phenomenon will be studied starting from the striking assumption that the classical economic mainstreams cannot explain how cluster works. As both Krugman and Schmitz admit, clusters are able to generate what in the typical conception of a Ricardian economy sounds absurd. Increasing returns exists and clusters generate them. However, this theoretical *impasse* is just a matter of mathematics. Although very difficult to frame in a systemic framework, increasing returns clearly exists, because of the direct proof experience provides us. Just, this existence is rather uncomfortable and it would mean to revise the very same pillar of the neo-classical economic model. Many scholars have recognized the importance of such a phenomenon. Romer (1986)[25], Murphy, Shleifer and Vishny (1989)[26] have been the pioneers of modern economic theory which include increasing returns. Krugman himself has

[25] P. ROMER, *Increasing returns and long run growth*, Journal of Political Economy, Vol. 94 No 5. pp. 1002-1037

[26] R. MURPHY, A. SHLEIFER, R. VISHNY, Industrialization and the big push, Journal of Political Economy, Vol. 97. 1989. pp. 1003-1026

been involved in such a revision activity. All these authors focused their research essentially on industrial districts and they found out that their huge growth during the last 40 years has been driven precisely by the creation of such increasing returns.

But, what are increasing returns? They are those economical phenomena which determine a more than proportional increase in the output in case of an increase in the input. Schmitz specifies that they can be called, even more precisely, increasing returns of scale. Clusters, *"through the impressive range of handling agents, transport specialists and marketing agents"*[27] have been able to go past the two main theoretical hinders to the acceptance of returns of scale. The specialization and labor process splitting up; the intermediate processes; the roundabout methods of production and distribution process are all phenomena which can trigger the "miracle". And clusters are the cradles of those phenomena[28].

Increasing returns and external economies are fundamental concepts when it comes to understand clusters' performances. In fact, these two issues are strongly connected to one another. As we have seen, external economies can be characterized as economic scenarios in which *"private costs or benefits do not equal social costs or benefits. If the social costs are higher than private costs, we speak of external diseconomies; when social benefits are higher than private benefits we speak of external economies"*[29].

In clusters, there are two typologies of external economies: pecuniary and technological. The first case describes the situation in which if a firm enterprises an investment, this will automatically produce an increase in the output for its suppliers and, consequently, a cheaper unitary price for all the suppliers' customers. On the other hand, a technological external economy emerges, for example, when a firm increases the skills of its employees, through training, formation courses and so on. If those

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[27] H. SCHMITZ, Collective efficiency and increasing returns, DS Working Paper 50. 1997. p.15

[28] *Ivi*. p.12-15

[29] H. SCHMITZ, Collective efficiency and increasing returns, DS Working Paper 50. 1997. p.15

workers change their employer, they produce spillovers in terms of technology, knowledge, information. This is of course not the only case. Similar spillovers can happen in case workers have personal relationships with other firms' employees, or through the stream of knowledge passing from suppliers and their clients. Within a cluster all information and knowledge pass from an actor to another with a higher speed than in a normal industrial environment. And this is one of the key of their success[30].

1.4. Clusters and government

Clusters do not have positive effects only over the confined industrial environment. As a matter of the fact, they provide direct and indirect benefits also to the whole economy of the country where they have settled. For this reason, governments and political institutions often tend to interfere or cooperate with the dynamics ruling the agglomerates. However, the political interference can be dangerous for the industrial districts. Great part of the clusters emerge spontaneously as a result of geographical and economic mechanisms. Attempts from political institutions to build industrial agglomerates from ground zero are generally doomed to fail.

However, governments and legislation organisms can have a very important role in the expansion of clusters. But, this involvement should be totally functional to the intrinsic dynamics and should not be directed to interfere or control them. Government can have an extraordinary importance when it comes to upgrade obsolescent or traditional clusters. In order to do so, the political organisms should seek policies which are not just focused on the firm or industry levels. On the contrary, a government plan should put its attention on the whole cluster level.

The role of government should be the one of linking and grouping together all the production and industrial actors operating within the cluster. It should not intervene

[30] H. SCHMITZ, Collective efficiency and increasing returns, DS Working Paper 50. 1997. pp.14-16

on competitive issue which could depress or modify the structure of the district. However, institutions should simply try to enhance and amplify the effects of the external economies and the spillovers.

The presence of political institutions operating in the cluster may support the formation of public and quasi-public goods, as well. Moreover, it can improve the level of the infrastructure, by pushing the public expenditures toward the cluster area. Finally, clusters are the living representation of market failure because of the presence of the external economies. Therefore, in some cases, the intervention of the political legislator seems almost necessary. As Putnam (1993) implies, within a cluster an interconnected action between the private and the public sector is the key for success, because an efficient cooperation between them can lead to synergies between the self-help organization and the public intervention[31].

[31] R. D. PUTNAM, *Making Democracy Work: Civic Traditions in Modern Italy*, Chichester: Princeton University Press. 1993

II. ENERGY PROBLEM AND WIND POWER

2.1. The energy problem in the globalized economy

In this second section, the actual subject of this thesis paper will be highlighted, by analyzing the importance of the renewable energies and the reasons why I have chosen to write about the wind power. In doing so, it is impossible not to deal with the energy problem.

The energy problem is one of the most important issues that mankind has faced in the last four centuries. In the modern world, at least once in a lifetime, everyone has heard some news about this impellent crisis which affects almost each and every aspect of human life. The energy problem stands behind many of the most important events of the last century's history, both the most cataclysmic ones and the ones which seems tightly connected with the daily routine. Examples can be the Ozone Hole over Antarctica; the Persian Gulf Wars I and II; the 2008 global downturn; the general heating up of the Earth Atmosphere; but also the daily increase of the oil and diesel prices.

Therefore, it is quite easy to notice the vast influence and repercussions that the energy problem has over the contemporary economic and political dynamics. However, it is not completely clear what we generally mean when we refer to this issue. Thus, a general definition is required. The energy problem is that challenging situation that human kind has to face and that derives from three different causes: the fact that fossil fuel resources are not unlimited; the political issue deriving from the difficulty to provide a secure supply of these resources and, finally, the impact that these resources have on the global environment.

These three issues are different faces of the same medal. In first place, the scarcity of the fossil fuel is a fact which cannot be denied. Fossil fuels are generated by the residuals of the process of anaerobic decomposition of buried living organisms and unicellular creatures, such as diatoms. To gather one liter of gasoline an almost 20 metric tons of accumulated organic material is needed. To complete the process from a living creature to a fossil fuel a period of averagely 650 million years is required[32]. These simple facts can give us a striking impression of the slowness of the gathering process which stands behind the accumulation of fossil fuel resources. And it can give an idea of the main reason of the scarcity and, therefore, high value of these precious resources. However, together with the natural lifetime of fossil fuels, there is a historical event which speeded up their consumption and led to the actual scarcity situation: the industrial revolution.

Since the invention of the steam machine by James Watt in 1764, the human kind has deeply modified and influenced the consumption and the natural life cycle of fossil fuels. Since late 1700, the human consumption of fossil fuels - overall coal and oil - has been growing at a monstrous growth rate and it seems that between 1990s and 2010s we are reaching the so called oil peak, the historical largest consumption of oil in the history, both in terms of past and future perspective[33].

Nowadays, coal and petroleum based sources of energy are by far the most widespread in the world and, at the same time, the lowest growing of all the energy sources. This fact is given by many factors: exorbitant prices, political instability of the producing countries and a physiological decline, which Hubbert oil peak plot represents in the graphic below. After a continuous and steep development over the past three centuries, the projections for the period 2007 - 2035 say that oil consumption will grow of a mere 0.9% per year, although being expected to remain the largest energy source.

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[32] D. J. C. MACKAY, Sustainable energy – without the hot air, UIT Cambridge. 2008. pp. 2-6

[33] http://en.wikipedia.org/wiki/File:Hubbert_peak_oil_plot.svg

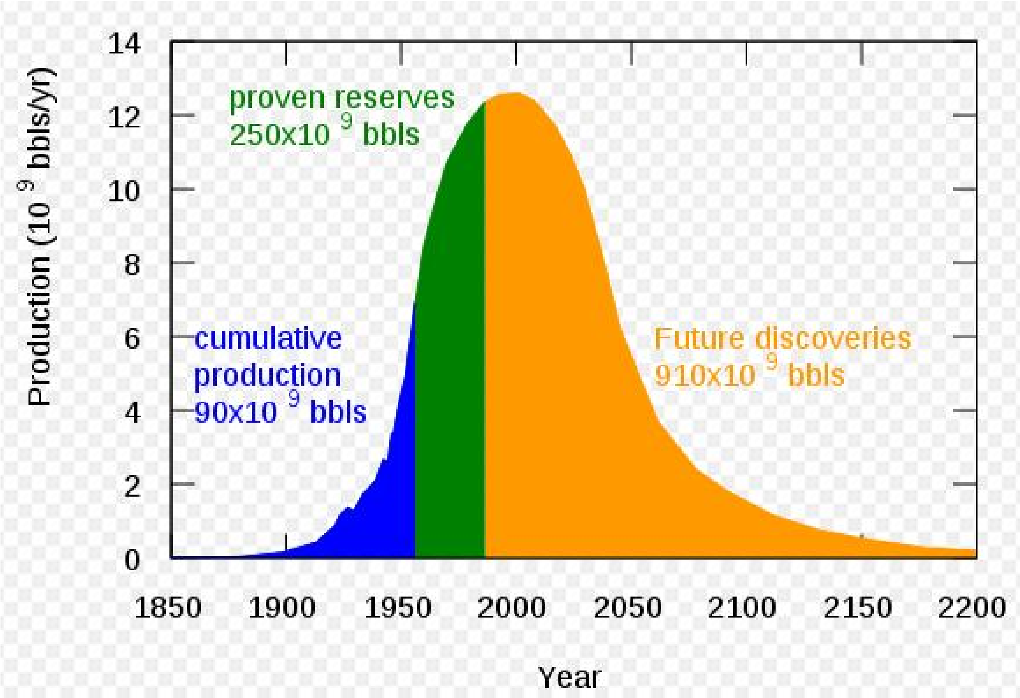

Figure 2.1: Hubbert oil peak curve[34]

The other fossil fuel sources will remain very important over the next 50 years, even though they are doomed to slow down their consumption as well. Statistics by the Energy International Agency (EIA), show that natural gas consumption will grow by 1.3% per year, from 108 trillion cubic feet in 2007 to 156 trillion cubic feet in 2035, with just a 0.9% increase between 2020 and 2035.

Coal is expected to grow more steeply because of the large consume of developing countries such as India and China. However, its usage will strongly decrease in the Western countries. This counterbalanced growth will lead to an average increase of 1.6 % per year from 2007 to 2035, however with a largest part of the demand increase occurring after 2020[35]. In the next four graphics we can have an idea of the general performances of fossil fuels over time.

[34] http://en.wikipedia.org/wiki/File:Hubbert_peak_oil_plot.svg

[35] International Energy Outlook 2010. http://www.eia.doe.gov/oiaf/ieo/world.html

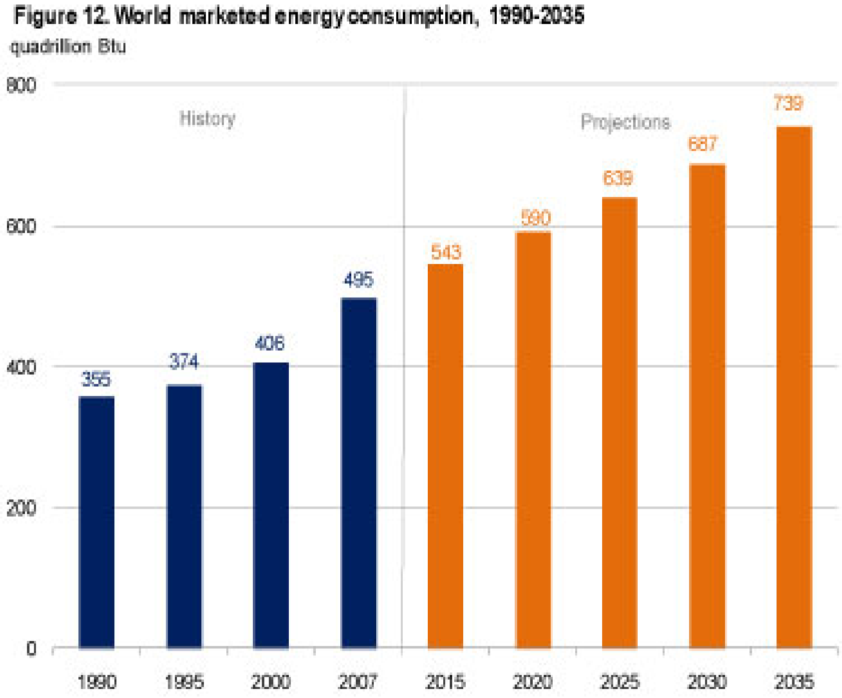

Figure 2.2: world energy consumption

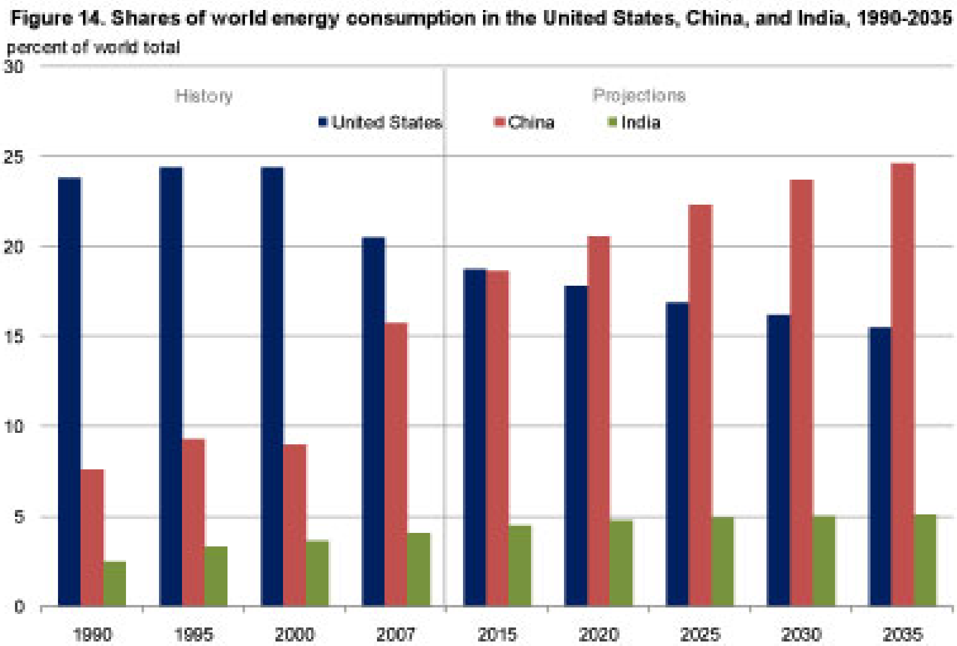

Figure 2.3: shares of world consumption in India, China and USA

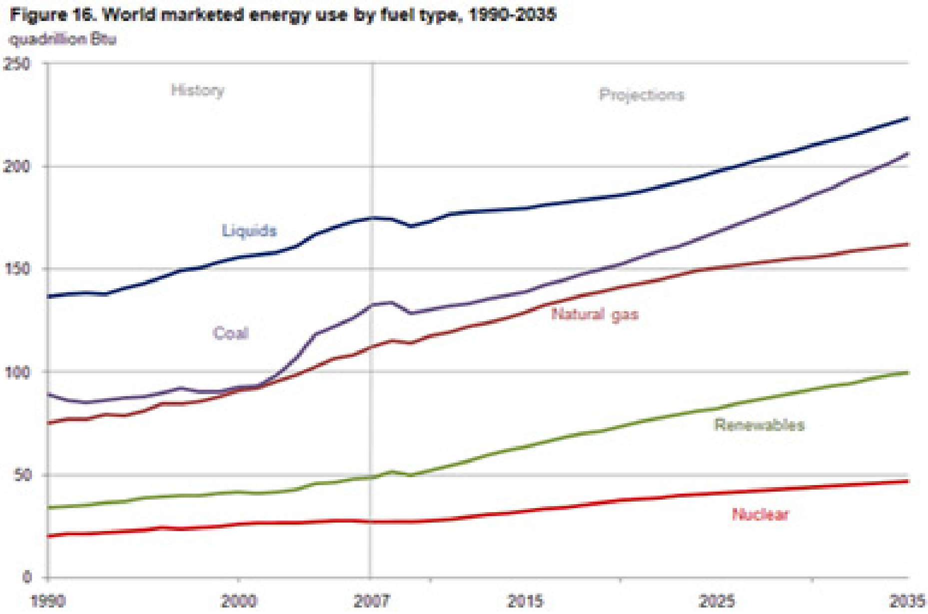

Figure 2.4: energy types by fuels

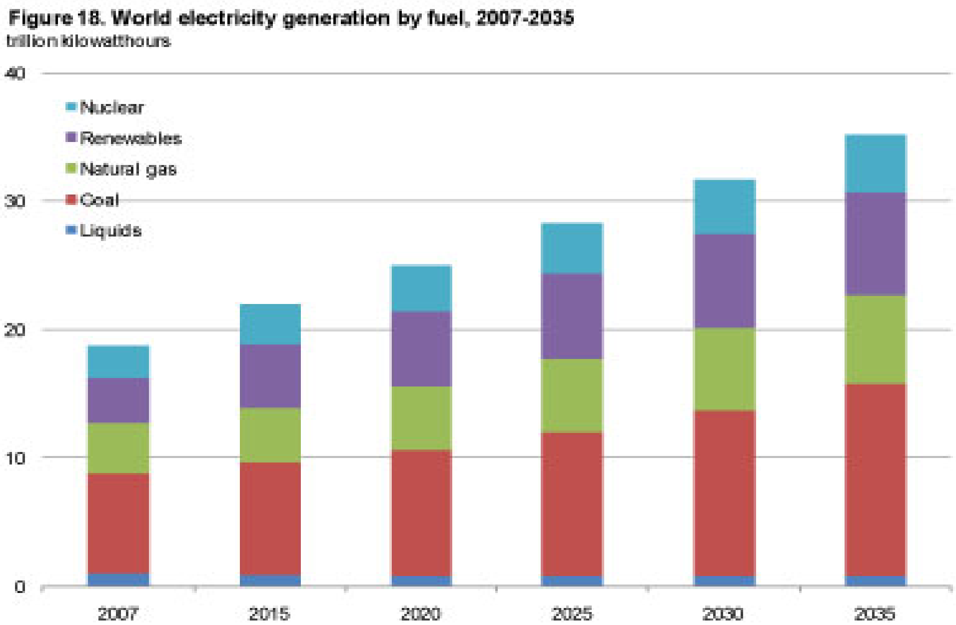

Figure 2.5: world electricity generation by fuel[36]

[36] International Energy Outlook 2010. http://www.eia.doe.gov/oiaf/ieo/world.html

The second component of the energy problem concerns the security of energy supply. The composition of the global demand for energy has been certainly changing in a way that will lead Asia to be the leader continent in consumption of energy, replacing Western countries. This means new competitors in a market which is dominated by very few raw material suppliers - namely the OPEC countries. Besides, the traditionally strained relations that these nations keep up with the Western countries, render the political situation very unstable. Generally the OPEC members - detaining 79% of world total reserves of crude oil - are ruled by autocratic regimes, often strongly critic against the capitalistic and Western model of development. This means: international tensions and high bargaining power of the fossil suppliers. If we add the rather endemic presence of the Islamic fundamentalism in these States, we can easily understand why Western world cannot feel secure when it comes to energy supply. Thus, it is imperative to find alternative ways.

This dangerous geopolitical situation can be considered as the main cause of many of the energy crisis which have happened since the beginning of 1970s. The 1973-1974 crisis; the 1979 one; the First and Second Iraqi Wars and the indecision that EU countries have in intervening in the North African Revolutions are just some examples of the incredible importance and power of bargaining these countries have in the international scenario.

Finally, the third part of the energy problem is strictly connected with the global warmth of the planet temperature and the greenhouse gas emissions, which are considered to be the main cause of this dangerous phenomenon. As it is shown in the following tables, the average CO2 emission rate remained steady and constant for over a millennium. Since 1000 a. D. until 1700s the emission rate has been stable on a level of 270ppm of CO2 concentration. The situation has drastically changed since the second half of 1700s, when the industrial revolution took place.

As MacKay (2008) explains, after this turning point event, the global consumption for fossil fuels - coal and oil, mostly - has hugely increased. In the sole Great Britain, from 1770 to 1870 the production of coal had raised of 1600 per cent. The UK coal peak happened in 1910, but the global production and extraction of fossil fuel has kept on for more than a century. And the increase of these sources of energy has been constantly followed by a proportional increase of greenhouse gases into the atmosphere. The following graphics show the tendencies of coal production and CO2 emission rates over the past 300 years.

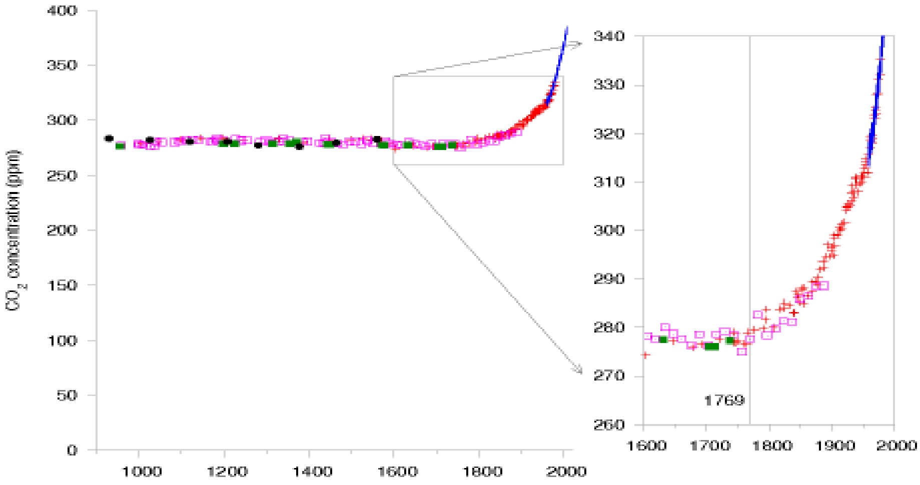

Figure 2.6: World carbon dioxide concentration in the atmosphere[37]

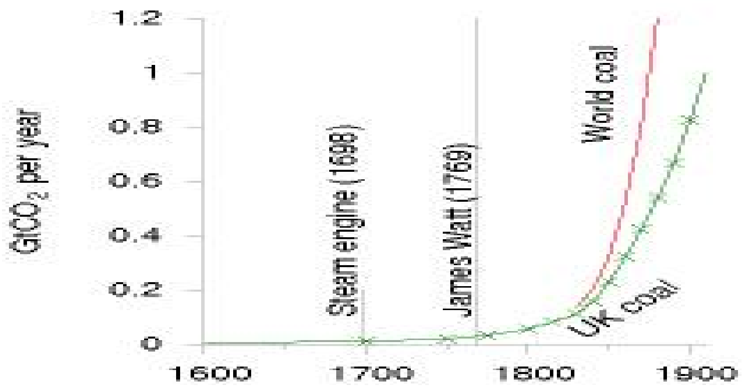

Figure 2.7: History of UK and world coal production[38]

[37] D. J. C. MACKAY, Sustainable energy – without the hot air, UIT Cambridge. 2008. p. 6

[38] *Ibidem*

Taking into consideration these data and having now an idea of what the energy problem is and which are its consequences, we can easily understand why the renewable energy represent a promising way out for the future of mankind.

2.2. The renewable energies as a solution and the case of wind power

In such an uncertain and unpredictable situation, the risk of a gradual but unstoppable society breakdown is not anymore just a science fiction scenario. The capitalistic society and economy relay almost completely on fossil fuels and the exhaustion of all the hydrocarbons seems to be a cataclysmic event that mankind has to seriously take into consideration.

The transition towards a non-fossil-fuel-based economy is just a matter of time. As we have already seen, the energy problem is undeniable and irreversible. When, in 1859, Edwin Drake extracted the first oil barrel, the mechanisms described by the Hubbert Curve started to influence the modern life style and economy. However, our biggest problem is to understand in first place how human kind has understood that a tragic final outcast is possible and which are the way-outs from that.

Concerning the first point, it is possible to draw a theoretical four stage analysis of how things are likely to happen in absence of a solution of the energy problem. The first step towards the plain realization of the dangers of a oil-based society can be called “Consciousness”. In the 1950s the first scientists started to study in depth the processes of formation and accumulation of fossil fuels and became aware of the extreme volatility of such a precious resource. However, they could not realize the dynamics and the timing of the exhaustion deadlines. Therefore, the most appealing solution seemed to be increasing the oil and other hydrocarbons’ prices. In few words: the end of the cheap oil age, with all the tragic consequences we have seen and studied over the past 50 years.

The second stage is the "Transition" from such a model of society towards a hydrocarbon-free one. People tend to be skeptical or indifferent about the consequences of depletion because they simply cannot picture a world without petrol and its derivatives. Transition is the longest and more delicate phase because it implies a *trauma*, perhaps one of the biggest shock of the human history. Therefore, such a transition can happen in an ordered way, through an initial state intervention or in a chaotic, anarchic way. If no alternatives are found, once all the fossil fuels are exhausted, mankind will go back to a rudimental society: this will be the "Scavengery" step, followed by a fourth one in which people will basically become "Self-sufficent" again.[39]

Of course this scenario does not take into consideration that humanity has the solution to the source of the energy problem all around in the planet where it lives. It is Earth itself the provider of an incredible and endless portfolio of energy sources that can be exploited without fearing of damaging the subtle equilibrium of almost any ecosystem: the renewable energies, of course.

In 1998, according to the UNDP report, *"renewable energy sources supplied about 14% of world primary energy consumption. The supply was dominated by traditional biomass (38 ± 10 exajoules a year). Other major contributions came from large hydropower (9 exajoules a year) and from modern biomass (7 exajoules). The contribution of all other renewables—small hydropower, geothermal, wind, solar, and marine energy—was about 2 exajoules. That means that the energy supply from new renewables was about 9 exajoules (about 2 percent of world consumption)."*[40]

In the next 10 years renewable energies have reached a tipping point. Nowadays renewables account more than 25% of the total energy supply and 18% of electricity power share. Moreover, the very same geography of renewable energy users is shift-

[39] P. THOMPSON, *The Twilight of the Modern World. The Four Stages of the Post-Oil Breakdown*, www.wolfatthedoor.org.uk. 2004. pp.4-5

[40] W. C. TURKENBURG, *Renewable Energy technologies*, in World energy assessment: energy and the challenge of sustainability, UNDP, 2000. pp. 219-221

ing in a very promising way. China and India are the "quantitative vanguards" of state-driven development processes which are giving results of prime importance. From 2005 to 2009, practically all the renewable sources of energies have faced astonishing growth. Solar power accounted an increase of 19% a year, biomasses and geothermal power also have grown in a significant share, with a meanwhile decrease of ethanol production of 20% a year[41]. The installed renewable energy capacity in 2009 was 1,230GW, with a 22% increase in respect to 2008. The following table gives a general idea of the amount and the increase of investments in renewables during the period 2007-2009.

SELECTED INDICATORS AND TOP FIVE COUNTRIES

SELECTED INDICATORS	2007	2008	2009
Investment in new renewable capacity (annual)	104	130	150 billion USD
Renewables power capacity (including only small hydro)[1]	210	250	305 GW
Renewables power capacity (including all hydro)	1,085	1,150	1,230 GW
Hydropower capacity (existing, all sizes)	920	950	980 GW
Wind power capacity (existing)	94	121	159 GW
Solar PV capacity, grid-connected (existing)	7.6	13.5	21 GW
Solar PV production (annual)	3.7	6.9	10.7 GW
Solar hot water capacity (existing)	125	149	180 GWth
Ethanol production (annual)	53	69	76 billion liters
Biodiesel production (annual)	10	15	17 billion liters
Countries with policy targets	68	75	85
States/provinces/countries with feed-in policies[2]	51	64	75
States/provinces/countries with RPS policies	50	55	56
States/provinces/countries with biofuels mandates	53	55	65

Figure 2.8: indicator in investments in renewable energies[42]

[41] AA. VV., *Renewables 2010. Global Annual Report*, REN21, Renewable energy policy network for the 21st century. 2010. pp. 8-11

[42] *Ivi*, p. 13

2.3. The wind power: facts and technology

Nowadays, the most outstanding growth and the source of renewable energy which seems to be the most affordable and reliable is by far, the wind power. Wind is the largest renewable energy for installed capacity (159 GW in 2009, with a 30GW yearly increase in 2009). From 2005 to 2009, wind energy was the fastest growing power source as well, with an average of 27% per year, which means that every year the installed capacity is more than 1/4 larger than the previous one.

The leader in wind power installation is China, that accounts almost 1/3 of the whole installed capacity whereas, just 5 years ago it did not reach 2%. In 2009, China added over 13.8 GW of wind power installed capacity; USA an additional 10GW and Germany 1.9GW. Together with this outstanding development, we have to include the power deriving from offshore wind farm, which nowadays account 641MW installed capacity, with a yearly increase rate of 72%. Wind provides large share of electricity to many countries. In Denmark, the 20% of electricity demand is faced by wind power; in Spain 14%; in Portugal 11.3%.[43]

Considering this huge potential, we will now try to give a slight overview about how wind power generates and which technologies stand behind this remarkable success. In doing so, we will take into consideration the "Wind power technology" report from EWEA, the European Wind Energy Association[44].

The modern designed wind turbine is an exceptional example of technology efficiency. It is a device which is projected to continuously produce electricity from the wind, whenever this natural resource is accessible. With an average activity life of 120,000 hours, it lasts almost 20 times more than a normal car engine. But, how is the turbine itself composed?

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[43] AA. VV., *Renewables 2010. Global Annual Report*, REN21, Renewable energy policy network for the 21st century. 2010. pp. 16-18

[44] EWEA, *Wind power technology. Operation, commercial developments, wind projects, grid distribution*, Renewable energy house. Bruxelles. 2005

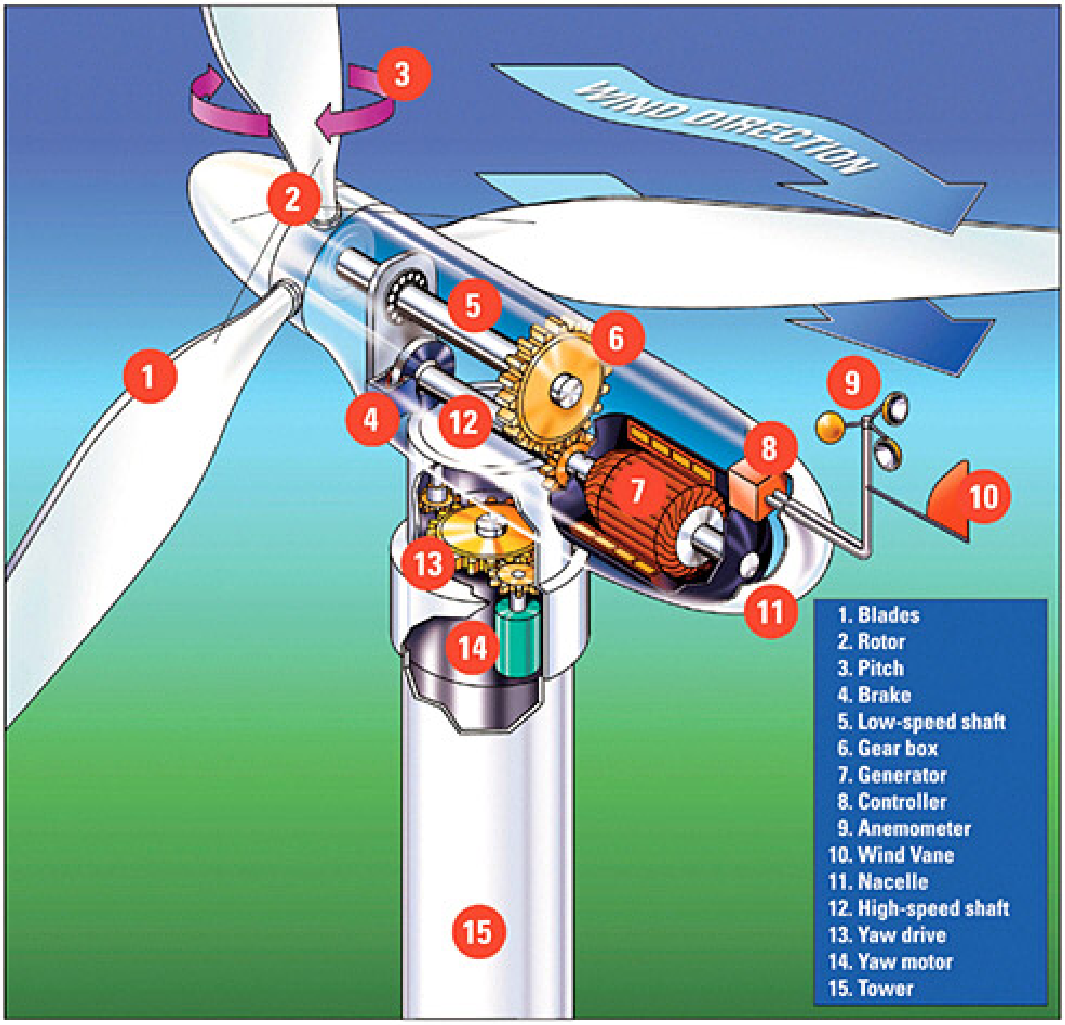

Figure 2.9: a wind turbine[45]

Figure 2.9 identifies a long metallic tower (n.15 in the picture) as the support for a three blade rotor (2), which has the function of capturing the wind breeze. This rotor is the fundamental component of the whole machine, because it transforms the wind into mechanical energy. It is made out of a fiberglass, polyester and epoxy composite material, often combined with wood or carbon.[46]

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[45] http://www.alternative-energy-news.info/technology/wind-power/wind-turbines/

[46] H. STIESDA, T*he wind turbine components and operation*, BONUS ENERGY A/S, Brande, 1999

The blades (1) are devices that regulate both the stall and the pitch - the rotation around the horizontal axis - of the rotor, through their speed and position. The stall can be controlled by the regulation of the blades' rotation whereas the pitch through the blades' angle shot. The wind is captured by the constant rotation of the blades. Successively, it passes through two shafts (5, 12) to a gearbox (6), or alternatively to a drive-train, that activate an electricity generator (7). All these components are hosted in a protective nacelle (11). Another important component is, as we have seen, the turbine tower that connect the rotor with the grid network[47].

Building and maintenance costs of a wind turbine, are relatively low. To build a 10MW wind farm the estimate time is two months, with an expected two member personnel each 25 turbines. Furthermore, a new turbine needs less than 40 maintenance hours per year.

Critical for the good functioning of a wind farm, is its connection with the grid – the electricity transmission and distribution network. There are three main problems connected with the distribution of wind energy: the fluctuations over the year of the wind as natural resource; the difference between traditional and wind based power stations and the location of wind farms. These problems imply the need of a superior grid system which can handle the intermittency problem, and face the challenging characteristics of variability and predictability.

In order to face the fluctuating input issue, the solutions are generally two: to produce a proportioned output of energy according to the wind availability in the area - namely, to forecast the output that a wind farm is likely to produce through short term meteorological analysis; or to connect the plants to the already existing grid. This is the case of the "Eltra" grid system in Denmark, which allowed the connection of northern Germany with the hydroelectric-power generators in Norway. A wind

[47] EWEA, *Wind power technology. Operation, commercial developments, wind projects, grid distribution*, Renewable energy house. Bruxelles. 2005

power penetration of 30% both in Norway, in Denmark and Northern Germany was guaranteed, with a risible adjustment of the local grid network.

The wide-scale commercialization of wind turbines is a relatively recent phenomenon. The first country to produce and sell turbines on a large range was Denmark in the 1980s. The first prototype of commercial turbine was a Danish 20 meters diameter rotor, with a productive capacity varying from 20 to 60KW. In time, the dimensions of such a device have increased sharply. Nowadays, an average turbine has a 60-90 meters diameter rotor with a capacity of 2MW - which is large enough to cover the energy demanded by up to 1,300 households. Today the world's largest turbine is the German Enercon E-126 with an overall capacity of 7.58 MW, a height of 198 meters, and a diameter of 126 meters[48].

Wind power is an incredibly versatile source of energy. As we have seen, its growth is constant and it reaches very high rates. Moreover, turbines are high technological machines based on a strong push on the development. This means that thanks to the constant improvement of a control and production mechanism, today an increase of the speed of the wind by 4m/s, create a growth of the energy output of 130%.

In Europe, it has been estimated that the mere onshore wind resource can generate an yearly average of 600 TWh electricity, with an additional 3,000 TWh, deriving from the offshore potential. To give an idea of the extent of these numbers, we just need to say that this 3,600 TWh, will largely exceed the whole European electricity requirement for one year. Concluding, considering these facts, we can state that wind power is a fascinating and incredibly promising energy source which can be considered as one of the most efficient answers to the perils of the energy problem and the depletion of fossil fuels.

[48] http://en.wikipedia.org/wiki/Wind_turbine#Largest_capacity

III. THE DANISH WIND CLUSTER

3.1. Facts and history of the Danish wind cluster

In this third section, the focus of the attention will shift to the main core of the *thesis*: the facts, the history, the forces and the strategies that render the Danish wind cluster one of the world's most successful example of how economic efficiency and environmental awareness can coexist and complete each other. In order to do so, firstly, we will study the history of the evolution of the wind industry in Denmark and afterwards we will apply some analysis framework which will provide us a critical approach and investigation over the phenomenon.

When it comes to wind power, it is rather impossible not to focus the attention on Denmark. The reason of this choice can be perfectly summed up by the words of Jan Hylleberg, the Danish Wind Industry Association (DWIA) CEO: *"Denmark is the first country in the world to pursue a climate plan for how to build an energy system that is independent of fossil fuels. Wind power already accounts for more than 20% of the total power consumption in Denmark. No other country has integrated so much wind power in its energy system. It is widely agreed that wind power will become the backbone of Denmark's future electricity supply. The Danish Wind Industry Association (DWIA) has defined a target that, by 2020, wind power should account for 50% of our electricity consumption. This target will drive developments in the wind industry – throughout the supply chain – so that Denmark, also going forward, will set high technological standards in terms of developing wind technology and the energy system of the future."*[49]

Going in depth with the analysis, in 2010, Denmark accounted an installed wind capacity of 3,752 MW, producing an average of 28,175 TJ (7.81 TWh) of energy, with

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[49] J. HYLLEBERG, R. B. NIELSEN, *Denmark: wind power hub*, Danish wind industry association. 2007. p.4

an actual average of production of 905.90MW and a share of 21.9% of the total electricity consume in the country - even though this number has often been object of several disputes[50]. In the following tables the trends of wind power in Denmark since 1977 are shown.

Year	1977	1978	1979	1980	1981	1982
Installed wind capacity (MW)	0.052	0.813	1.090	2.7	6.3	10.6
Electricity generated (TWh)	-	0.12GW*	0.24GW*	0.002	0.005	0.012
Year	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**
Installed wind capacity (MW)	14.3	19.8	47.0	72.4	111.9	190.3
Electricity generated (TWh)	0.019	0.026	0.044	0.104	0.154	0.266
Year	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
Installed wind capacity (MW)	246.7	326	393	436	468	521
Electricity generated (TWh)	0.398	0.57	0.68	0.83	0.92	1.06
Year	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Installed wind capacity (MW)	600	814	1,123	1,438	1,753	2,390
Electricity generated (TWh)	1.09	1.19	1.89	2.76	3.00	4.22
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Installed wind capacity (MW)	2,497	2,890	3,116	3,123	3,127	3,135
Electricity generated (TWh)	4.31	4.86	5.56	6.58	6.61	6.11
Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Installed wind capacity (MW)	3,124	3,163	3,482	3,752		
Electricity generated (TWh)	7.14	6.98	6.72	7.81		

Figure 3.1: wind power in Denmark 1977-2010

[50] http://www.ens.dk/da-DK/Info/TalOgKort/Statistik_og_noegletal/Sider/Forside.aspx

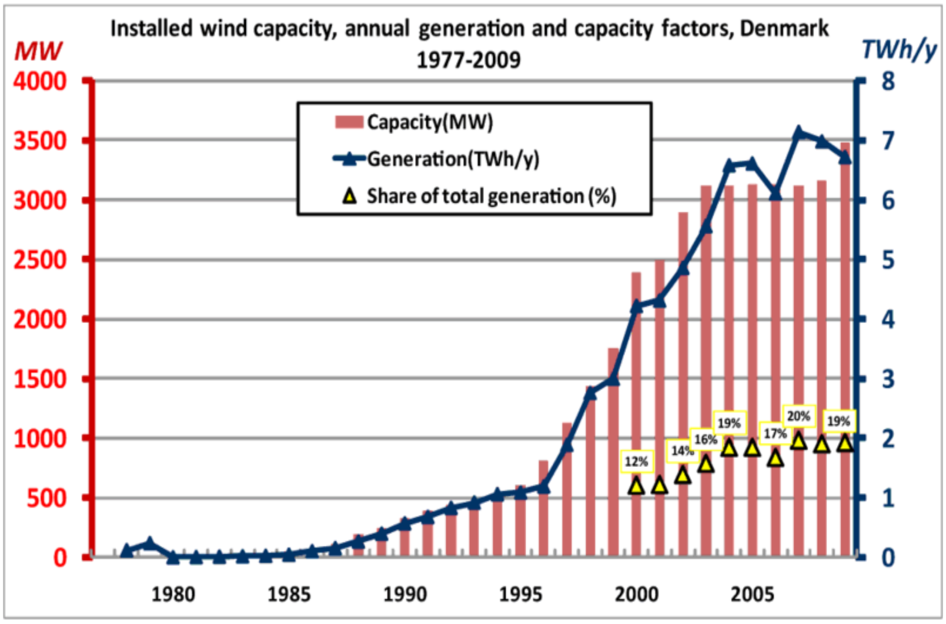

Figure 3.2: Danish annual generation and capacity factors[51]

In order to understand the success of wind turbine industry in Denmark we must primary focus on the Danish electricity system. In order to do so, it is fundamental to understand that the Jutland wind cluster - which will be the main focus of this analysis - has very poor connections with the Sjaelland Island and the rest of the many islands that Denmark comprises. Hence, it is complicated to talk about a nationally integrated electricity grid.

The Jutland peninsula, the real hard core of the Danish wind cluster, is mainly linked with an international electricity network which links Germany with the UCTE, a grid built by the Union for the Coordination of Transmission of Electricity (UCTE) which connects France, Germany and Switzerland. On the contrary, the Sjaelland grid system is coordinated within the NORDEL, the Scandinavian electricity network operating in Sweden, Norway and Finland.

The fast development of wind power in Denmark, strongly relies on the efficiencies of these two grid systems. In fact, both of the Danish portions of electricity networks

[51] http://www.ens.dk/da-DK/Info/TalOgKort/Statistik_og_noegletal/Sider/Forside.aspx

enjoy a vast number of interconnectors, which exceed the wind turbine generating capacity.

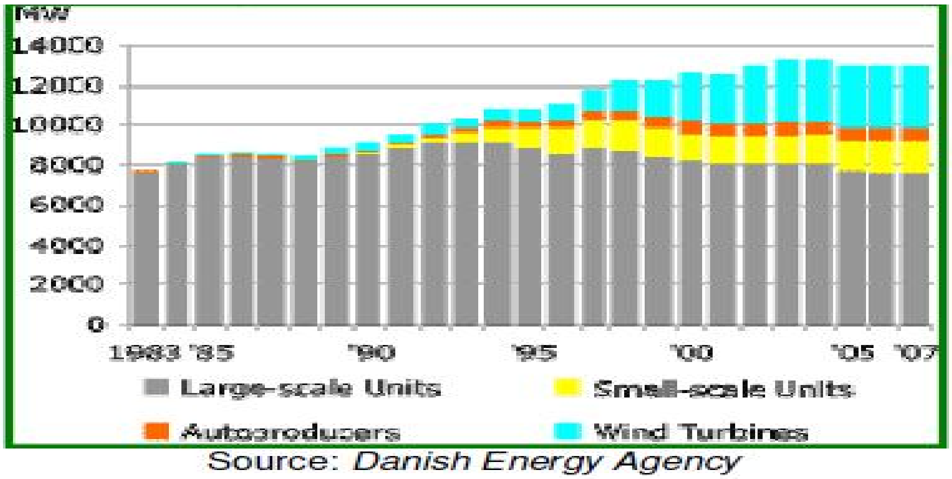

Figure 3.3: Danish electricity generating capacity[52]

Both of the electricity grids are based on few, centralized plants that act as a stabilization point for the grid, for the electricity coming from the multiple and wide-spread local installation, including the wind farms.

Being essentially a connection system, the Danish grid lacks of a storage system for the large amounts of electricity produced. This implies a strong necessity for Denmark to seek a necessary equilibrium between the electricity produced and required. On one side, for example, if the electricity supply is overwhelming the grid capacity, the too high voltage and current frequency can determine serious damages to the grid system; on the other side, if the supply is lower than the electricity required, there is a risk of “brown-outs” and low voltage in the power supply and frequency.

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[52] H. SHARMAN, *An Assessment of Danish wind power: The real state of play and its hidden costs*, in Wind Energy – The Case of Denmark, CEPOS, Copenhagen, 2009. p.8

In Denmark this stochastic inconvenient is solved by a "*minute to minute, transmission system operators (TSOs) [that] require access to significant amounts of fast, short term balancing or regulating reserve to offset these surprises*"[53]

Thanks to this control system and the Danish government technical and financial flexibility, this Scandinavian country is able, in some moment of the year to export up to the 57% of the wind electricity in the exact same moment of its generation to the countries which are interlinked by the grid - namely Germany, Norway and Sweden. Both the NORDEL and the UCTE can equilibrate the variation in wind supply from Denmark, overall in Scandinavia where it can be counterbalanced by the constancy and the repetitiveness of hydropower, which supply most of Norway's and Sweden's electricity demand[54].

Thanks to this electricity network, the Jutland peninsula is the place in the world with the highest wind energy *per capita*, with a 0.9 kW wind energy capacity per inhabitant, followed by Spain (0.43 kW) and Germany (0.29 kW per inhabitant). Denmark exports are strongly dependent on the wind industry. However, the wind energy export issue is quite a bind. According to the CEESA research project[55], in 2008, Denmark supplied an average 6,978 GWh, facing the 19.3% of the national demand. In some particular hours of the day, the most windy, the production system was able to overcome this demand and, furthermore, to export more than 90% of the electricity produced. However, in some other hours, when the wind is almost not blowing, exports reduce to zero. In general, in 2008, the total house consumption of wind energy

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[53] H. SHARMAN, *An Assessment of Danish wind power: The real state of play and its hidden costs*, in Wind Energy – The Case of Denmark, CEPOS, Copenhagen, 2009. p.10

[54] AA.VV., *Danish Wind Power, Export and Cost*, Department of Development and Planning, lborg University, 2010. pp.6-25

[55] *Ivi*, pp. 14-21

accounted a total of 4,398 GWh, the 63% of the total yearly supply, with a remaining 30-40% doomed in part to export[56].

Denmark has the world's largest wind turbine industry as well. Its competitive advantage over the wind power has deep and strong roots and it derives by the ability of pioneering the wind industry for more than 30 years. Wind power represents a large share of Danish economy. In fact, it employs more than 25,000 highly skilled and trained workers and it comprises around 8.5% of the total country's exports, with positive projections also for the future, thanks to the penetration in foreign markets, such as Germany, UK and Netherland.

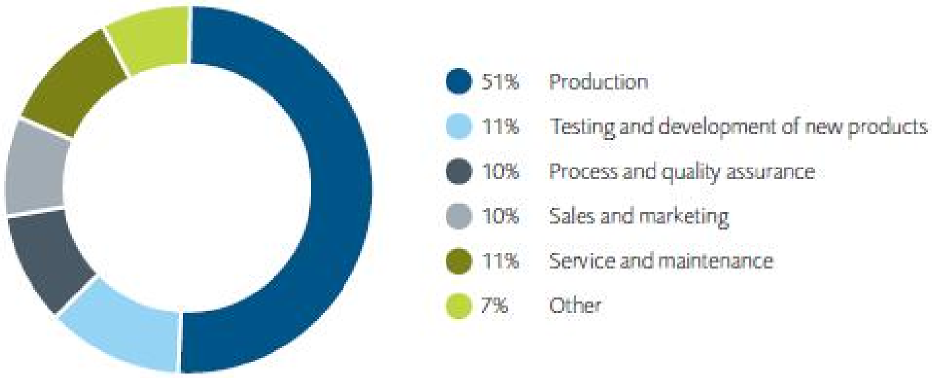

Figure 3.4: structure of wind power labor force in Denmark[57]

Another fundamental component of the Danish wind industry success, is the efficient and unique supply chain, which includes world-class manufacturers, such as Vestas, Siemens, Gamesa and Suzlon and that allow Denmark to provide its inhabitants with electricity that derives for more than 20%, with an ambitious objective to reach a 50% share by 2020.

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[56] H. SHARMAN, *An Assessment of Danish wind power: The real state of play and its hidden costs*, in Wind Energy – The Case of Denmark, CEPOS, Copenhagen, 2009. pp.6-17

[57] AA.VV., *Danish Wind Power, Export and Cost*, Department of Development and Planning, Ålborg University, 2010, p. 8

In 2003, Danish wind turbine companies accounted the 38% of the global market share. In 2009, this share has sensitively decreased down to around 20%, because of the entrance in the wind industry of new large Chinese and Indian companies. However, Denmark still accounts a huge market share of both inshore and offshore wind farm components. Around 90% of these components are produced in Denmark or derive from Danish technology. This phenomenon of the shifting production towards new markets and location form the Danish cluster which will be analyzed more in depth in the last chapter of this *thesis*.

3.1.1. Denmark wind cluster and government policies: a driver to success

Once exposed some of the basic figures and numbers of the wind industry in Denmark, it is of primary importance to understand which are the main historical events and steps that have led this country to build up such a striking competitive advantage. Before doing so, it is important to geographically frame the industrial district we are going to describe.

As we have seen in the first chapter a cluster is a *''geographic concentrations of interconnected firms, specialized suppliers, service providers, firms in related industries, and associated institutions in particular fields that not only compete but also cooperate''*[58]. This definition seems to apply perfectly to the configuration of the Danish wind industry. As we can see from the image below, most of the Danish territory houses a huge number of wind farms of every type and dimension. The geographical condition of Porter's definition is clearly satisfied.

[58] M. PORTER, *On competition*. Boston: Harvard Business School Press. 1998. p. 197

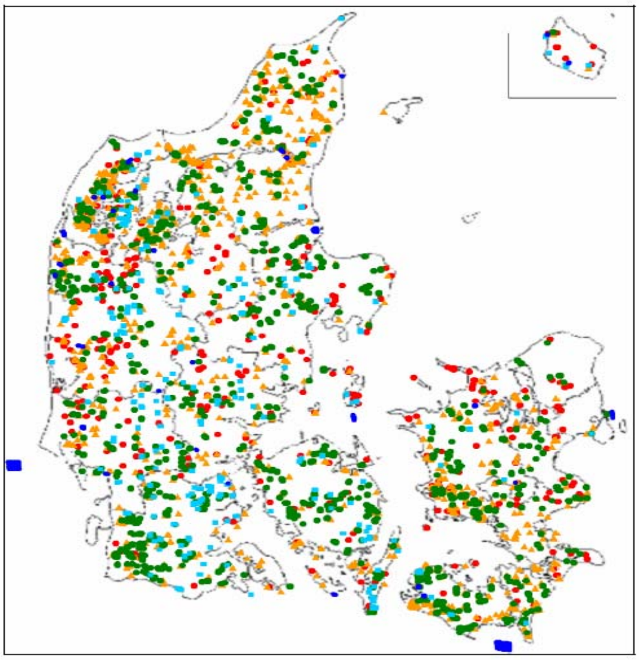

Figure 3.5: geography of wind farms in Denmark[59]

However, the actual wind cluster consists in the sole Central and Northern part of the Jutland peninsula. In these two regions, is settled the highest concentration of wind farm in the country and the largest part of the wind power installed capacity.

Moreover, moving to a productive perspective, in the Århus-Ålborg - the two most important cities of the Jutland - cluster we can find over 400 different manufacturers, active all along the wind industry supply chain. The second condition of the cluster definition is satisfied, because in a rather small territory, we can find not only the wind turbine or blade producers, but every kind of activity, service and support that render a cluster an independent, functional unit.

The picture is completed by an incredible amount of research and R&D institutions that operate within this area: the Århus University and the Århus School of Business; the Ålborg University; The Syddank University; the Risø National Laboratory and the Technical University of Denmark; but also a vast number of private and public

[59] http://www.scotland.gov.uk/Publications/2008/03/07113554/7

agencies and research institutions that make the Jutland one of the most advanced area in the world in terms of R&D in the wind sector.

Thanks to these features, the Danish wind cluster has become one of the paradigmatic examples that scholars provide when it comes to deal with industrial conglomerates. Until 2004, the Danish wind cluster comprised more than half of the total labor force of the global wind industry. The accumulation of expertise, ability, skills and competences accumulated in such an industrial district, combined with manufacturing techniques, research, development and engineering services, determines an outstanding phenomenon. In Jutland (29,777 kmq and 2,528,129 inhabitants), a significant global share of the industrial production of wind turbines has clustered, giving Denmark a remarkable energy stability, overall considering its small size and the almost total lack of fossil-fuel resources.

Once demonstrated that the definition of cluster is very applicable to the Danish wind turbine industry, it is now the case to eventually focus the attention on the historical, economic and political events that guided the district to a plain success. The wind industry has been one of the most important drivers for Denmark development since the early 1970s and the first oil crisis. However, to understand the dynamics which led to the triumph of this industry in the Nordic country, we have to mention some information about the events which took place in 1973-1974, and that triggered the *exploit* of the wind industry in Denmark.

In October 1973, the members or the OAPEC - Organization of Arab Petroleum Exporting Countries, consisting of the members of OPEC, plus Egypt, Syria and Tunisia - declared an oil embargo against the Western countries to react in opposition to the US aid to Israeli troops in the Yom-Kippur war. This “oil-strike” lasted almost 6 months, generating an unprecedented economic and politic breakdown all over the capitalistic world. The main reason behind the demonstration was the OPEC reaction against the US and European meddling in their own oil policies. The strike determined a leveraging of the oil price to stabilize the producer countries’ incomes. The consequences over the strongly dependent on fossil fuel economies were devastating.

The strong inflation and the stock exchange market breakdown, caused a sharp increase of unemployment and deep economic recession.

After this epochal event, many countries, overall in Europe, realized the danger and the shocking results of an energy policy which was totally dependent on other countries. For this reason, during the 1ate 1970s and 1980s, renewable energies became one of the most appealing, future technologies. Denmark government was one of the first to understand the strategic importance of the security of energy supply, and this far-sightedness allowed Denmark to gain a considerable competitive advantage in the production of the renewable power that most of all was abundant in the territory: wind.

Therefore, the history of the Danish wind cluster birth and expansion, is strongly linked with government interventions and political or institutional actions and directives. But let's start from the very beginning. The appearance of the first wind farm prototype can be traced back in 1887 by Prof. James Blyth from Glasgow, Scotland and by Mr. Charles F. Brush, in Cleveland, 1888. However, Denmark was the first country to exploit this device on a large-scale[60]. In 1890s, the Danish Prof. Poul la Cour was the first engineer attempting to build windmills to trap mechanic energy and produce electricity. As a matter of the fact, by the beginning of 1900, in Denmark, almost 2,500 windmills could reach a power peak of 30 MW[61].

However, the real turning point of the history of Danish wind industry took place in 1956, when one of the most brilliant students of Prof. La Cour, Johannes Juul, built the first AC (alternating current) wind turbine in the world, in Egesborg, on the Vester coast of Denmark.

[60] http://windenergyfacts.eu/brief-history-of-wind-energy.html

[61] http://en.wikipedia.org/wiki/History_of_wind_power

Figure 3.6: The Vester Wind turbine

This prototype was a 24 meter diameter wind turbine with a producing capability of 200KW. It was built for the SEAS, a Danish electric company, in Egesborg, Southern Denmark. The most innovative part was the three-bladed turbine supported by a yawing and a generator which allow the storage and creation of electricity. The prototype was controlled by aerodynamic mechanisms, such as an emergency tip break, which allowed to maintain the stall at a fixed level[62]. The Vester model run from 1956 until 1967 without maintenance, proofing the high quality job of the Danish engineer.

As we can easily see, Denmark has a long tradition history when it comes to wind power that can be traced even before the 1973-1974 oil crisis. This certainly facilitated the decision of the political authorities to shift from fossil-fuel toward a "green energy" economy, already in the 1970s.

[62] http://guidedtour.windpower.org/en/pictures/juul.htm

The main agent behind this revolutionary policy was, out of doubt, the Danish Government. Already in the second half of 1970s, the Danish political institutions set a large amount of quantitative targets - generally in form of agreements between the government and utilities – in order to push the production of wind turbines throughout the national territory. The Government actions focused mainly on these three issues: R&D activities financing; turbine certification through the Risø Test Station for Wind Turbines; and capital subsidies, with an average 30% refunding of the ininitial investment.

In 1981, the first target plan - Energy Plan 1981 - forecasted that by the year 2000, 10% of the national electricity should have been supplied by wind power. In order to do so, it was planned the building of more than 60,000 wind farms. This objective was reached in 1998, but with a considerable difference comparing to the original government intentions. Instead of 60,000, in 1997, the turbines numbers in Denmark was inferior to 5,000 units. This incredible result was possible thanks to the increased size of the turbines and the outstanding technology progress that the country had reached by then[63].

Another important measure of the Danish Government, was to establish a set of investment incentives to encourage the private installation of wind farms and the R&D sector of the wind industry. In 1979, the Denmark's government offered a 30% reimburse to each citizen who decided to build up his/her own wind turbine farms. This incentive policy, lasted until 1989. In 10 years, the government lavished more than 280 million DKK (almost 38 million €).

Moreover, in 1984 the wind power producers were subsidized with a 70–85% feed-in tariff on the retail electricity price and a State payment for the connection to the

[63] P. AGNOLUCCI, *Wind electricity in Denmark: A survey of policies, their effectiveness and factors motivating their introduction*, Environment Group, Policy Study Institute, London, 2005. pp. 952-953

grid[64]. A feed-in tariff is a governance mechanism that is designed with the main objective of increasing the wide spreading and the development of renewable energies in a geographically and politically bounded area. It is based on long-run agreement between the State and the suppliers of electricity from renewable sources. A feed-in tariff rewards the producers with a price depending on the generation and installation costs.

This mechanism has been universally recognized as the most effective in subsidizing the renewable energies' industry. As a matter of the fact, a feed-in tariff implies three cardinal standpoints that are essential for the aim they are designed to: they guarantee the producer the grid access; they imply long-run contracts in the electricity production process; and they recognize the costs of generation as a fundamental discriminant. The effect of a feed-in tariff is that electricity producers are paid in a proportional way to the electricity they supply. However, the compensation rate has to take into consideration also other features, such as: the type of renewable source that has been used in order to produce electricity (wind, for example is less incentivized rather than photovoltaic, as easier to produce); the geographical position; the weather conditions and so forth.

Coming back to the history of the wind cluster, in 1990 some foreseeable clashes arose between the wind power producers, and the utilities owning the grid. The reason of this disagreement was precisely the methods and the dynamics of the connection of the energy supplier with the grid system, which of course was penalizing the grid utilities. In fact, they had to deal directly with the State, and not with the private suppliers in order to grant them access to the grid. In 1992, the Parliament approved a law which imposed the utilities to accept the requests of the renewable energy suppliers. The utilities were ordered to support the connection through a tariff payment,

[64] V. LAUBER, *The different concepts of promoting RES-electricity and their political career*. In: F. BIERMANN, R. BROHM, K. DINGWERTH, *Proceedings of the 2001 Berlin conference on the human dimensions of global environmental change 'Global environmental change and the nation state*, Potsdam institute for climate impact research; Potsdam, 2002. p. 296–304.

which would have discounted the costs of connection of the generators. However, two years before, in 1990, the government also signed an agreement with the utilities to install 100MW building capacity in the same year, the Energy Plan 2000. This agreement was enlarged in 1996, for the installation of 1500MW for 2005. In 1998 this plan was emended, and the so-called E-21 Plan (Energy for the 21st century) was born. This last objective-plan required the building of up to 750MW offshore wind power capacity.

Furthermore, the new technology investments were managed by the Energy Research Programme and the Development and Diffusion Programme for Renewable Energy, founded in 1992. For each experimental wind turbine project presented, the Danish government granted a covering of the costs between 20% and 40% of the total expenses. Furthermore, many incentives were given to test/control organisms, research institutions and consultancy agencies.

In 1997, the Development of New Renewable Energy Technologies institution was established in order to fund and speed up the development of the new offshore wind turbines. In 1999, repowering and replacement mechanism for the old turbines were introduced in the new electricity reform. In brief, the old device owners who had accepted to buy a more modern turbine, could have bought a triple share of electricity in respect of the one they were actually able to supply. In addition, they were also provided with a fixed monetary incentive of 0.60DKK/KWh, for the first 12,000 hours of activities[65]. It has been calculated that in the period between 1997 and 1999 almost 130 Million DKK (17.5 million €) were given to the renewable energy industry from the government.

However, considering the dimensions of Denmark, this striking funding policy sounds almost miraculous. In fact, the incentives to the industry, have always been backed up by a large and complex taxation system which allowed the Danish State

[65] P. AGNOLUCCI, *Wind electricity in Denmark: A survey of policies, their effectiveness and factors motivating their introduction*, Environment Group, Policy Study Institute, London, 2005. p. 953

not to enlarge too much its public expenditure. As a matter of the fact, direct taxation and production incentives have been the counter-balance of this wide incentive policy. In 1996, the policy of favorable taxation to the private owners of wind farms, was abolished, and these economic actors were equalized to all the other economic activities. The same goes for the utilities. Before 1996, they were not subjected to any taxation, while, after the reform, all the revenues generated from the utility-owned turbines started to be charged as if they were normal business[66].

Summing up, a vast reform of the system was needed to face the overwhelming increase of the cost of such an expensive energy policy. This is the reason why in 1999, the whole structure of public incentives was abandoned and a new enticement system introduced: the green certificate system. These certificates consisted in "*tradable commodity proving that certain electricity is generated using renewable energy sources*"[67]. This new financing method stood on the benchmark that citizens had to commit to purchase a fixed amount of their electricity from wind and other renewable sources in general. Danish customers had to purchase at least a 20% of their electricity consumption from renewables by the year 2003. The "green certificate" price was set between a minimum of 0.10DKK/KWh and a maximum of 0.27DKK/kWh. This method implied a saving of over 300 million DKK (40 million €) with a conspicuous 66% reduction on the national budget[68]. However, the green certificates' emission created a very unstable situation that was eventually restored in 2003, with the amendment of the Energy Reform, restoring feed-in tariffs.

Anyway, the need of saving money and reducing the energy public expenditure were real issues. As a matter of the fact, several cutbacks came from the re-utilization and

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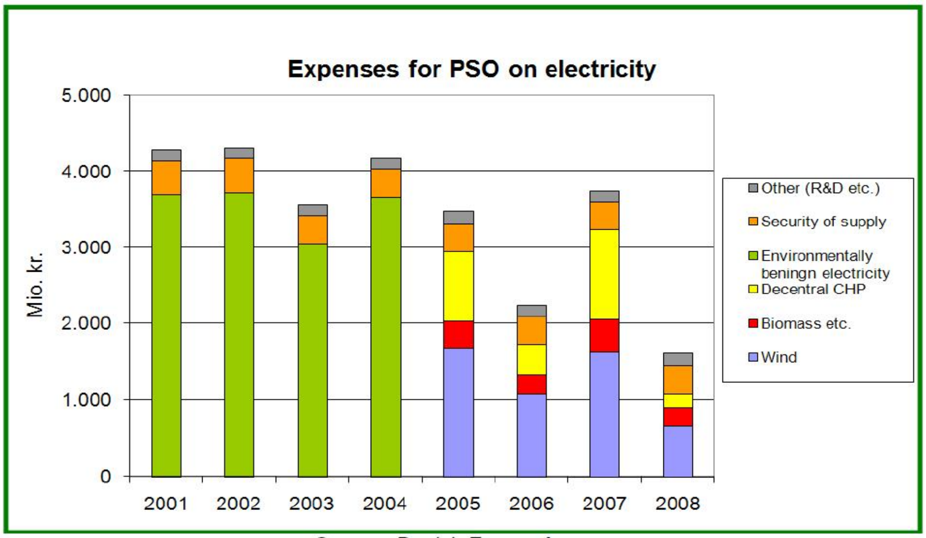
[66] R. HAAS, *Survey on and review of promotion strategies for RES in Europe, in European network for energy economics research (ENER),* ENER forum 3: successfully promoting renewable energy sources in Europe the Fraunhofer institute for systems and innovation research ISI, Karlsruhe 2002. pp. 19–26.

[67] http://en.wikipedia.org/wiki/Green_certificate

[68] P. AGNOLUCCI, *Wind electricity in Denmark: A survey of policies, their effectiveness and factors motivating their introduction*, Environment Group, Policy Study Institute, London, 2005. pp. 954-955

recycling policy of old wind turbines. Whoever wanted to update its wind to more modern and efficient models, was paid a scrap premium, passing from 0.17DKR/KWh in 2004 to 0.12DKR/KWh, in 2009.

From 2001 on, the subsidies were set behind the direct control of a program called Public Service Obligation (PSO), financed mainly thanks to the household taxation mechanism. In the following chart it is shown the actual subsides distribution in the last decade. However, this *thesis* will analyze in depth the present situation of the governmental subsides to the Danish wind industry in the next chapter, when a study about the future trajectories of the cluster in terms of financing and political intervention will be provided.



Source: *Danish Energy Agency*

Figure 3.7: expenses for PSO on electricity[69]

As we can see, in the last 10 years the amount of wind power subsides have varied sharply from year to year. It has been calculated that the total wind industry subsides have been 1.9 billion DDK, (257 million €). The importance of the subsides for the electricity providers is huge. In fact, these aid measures are designed to enable the wind farm owners to receive the total amount of the investment in 10 years, or max-

[69] H. SHARMAN, *An Assessment of Danish wind power: The real state of play and its hidden costs*, in Wind Energy – The Case of Denmark, CEPOS, Copenhagen, 2009. p. 20

imum 14 (in the offshore wind turbines). However, on the other face of the coin, these subsides have been particularly oppressive for the electricity customers.

As we have seen, the financing of these subsidization mechanisms is primary connected with the tax burden, which, in Denmark, is one of the highest in the world. In fact, the taxation over the electric consume, renders the Danish household electricity consumption the most expensive in Europe. However, as we can see from the graphics below, the tax burden is carried principally by the families, whereas the electricity consumption for industrial actors is much cheaper.

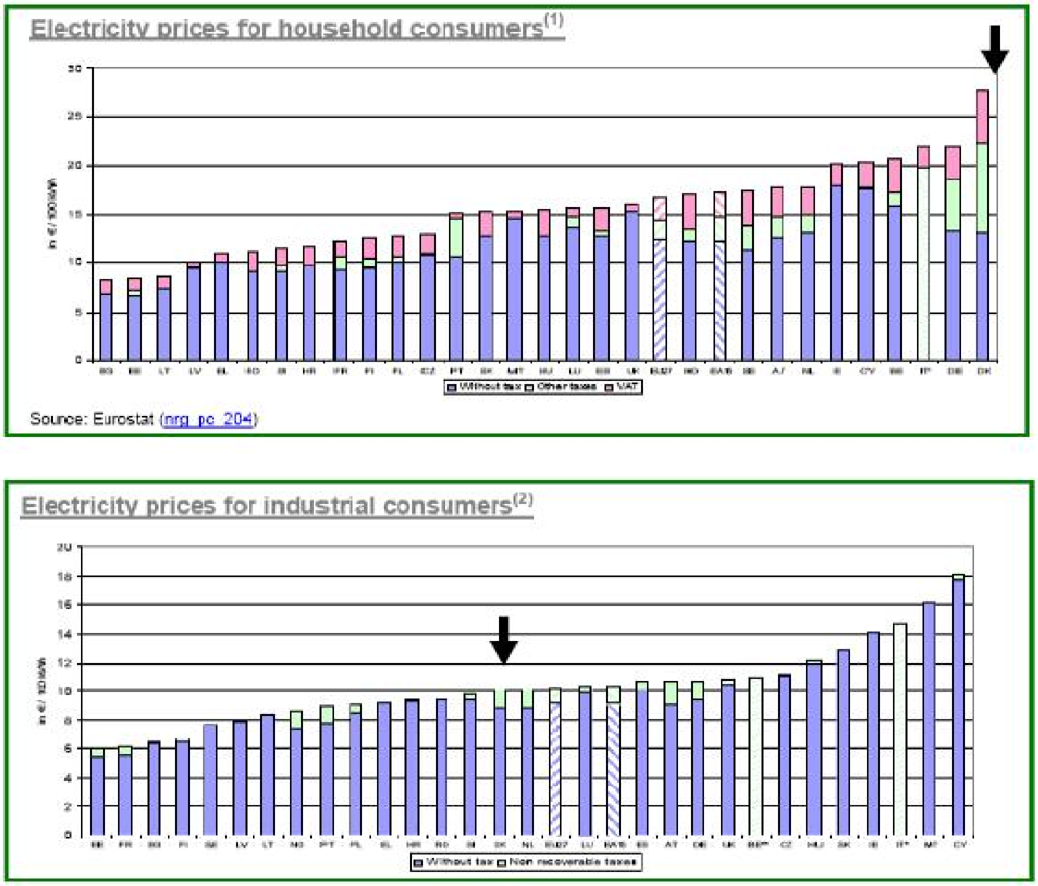


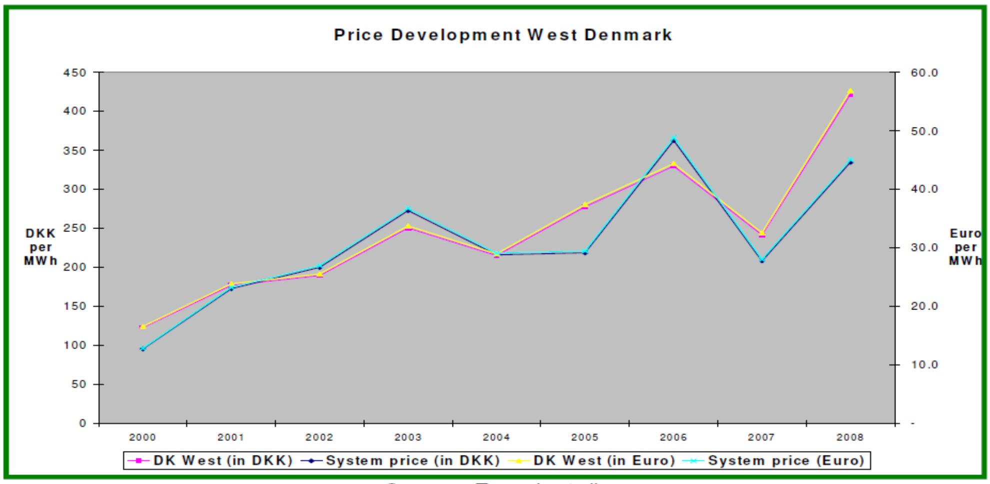
Figure 3.8: household and industrial consumers electricity prices in EU[70]

[70] H. SHARMAN, *An Assessment of Danish wind power: The real state of play and its hidden costs*, in Wind Energy – The Case of Denmark, CEPOS, Copenhagen, 2009. p.18

This discrepancy is given by the government willing of keeping the Danish energetic industry competitive and innovative. In this way, household pay averagely 2.5 times more taxes than corporations in the system.

The Danish Energy Agency, in July 2009, declared: "*The level of support for electricity produced from wind turbines was increased in the summer of 2008. New wind turbines as well onshore as offshore receive a price premium of 25 øre/KWh for 22.000 full load hours. Additional 2,3 øre/KWh in the entire lifetime of the turbine to compensate for the cost of balancing etc.*

Household wind turbines below 25 kW receive a fixed feed in tariff of 60 øre/KWh. For special wind parks at sea the support are settled by a tender procedure. In previous tenders the Horns Rev II wind park of 200 MW ended at fixed feed in tariff of 51,8 øre/KWh in 50.000 full load hours, while Rødsand II wind park of 200 MW ended at a fixed tariff of 62,9 øre/KWh for 50.000 full load hours"[71]



Source: *Energinet.dk*

Figure 3.9: Electricity prices per MW in Jutland[72]

[71] http://www.ens.dk/en-US/supply/Renewable-energy/WindPower/Facts-about-Wind-Power/Subsidies-for-windpower/Sider/Forside.aspx

[72] H. SHARMAN, *An Assessment of Danish wind power: The real state of play and its hidden costs*, in Wind Energy – The Case of Denmark, CEPOS, Copenhagen, 2009. p.19

As it is easily noticeable - even without considering the two peaks in 2003 and 2006, corresponding to dry years when hydropower in Northern Scandinavian countries was below the average - the prices are constantly and sharply growing.

Summing up, all these government measures steadily increased and stabilized the wind industry and all other renewable energy consumption in Denmark over the past 40 years. The Danish model has been replicated all over the world as a winning model to imitate and replicate. The public intervention in the Danish wind industrial district has also represented a model to follow for many markets in the world, such as France, Spain, China, Germany and Argentina. In brief, the Danish wind cluster development has been for years a powerful engine for Denmark growth, and at the same time, it has represented a lighthouse for all the enthusiasts of the potentialities of renewable energies[73].

3.1.2. The path creation and path dependence in the Danish wind turbine industry

Once analyzed the politic and economic dynamics, which seems to favor the expansion of the wind energy in Denmark, it is the case to show how this development is strongly influenced by a path dependence model of growth. In order to do so, the focus will shift on the sole wind turbine industry. In this paragraph it will be demonstrated how the path creation and dependence system triggered a transformative process, that enabled a continuous and concatenate increase of the industry's level of productivity.

However, before starting, an explanation about what path creation and a path dependence are and what they represent in the wind turbine industry, is mandatory. The idea of creation and dependency path is a residual of the so called Social Construction of Technological System (SCOT), a theory which is strongly related with social constructivism. SCOT's main argument is that technology is not a determinant for human behavior. However, the human action itself is the main driver that generates

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[73] H. SHARMAN, *An Assessment of Danish wind power: The real state of play and its hidden costs*, in Wind Energy – The Case of Denmark, CEPOS, Copenhagen, 2009. pp.18-21

technology. This means that understanding a technology is impossible without a deep knowledge of how this technology fits in with the surrounding context[74].

This implies that there are many, different actors that influence the growth of a particular technology. Each of these actors is embedded in a peculiar field and tends to develop a different fraction of the technology. In doing so, every participant puts into the product and into the developing process, an original contribution of techniques, know how, learning by using, learning by doing, beliefs, theories and standards which will eventually shape, together with the others' contributions, the final features of the whole industrial characterization. We can categorize the contributions to the developing process in three classes: contribution to the production, to the usage and to the regulatory system.

The actors, while operating in their respective areas of interest, do not influence only their specific frame. On the contrary, their contribution is widely connected with the whole process, until a completely new and innovative procedure arises. The intersection of the three areas generates the institutionalization of a completely different pattern of development, the so called technological trajectory. Trajectories are the core issues of the path creation and dependence theory. As a matter of the fact, they are "*path along which a technology develops on previous choices and future expectations*"[75].

On one hand, path creation is the act of choosing a particular pattern of development, through the analysis of future supposed opportunities. On the other hand, path dependency is not only based on the evident importance on the whole growth process coming out from the original choice. On the contrary, it also refers to all the indispensable changes and future developments which, although being strongly influ-

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[74] T. J. PINCH, W. E. BIJKER, *The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other*, Social Studies of Science 14, 1984. pp. 399-441

[75] R. GARUD, P. KARNØE, *Path creation and dependence in the Danish Wind Turbine field.* Papers in organization, No. 26. 1998. p. 4

enced by the original trigger event, will be able to modify and, sometimes, revolutionize the pattern of development of the technology in consideration.

These notions seem to be particularly effective in describing the dynamics that stand below the expansion of the Danish wind turbine industry, over the past 40 years. The wind turbine technology, as we have seen in the previous paragraphs, is particularly complex. In fact, wind turbines are systemic technologies, where all the components are produced in accordance to several, different patterns of studies and subjects, such as aerodynamics, electronics, structural design, material engineering, hydraulics, chemistry, physics of the movement and so on.

Wind turbines are not the products of a dramatic breakthrough innovation, but they generate from a slow, continuous course of growth that roots its origins in the medieval windmills. Of course, Vester Turbine speeded up noticeably the development towards new and more modern horizons. However, it is rather clear that the wind industry is a typical example of path creation and dependence model of growth. Let’s see how, by analyzing the expansion of the wind turbine industry and technology since the 1970s.

Up to the introduction of the Vester turbine, wind industry remained substantially dormant, until the 1973-1974 energetic crisis. As a matter of the fact, the 1970s were years of experiments. Many engineers and technicians experimented and tried to create prototypes of large-scale-production wind turbines, in order to guarantee Denmark the security of energy supply and to accomplish new environmental targets. Some examples were the testing samples developed by the Danish carpenter Christain Riisager, the archetypes of the Tvinde School, and the Heldge Pedersen wooden bladed turbine. In any case, Denmark began to attract a larger and larger number of engineers, meteorologists, scientists, that would become the hard core of the highly skilled labor force of the Danish wind industry in the following decades.

The practical outcasts of this growth were the creation of an active yaw system resolving the issue of the slowness of responses of the turbines to the wind change of directions; and the introduction of the fiberglass as construction materials for the blades. The first buyers of these innovative projects were, of course, few pioneers which were driven mainly by ideological and security of energy supply motives. In order to improve and guarantee a certain, stable supply and the safety and reliability of wind turbines; these users set up a cartel, the Danish Windmill Owners Association (DWOA), in 1978.

This union had an active, fundamental role in the development of the industry. It gave birth to a monthly press publication, with all the needed information and reports on the industry trajectories; it bargained the price of the wind electricity and the access of the wind turbines' owners to the grid network, with the electric utilities; it sponsored the creation of new committees and associations, particularly interested in the wide spreading the wind industry, such as the Renewable Energy Committee, the Danish Board of Technology and so on.

During the 1980s, many other innovations came directly from the agricultural field. As a matter of the fact, many manufacturers - which were active in the primary sector as transporter producers (Vestas), oil and water tanks (Nordtank) or watering equipment (Bonus) - started to look at the wind sector with increasing interest, and spilled over their previous knowledge in the industry, becoming the three main actors of the large expansion of the Danish wind cluster in the 80s. Starting with a close to zero experience in turbine design, these three producers adopted a trial and error method for developing more and more perfect turbines, often sharing information and benefiting of the cluster proximity and spillovers. This mechanism enabled also the creation and the specialization of an incredibly highly skilled labor force which would become one of the pillar of the Denmark's success.

The blades' aerodynamics problems which had affected the industry development until that period, were cleverly solved through the introduction of new materials and chemical knowledge on the fiberglass, also thanks to the important aid of the support of the knowledge institutions, such as the Danish Technical Service Institute and the Jutland's Universities.

Moreover, the clustering phenomenon favored an increasing linkage among suppliers, producers and buyers, and the rising of new skills and productive techniques, models and technologies. This seemed to create a small and medium-sized enterprise system, according to the typical Danish capitalistic model.

However, it was only after 1985 with the so-called California “gold rush”, that the configuration of the Danish market started to become more concentrated with few large companies being active all along the value chain. The new export opportunities towards the American largest State had a positive effect on the development of the technological pattern of the industry as well. By 1986, the share of Denmark in the Californian wind industry, in terms of annual market share, passed from zero to a striking 65%, with an installed capacity of 1,250MW (ten times bigger than the Danish installation in the home country)[76].

Consequently, the export market had a positive effect on the technology standard in Denmark. Having to face an increasing demand for highly specialized and specific products, insurance companies and institutions required higher technological standards and criteria. New, more specialized work team were institutionalized within the companies and more modern and precise control systems introduced. The small 1986-1990 crisis, given by the governmental introduction of some restrictive measures over the sites of the turbines - which could not be installed closer than 10km from a private house - and a decrease of the market penetration in California, did not particularly affect the industrial growth. Evidently, the path had already been treaded. By 1990, the wind industry in Denmark could enjoy 200 million$ in turnover, 1,600 employees and 326MW of wind power installed capacity[77]. Moreover, the Danish Parliament had already approved the Energy Plan 2000, setting ambitious objectives in terms of installed capabilities by the beginning of the new millennium.

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[76] R. GARUD, P. KARNØE, *Path creation and dependence in the Danish Wind Turbine field.* Papers in organization, No. 26. 1998. p. 16-17

[77] R. GARUD, P. KARNØE, *Path creation and dependence in the Danish Wind Turbine field.* Papers in organization, No. 26. 1998. p. 18-19

Once considered this brief history of the wind turbine industry enlargement, it can be very useful to track both the importance of the path creation (the introduction of the novelties) and the path dependence (their continuous development). The trajectories that are going to be studied will be framed in a endogenous perspective, that will provide a general idea of the generative forces and their evolution within the system.

If it is easy to identify the path creation with the Vester and Juul turbine model, the process of characterizing the path dependence, is rather complicated. Path dependence, and in a minor measure path creation, is a cumulative product of a sequence of pushing and dampening events which ends up in giving the Danish wind turbine industry its actual shape. As it emerges from the industry history, the three main events that amplified the technological sphere of the Danish cluster were the governmental action, the export boom, overall towards the American market, and the control and insurance system of the Danish companies. On the other side, the hampering events seemed to be some governmental restrictions in late 80s, the obvious doubts which were embedded in the entrepreneurial Danish setting about the efficiency and the profitability of wind turbines, and the 1986-1990 crisis given by the downturn in terms of export towards California. However, both the positive and the negative events, appear to be faces of the same medal. As a matter of the fact, it is very common that from a positive event, a negative one rose, and vice versa - see the expansion into the California’s market and the consequent downturn in the whole Danish wind turbine industry. This means that all the events tend to form a sort of a chained subsequence of facts, a trajectory that shapes the emergence of an organic, systemic set of knowledge and technology.

Furthermore, the compound presence of a strong and complex learning system facilitated the knowledge spillovers among all the cluster’s actors. The feedback and control system of the insurance organisms, the mutual and reciprocal support given by the unions and the associations that have risen over the decades, the know-how and the learning by using, by doing and by interacting connections, and the presence of many public and private knowledge institutions, rendered Denmark the perfect setting to venture and experiment new technological challenges based on the renewables. Finally, the cluster framework gave Denmark the opportunity to shape a local model - based on the strong connection and social networking among private firms, public institutions, utilities and customers - to a global and rapidly transforming world.

3.2. The Danish wind cluster: applying frameworks

In this second paragraph, some of the most popular theoretical and strategic frameworks will be to the study case of the Denmark's wind cluster. Focusing on a managerial aspect, the main aim of this research will be understanding and analyzing the sources of competitive advantage and the future opportunities that this incredibly dynamic and complex industrial cluster, can offer.

3.2.1. Switch point and first-mover analysis

In this section it will be shown how the Danish wind cluster creation and development can be explained through the study framework of the switch point and first-mover advantage. In order to do so, it has to be clear what switch point and first-mover advantage are and how to apply those concepts to the case study of the Danish wind cluster.

To better understand the phenomenon, we have to start from a fundamental assumption: in general, States or enterprises, which are particularly interested in developing their renewable energy portfolio by focusing on technological innovation, tend to seek a position of first-mover.

If a further development of the usage and innovation of the renewable energies, in opposition with a future decline of the classical fossil fuels, will be considered as historically and physiologically necessary, then the assumption that the marginal costs of producing fossil fuels will eventually rise endlessly, sounds rather reasonable.

Moreover, it must be recognized that, being the renewable energies theoretically limitless, marginal costs of producing wind and other sources of “green energies” will remain approximately constant.

Therefore, what is expected to happen, is that, at a certain time, the changed cost situation will make much more convenient to switch from a fossil fuel based source of energy to a renewable one. This postulation describes relatively precisely the concept of switching point. This is the moment in which the cost structure of two goods, commodities or services happens to change and render the previously cheaper goods more expensive and vice versa. This obviously implies a shift of the consumption, as well.

In some cases, a switching point situation may be accelerated by an external push from the institutional environment, by an external shock or other unexpected events. In the most common cases, the Government of a State subsidize the renewable energies or penalize the fossil fuels through a specific levy.

As Urs Steiner Brandt and Gert Tinggaard Svendsen (2004) argue, this analysis based on the switch point is particularly interesting if applied to the wind power industry.[78] Taking into account *Figure 3.11*, it emerges that, in their study, Brandt and Svendsen took into consideration two alternative energy production: coal and wind. In this environment they considered two different scenarios. In the first (Coal NT) they do not consider international restrictions over permits in trading CO2 emissions. Therefore, Coal NT is the price of coal energy in a non-trade situation. On the other side, Coal FT refers to the opposite situation: where a full-trade scenario occurs.

[78] U. S. BRANDT, G. T. SVENDSEN, *Switch Point and First-Mover Advantage: The Case of the Wind Turbine Industry*. Department of Economics. rhus School of Business. 2004. pp. 5-7

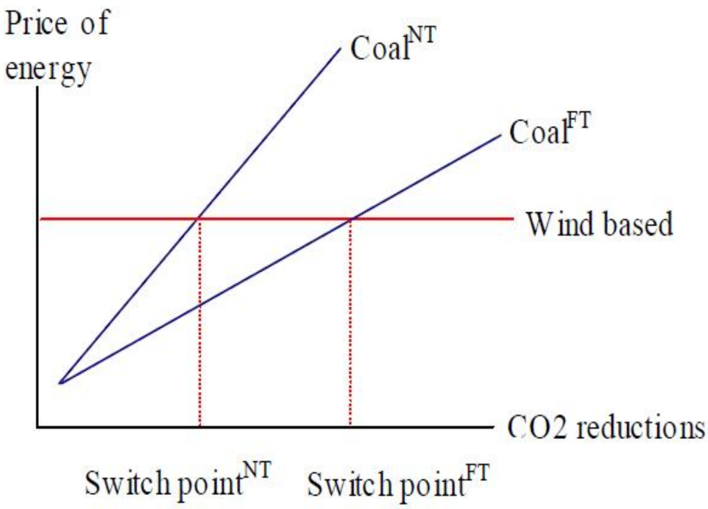

Figure 3.11: Compared switch point analysis: Wind and Coal energy[79]

As it is easily noticeable, wind energy is meant to be more affordable in comparison with coal, when it reaches the respective switch points. This means that when the price of wind becomes cheaper, then coal price increases, at a correspondent level of CO2 emissions. Of course, a switch point *momentum* is more likely to happen in a non-traded case than a free traded situation

In such a situation in which a switch point is highly foreseeable and probable, it is very likely to incur in first-mover advantage opportunities. This is true for the countries that are in a situation of technological supremacy which can lead to a strong increase in the export opportunities, such as Denmark for wind energy. Brandt and Svendsen (2004) identified two sources of this type of strategic advantage. In the first case study scenario, the first-mover advantage produces a mere increase in the exports towards those countries which are struggling to substitute the old technologies with new and more modern ones. In the second case, however, a first-mover advantages can lead to the creation of technologies which are competitive even in countries where there are not consistent pressures on the CO2 reductions. Of course the

[79] U. S. BRANDT, G. T. SVENDSEN, *Switch Point and First-Mover Advantage: The Case of the Wind Turbine Industry*. Department of Economics. rhus School of Business. 2004. pp. 5-7

development of new technologies affects the occurrence of the switch point. Many countries, overall in Europe have large wind or renewables' potential. Thus, a development of new technologies in a certain country can trigger the production abroad. This virtuous circle is completed by the situation in the home country which is actually undertaking the investments in the new technologies. Its products become more and more requested and this renders the investments in R&D very likely to create large margins of profit.

The conditions affecting the success of a first-mover country in the wind sector are the following three. In first place, the operational costs of the latest innovation have to be inferior or reasonably similar to the old technology's ones. Moreover, the level of CO_2 emissions of the newest technology has to be consistently inferior in respect with the old one. Finally, it is primary important to clearly understand how much the new technology is likely to reduce the level of CO_2 emissions in the countries purchasing the innovation.

Once we have understood the actual mechanisms which stand below the switch point and the first-mover advantage in the wind energy sector, we can finally understand how these phenomena have been applied to the Danish wind cluster. The wind power industry faced a fast expansion during the first 1970s because of the oil crisis in 1973-1974. This event clearly showed the dangers of relying completely on fossil fuels: oil and natural gas are scarce and they are likely to be exhausted by the end of this century; they are placed in strongly unstable geo-political areas and their distribution and production is often subjected to the whim of perilous and anti-western regimes.

In order to find a solution to these issues, many countries started to subsidize the renewable energy industry. Out of doubt, Denmark is the most important and emblematic case of this kind of policy. As we have seen later in this paper, when investigating the importance of the government actions in the expansion of the Denmark's wind hub, the Danish political institutions attempted to build a large internal market for the wind power related products. During the decades following the oil crisis, Danish suppliers have been able to enjoy a first-mover advantage position over the global markets[80].

The subsidizing policy determined a growth both in the demand and in the supply of new generation wind turbines. In the 1980s, the Danish production *apparatus* prepared the field to the 1990s' boom in exports. Already at the beginning of 1980s, Danish manufacturers succeeded in creating a first-mover advantage position. This position has been strongly reinforced during all the 1990s. In the five years between 1994 and 1999, the wind power sector in Denmark had a medium increase of 40% a year and in 1999, Danish market share for wind turbines accounted almost one half of total world production.

The development of the wind energy cluster, favored a general expansion, both from an economic and social point of view. In 2001, the world wind sector employed about 40,000 people, out of which 12,000 were working in the small Scandinavian country. Moreover, this growth had a huge befit on the large firms, such as Vestas, that in early 2000s, gained an almost absolute global monopoly in the production of turbines (83.4%)[81].

[80] E. MADSEN, C. STRØJER, J. D. HANSEN, *Scale in Technology and Learning by Doing in the Windmill Industry*. Journal of International Business and Entrepreneurship. 2003. pp. 27-35

[81] U. S. BRANDT, G. T. SVENDSEN, *Switch Point and First-Mover Advantage: The Case of the Wind Turbine Industry*. Department of Economics. □rhus School of Business. 2004. pp. 13-14

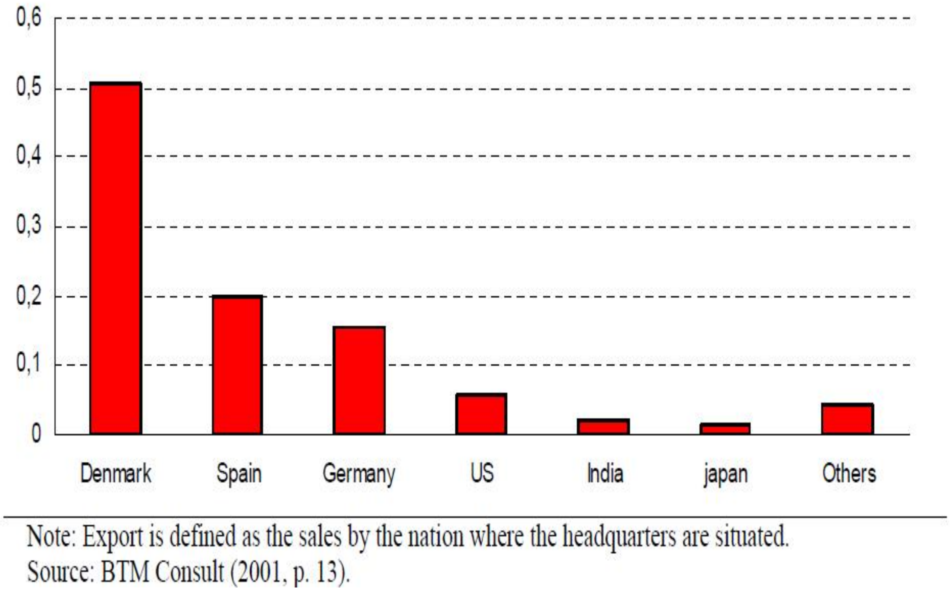

Figure 3.12: Country market share in 2000[82]

In addition to this, it is impossible to avoid to consider that Denmark has reached a strong first-mover advantage in the offshore wind power production. In 1991, Denmark was the first country to install an offshore wind farm in Vindeby, Syddanmark. Already in 1997, the Wind Turbine Action Plan, sponsored by the Danish Energy Agency was established in order to build up over 4,600 MW of offshore wind farms exceeding the whole national electricity demand.

Horns Rev I (160 MW) and Nysted I (165 MW) wind farm complexes, in 2002-2003; Horns Rev II (200 MW) and Nysted II (200 MW) in 2009-2010 and the forecasted Anholt (400 MW) in 2014, are just some of examples of the Danish offshore wind turbine overwhelming productive technology.

From this research, it emerges that Denmark was able to enjoy a first-mover advantage, also thanks to the impelling requested of CO_2 emission reduction in other countries, overall in Europe. The main source of this advantage resides in the innovation

[82] U. S. BRANDT, G. T. SVENDSEN, *Switch Point and First-Mover Advantage: The Case of the Wind Turbine Industry*. Department of Economics. □rhus School of Business. 2004, p. 13

in terms of production of renewable powers that Denmark has succeeded to build over time, since 1970s.

The subsidies of the Danish Government to the wind industry have been able to create an important internal market which functioned as a test for the further developments. Within the home market, Danish companies could test their products and through a process of learning by using and learning by doing, firms acquired enough experience to lead the wind turbine world market and finally employees gained high experience.

As a conclusion to this analysis it is reasonable to state that offering a highly technological product at a price which was completely deprived by all the external cost influence ,made Denmark able to enjoy a leading position.

3.2.2. Spillover effects within the Danish wind cluster

This section will provide a revision of the mechanisms that determine one of the most typical and characteristic phenomenon emerging in a cluster: the technological spillover. In the first part the focus will be on the so-called internal spillovers - namely those that affect the inside industry; whereas in the second part, the external spillovers i.e. the ones that spread their positive effect outside the domestic territory - will be deepened. In the last section of this paragraph, a particular approach, which will examine the spillovers in the Danish wind cluster, according to the contribution of three authors: Linda Manon Kamp (2002, 2004); Ger Klaassen (2003), and Martin Junginger (2004), will be adopted.

When it comes to deal with any kind of industry, which is linked with issues like energy, environment protection, CO2 emissions, etc…, it is indispensable to consider that there are two different kinds of spillovers that can arise. The first ones are negative spillovers. These refer to the general leakage of CO2 emissions, pollution production, and so forth, and they generate from a particular aspect of the industrial production that, however, is strong enough to affect the whole global ecosystem. On the other side, positive spillovers are related with the diffusion of innovation, information, knowledge and technology that influence, in a positive way, the whole productive structure of industrial system[83].

In a clustered environment, the occurrence of positive spillover is particularly elevated and this renders this particular economic environment mostly attractive for R&D, knowledge and technology-based businesses. Denmark is a particular fertile example to study in order to look at the effects that positive spillovers can have both within the industrial environment itself and outside the cluster affecting foreign countries and corporations.

The Danish wind industry is a rapidly growing and is a highly innovative one. Therefore, this industry is particularly suitable to provide an example of how spillovers operate. In order to do so, the first step to undertake is investigating the dynamics of the internal spillovers. This implies a further distinction between direct and indirect internal spillovers that will be best clarified in the last chapter of the *thesis*.

In this section it will be enough to say that internal spillovers can be defined as the accidental effects deriving from the interconnection and the relations among all the actors operating in the system. In brief, indirect spillovers are those rising from word to mouth among engineers or managers from different firms; academic conferences attended by several experts and specialists and so on. On the contrary, the direct spillovers are those emerging from intentional and, often, official, relations among the industry's actors: knowledge sharing contracts, institutionalized and cross-firm project works, sharing of official documents and so forth.

Wind industry has always been one of the most important business of the Danish economy. The Danish government was one of the first to realize the importance of security of energy supply and to start a policy of renewable energies valorization. On

[83] AA. VV., *Spillovers of Climate Policy. An assessment of the incidence of carbon leakage and induced technological change due to CO2 abatement measures*, Netherlands Research Programme on Climate Change Scientific Assessment and Policy Analysis, Report 500036 002, December 2004. p. 9

one hand, already in the late 1970s, the Research, Development and Deployment program (RD&D) was launched in order to give the proper technology support to the large wind turbine producers. On the other hand, towards the end of 1980s many tools were also given to the small and medium wind turbine suppliers in order to improve their innovativeness and their R&D activities. This last policy was based on a market-oriented approach comprising feed-in tariffs, R&D programs and export guarantees.

This approach favored the emergence of positive spillovers which can be summed up in the following facts. Firstly, the wide spread of a high value technological pattern in the local wind industry that positively affected not only the innovation and the technological receptiveness within the cluster, but that also increased significantly the exports, the GDP, the employment and the foreign exchanges. In second place, the striking technology standard reached by Danish wind turbine suppliers caught the attention of other countries that were particularly interested in the wind sector such as Germany, India, Netherlands, USA and Spain. Finally, the highly efficient government policies became a paradigm as the perfect example of how to lead the growth of an efficient and promising industry starting from zero.

The surprising, positive results of the wind industry in Denmark promoted a new, global enthusiasm for the renewable energies providing a positive effort both in Denmark and abroad, improving and developing the overall industrial technological standards. Furthermore, in Denmark, with the accumulation of learning in terms of knowledge and experience arising from the cluster's activities, the cost of implementation of new technology followed a steadily descendent curve giving new economical resources for further R&D expenses and investments. Through this virtuous mechanism, technologies became cheaper and cheaper and knowledge and information tended to wide spread rapidly thanks to the geographical and economic conformation of the cluster.

The best way to understand how this has happened is to focus on the importance of the indirect spillovers. In the Danish wind cluster proximity is a fundamental issue.

In such a close environment, people working in similar projects get to know each other. Knowledge flows indirectly, details arise involuntarily or voluntarily from their speeches, their exchange of ideas and their social relations, enlarging their respective knowledge and rising up the competitive advantage of the national industry. Furthermore, the presence of academic institutions so close one with each other makes the knowledge flow even more dynamic and fluid all over the industrial environment.

Another interesting study of internal spillovers has been provided by Lena Neij (2003). Her study is funded on the concept that energy policies in Denmark, (and Germany, Spain and Sweden) has strong effects on the respective experience curves This curve, better known as learning curve, is, in fact, a function describing "*the cost reduction of a technology as a function of cumulative experience in terms of units produced, units sold, etc.*"[84]. According to Neij, experience can provide a striking cost reduction when it operates in a proper, expanding market environment.

Starting from this theoretical base, Neij used the data collection from the EXTOOL project to demonstrate how energy policies have affected the Danish wind industry learning curve. Actually, this project consisted in the collection and analysis of a vast amount of quantitative data from more than 15,000 wind plants. Using a large number of data-collecting tools, such as historical data, technology foresight, technology forecasting, extrapolations, S-curve analysis, experience curve analysis, and enjoying the cooperation of ISET (Germany) and Risø National Laboratory (Denmark), this large project aimed in having a better understanding of the relations between the wind farms and the learning process in the industry.

According to Neij findings, the Danish progress ratio (PR) of the wind industry was 83%. PR represents the production cost when the level of production doubles. In short, if a product has a PR of 70% and a 1€ unitary cost when we produce 100 units,

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[84] P. LAKO, *Spillover effects from wind power. Case study in the framework of the project Spillovers of climate policy*, ECN-C--04-058, 2004. p.17

the total cost will be 100€; however, with the doubling of production, the cost of producing the additional 100 units will be just 70€. Neij's results are rather interesting because PR is strictly connected with the concept of learning-by-doing. As a matter of the fact, the larger the routine and experience capabilities accumulated by the employees, the faster and the better they will accomplish a particular, routine task. The tendentially low 83% PR, shows that in Denmark, experience spillover had an important role in the production costs reduction and the formation of a highly skilled and specialized labor force[85].

However, within the Danish wind cluster, an issue that is going to be better studied in the last chapter of this *thesis* but that cannot be neglected, rises some problematic questions. The direct spillovers in the Danish wind cluster are often hindered by the presence of non-disclosure and secrecy clauses. This hypothesis is based on the direct accounts of basically all the managers and academics that I have interviewed during my staying in Denmark. Thus, it can be affirmed that direct flow of knowledge, information and technology in the Danish wind cluster is not as efficient as it could actually be. As a matter of the fact, basing their strategies more on a residual tradition than on serious competitive advantage seeking, the most important companies operating within the Danish wind cluster (Vestas in the inshore segment and Siemens Wind Power in the offshore one), tend to make a disproportioned use of non-disclosure clauses. These particular forms of protective measures are focused on strong limits above the information flow and the working force mobility.

On one hand, the typical non-disclosure clauses are the ones imposing the secrecy and the silence about details of bilateral contracts between a supplier and a buyer. In most of the cases this happens between a large buyer like Vestas and a small or medium supplier. On the other hand, these companies hire very highly specialized employees. However, they impose in their contracts the obligation not to work with any of their direct competitors, for an average period of 1 or 2 years in case of them leaving the job; 6 months in case of them being fired.

[85] *Ivi*, pp.17-22

Therefore, we can easily see how the spillover phenomenon has been strongly influenced and penalized by this protective structure of the information flow. However, this situation will be analyzed more in depth. In fact, it is impossible to give an objective judgment on a particular topic without explaining the future trajectories of the R&D system in the Danish wind cluster.

In this section the attention will remain on the second type of positive spillover which are centered on a more globalized and international outlook. External spillovers are particularly important when it comes to examine the relation of a cluster with its surrounding global environment. The first research that will be investigated is Linda M. Kamp's one. She focuses her attention on the importance of the learning process in the expansion of the Danish wind cluster and the external spillovers, that she defines as technological spillovers towards foreign countries and not within the cluster itself.

As a matter of the fact, before 1980s, in Denmark, the scale of the wind industry was principally based on a national level. Since then, things have changed sharply. In year 2002, Vestas was by far the largest wind turbine producer of the globe, with other three companies (NEG-Micon, Bonus and Nordex) placed in the first seven ranks of this chart. In 2003, the merger of Vestas and NEG-Micon amplified this predominance even further. Considering this development in the width of the production capacity of the Danish suppliers, it is easier to understand how technological spillover were very likely to happen. The dominance of Danish company in the world market set Denmark wind technology as a standard. Therefore, it was very likely that technology spillovers happened from the Nordic countries towards the rest of the globe. As many States started to open their market towards Danish high tech turbines, the technological progress of the global wind industry was just a consequential effect.

These technology spillover affected overall those countries that had already a strong and growing national wind industry, such as Germany, Netherland, Spain and USA. However, also some developing countries, with China and India on the front line, could enjoy a large development, strongly linked with the adoption of Danish technology. As an example, Suzlon produced its first 2MW turbine in 2004 following some Vestas sketches.

However, according to Kamp, there is another more important typology of spillover that, emerging from Denmark, affected both the global wind market: the imitation of Danish policies in favor of the wind industry by the governments. Starting from the Danish experience, many countries (Germany, Spain, Netherlands), began to introduce feed-in tariffs to subsidize and incentivize the R&D in the sector. In fact, according to this author, the process of technological learning is fundamental. She distinguishes among 4 types of learning process: learning-by-doing, learning-by-using, learning-by-searching and learning-by interactive[86].

Kamp argues that the Danish wind cluster development has been the product of a spread over of the learning-by-interacting process where the linkages and the collaborative relations between users and producers were the key for the success of the spillovers' diffusion. In general, the learning-by-interacting process favor the formation of an interactive environment that she calls selection environment. In this setting the most promising and valuable innovations, once introduced, tend to impose on the previous and less efficient technologies and been selected from the suppliers. This environment however is a concept that goes beyond the sole market but it includes also a set of norms, beliefs, regulations, expectations of both economic and political policies[87].

The second perspective in analyzing the spillovers that arises within the Danish wind cluster and is provided by Klaassen. His study starts with an investigation about the primary role that public R&D and cumulative sales had on the cost reduction within the cluster. Revising the traditional mainstream that suggested the expansion in pro-

[86] L. M. KAMP, *Notions on learning applied to wind turbine development in the Netherlands and Denmark*. Energy Policy 32, 2004. pp. 3-5

[87] P. LAKO, *Spillover effects from wind power. Case study in the framework of the project Spillovers of climate policy*, ECN-C--04-058, 2004. pp. 9-12

ductive capacity being the main factor behind the typical cost reduction within an industrial district, Klaassen hypothesizes that public R&D was the most important driver behind the Danish wind industry high level of innovativeness and advance.

In this way, he highlights two different kinds of external spillovers. The first kind is a particular typology of knowledge spillover that generates from Denmark and directed towards Germany and a second type which relays mainly on "manufacture" spillovers generated from Denmark and affecting a sharp price reduction in US

As we have seen, the two-factor learning process of Klaassen is based on the two main variables of public R&D and cumulative sales. The author, studying the Danish, German and British wind industry, performs an analysis aiming to discover the relation between the investment costs over time and the cumulative capacity with the knowledge stock in terms of public R&D.

Once gathered some important data (the investment cost per KW; the cumulative capacity, and the annual public R&D expenses), he comes out with the conclusion that a particular period of time, that occurs before the R&D expenses, really add value to the knowledge stock and must be taken into account. In fact, during this stage the knowledge stock is subjected to a sort of depreciation. Following some other studies related both to the solar photovoltaic industry and wind industry, Klaassen theorized that this depreciation, in Denmark, is around 3% per year, whereas the time period between the R&D investment and the addition of value to the national knowledge stock is around 2 years, with learning rates of 5.4% for learning-by-doing and 12.6% for the learning-by-searching R&D[88].

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[88] P. LAKO, *Spillover effects from wind power. Case study in the framework of the project Spillovers of climate policy*, ECN-C--04-058, 2004. p.15

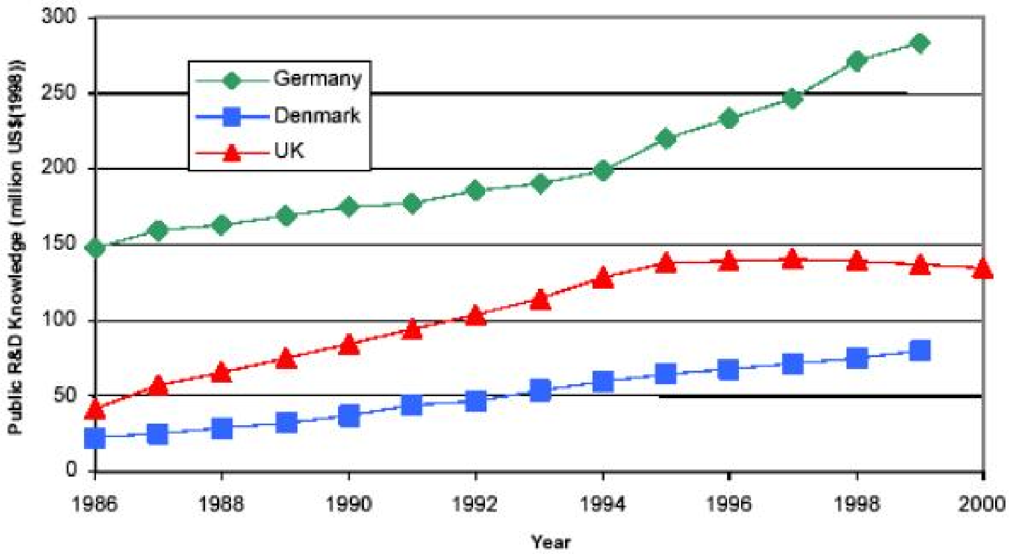

Figure 3.4 *Development of the R&D based knowledge stock for wind power*
Source: Klaassen et al., 2003.

Figure 3.9: R&D based knowledge for wind power[89]

However, these calculations tend not to include some important variables. R&D expenses from the private system are very important as well in the Danish system. Besides, more than focusing on the augmentation of the knowledge stock, the Danish government has always sought a rather stable wind market in Denmark, often implementing export-based strategies as it has been clarified in the former paragraphs. Moreover, the governmental financial incentives were often directed to increase the turbines' sales, and therefore the R&D towards the privates. As Lako (2004) suggests: "*commercialization of technologies is intimately linked with R&D. Or, the cycle reinforces itself; it is a 'virtuous cycle'. There is a double boost from the sales on the market and from the improvement of knowledge through R&D*"[90].

Concluding from this theoretical assumption, the only possible technological spillover that can emerge are those from Denmark to Germany where governments' policies

[89] *Ibidem*

[90] P. LAKO, *Spillover effects from wind power. Case study in the framework of the project Spillovers of climate policy*, ECN-C--04-058, 2004. p.16

and entrepreneurial setting are very similar, and “manufacture” spillovers from Denmark to the UK. This latter is the consequence of a strong export based policy that UK undertook in the 2000s by importing more than 80% of its wind turbine from Denmark suppliers and automatically sharing some of their technology and innovations[91].

Finally, the last perspective is the one provided by Junginger who examines the technological developments both in the onshore and the offshore wind turbine industry. His bottom-up investigation tends to focus on the great potential of the offshore sector and on the investigation of the connections between the investment cost of offshore installations and the coat reduction and technological developments arising from them. According to Junginger, offshore wind farms have an average 50% higher efficiency compared with the onshore ones. This appears to happen thanks to the more elevated wind exposition by the sea. Moreover, offshore farms present a lower environmental impact in terms of noise and visual impact.

In his analysis, the author takes into consideration the drivers necessity to make an offshore wind farm work, such as the cost of the components, the grid connection, their foundation and so on. In doing so, he draws two different scenarios of analysis. In the first one, that he calls “sustained diffusion”, is a rather positive one and it implies an offshore wind installed capacity of 50,000 MW in Europe, and 70,000 MW in the world by 2020. The second - “stagnating growth” - is a rather negative one and implies that the actual average rate of growth of around 15% per year will decrease to a mere 10% per year.

[91] *Ivi*, pp. 13-17

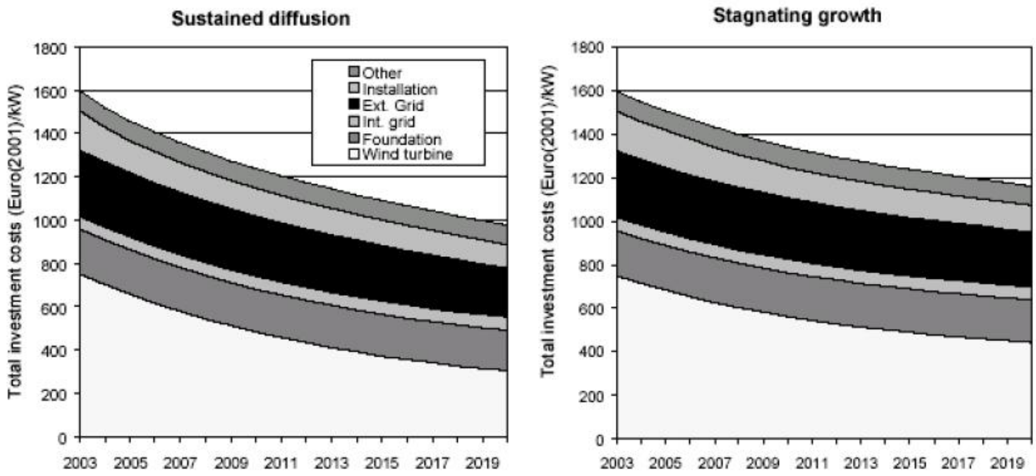

Figure 5.2 *Specific investment cost of offshore wind farms in two deployment scenarios*
Source: Junginger et al., 2004.

Figure 3.10: specific investment cost in Junginger scenarios[92]

In the first scenario, according to Junginger calculations, "*specific investment costs of offshore wind farms would come down from €1,600/kW in 2003 to €980/kW in 2020 in sustained diffusion and to €1,160/kW in stagnating growth*"[93]. From this technological environment it emerges that long-run offshore projects create cost reductions overall in terms of installation costs[94]. However, the offshore industry is still too young and at a too early stage. That is why it is very difficult to know if some spillover will generate. As Lako (2004) says: "*EU countries with offshore wind potential and the EU may be interested to support offshore wind power […] also in view of the potential of offshore wind in other parts of the world. Therefore, EU […] could consider possible spillover effects from offshore wind turbine technology. For other world regions, it would be a sensible strategy to open up their markets for offshore wind technology becoming available from the EU and the US. […] It would be beneficial for these regions to profit from the high technological level of offshore wind turbines etc., developed in the EU and the US. Other world regions would then act as*

[92] P. LAKO, *Spillover effects from wind power. Case study in the framework of the project Spillovers of climate policy*, ECN-C--04-058, 2004. p. 25

[93] *Ibidem*

[94] *Ivi*, pp. 23-27

'late adaptors', with the advantages of higher reliability, lower costs, etc. Although these regions would then rely on import of offshore wind technology for some time, there could also be scope for development of an indigenous offshore wind try"[95].

3.2.3. The Danish wind cluster competitive advantage: a Porter's diamond study

We have seen how development, within an industrial district, can be driven by two main forces: technology or market. In the former case they respond to a technology push approach, in the latter to a market pull one. These two different approaches are the theoretical basis for two different kinds of strategic programs that can be undertaken when it comes to forecast performances and growth of an industrial environment.

The first strategy is the top-down strategy. This takes place when "*the development aspires to achieve fast technological advances and radical innovations regarding the size and efficiency of the wind turbines. It is based on national "Science-technology push" policies and therefore, characterized and controlled by restricted governmental programs or institutions, which finance development contracts to "promising" companies*"[96]. The enthusiasts of this particular kind of development strategy are convinced that science is the base for technology, which is nothing but a surrogated and a product of the former. This means a strong attention on the theoretical foundations of science as a starting point for any technological research.

On the other side, a bottom-up strategy consists in a set of "*market pull policies and contains less radical innovations and gradual technological improvements directed towards an existing market (it is open for discussion whether or not the activities are*

[95] P. LAKO, *Spillover effects from wind power. Case study in the framework of the project Spillovers of climate policy*, ECN-C--04-058, 2004. p.30

[96] J. VESTERGAARD, L. BRANDSTRUP, R. D. GODDARD, *Industry Formation and State Intervention: The Case of the Wind Turbine Industry in Denmark and the United States*, Academy of International Business, Conference Proceedings, November 2004. p.2

fully market driven as the market for many years is subsidized as well as the fact that a lot of the research is funded from allocated resources from state programs)."[97] In this case, technology and science are much more interconnected to one another and they tend to be more focused on the practical and factual side of the knowledge phenomenology.

The Danish wind cluster has followed a particular and unique development pattern which cannot be totally included in one or the other strategy. On the contrary, for some particular aspects, the Danish strategy seems to be based on a strict governmental control and consequently being related to a top-down strategy. Nevertheless, as we have already seen, the incredibly interconnected level of relations among the Danish cluster's actors is a typical consequence of a bottom-up strategy.

In the final part of this chapter, it is advisable to comprehend the sources of the striking competitive advantage of the Danish wind industry and the roots of the strategies that brought it to occupy its actual paradigmatic role all over the globe. The most appropriate investigation framework to value the overwhelming and decisive Danish strategic advantage is the Porter's Diamond of National Advantage.

This analysis tool has been developed by Michael Porter to summarize both the industry-based approach and the resource-based approach towards the accumulation of competitive advantage within an industry. According to Porter, in order to understand the dynamics standing behind the functioning of an industry, it is not sufficient to select one single approach and develop it. On the contrary, a general, holistic and comprehensive analysis is the base to recognize the mechanics of an industrial structure.

Michael Porter's National Diamond investigates over the causes that lead to a strategic choice not only by taking into account the amount of resources or the industrial

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[97] J. VESTERGAARD, L. BRANDSTRUP, R. D. GODDARD, *Industry Formation and State Intervention: The Case of the Wind Turbine Industry in Denmark and the United States*, Academy of International Business, Conference Proceedings, November 200. pp.2-3

environment. As a matter of the fact, this strategic framework tries to examine an industrial setting through four different kinds of interconnected approaches. The first one - the factor endowment - recognizes the importance of a conscious appreciation of the territorial resources that are present within a particular, national industry. On the other hand, the other three components tend to be more related to an economic macro-environment point of view - related industry, demand condition and strategy, structure, and rivalry.

Once described in brief what the National Diamond is, it is time to begin a revision about the Danish wind cluster based on Porter's tool. In doing so, it will be evaluated how the Diamond's forces apply within the Danish cluster. However, the attention will be principally focused on one particular component of the Diamond: the related industry within the cluster. This choice seems obvious when it comes to describe the competitive advantage of a cluster. In fact, the main reason for a cluster success stands in the high degree of interconnection among all the components operating within the district. The presence of both within-industry and outside-industry competitors, suppliers and buyers is one of the main causes that gives clusters their peculiar dynamicity, innovativeness and swiftness to react to market demand and changes. Therefore, applying the National Diamond framework to a clustered district mostly means to understand the connections and the interlinks that makes this business unit so vibrant and competitive.

However, although the primary importance of the related industry force, restricting our analysis just to this fundamental component, would be a mistake. As a matter of the fact each industrial district has deep connections with the factor endowment of its geographical site. However, for factor condition, we do not consider just a "physic" perspective. Factor conditions do not refer only to the physical resources of the territory. However, as we will show in this paragraph, it can concern also intellectual, technological and knowledge resources.

Denmark is a set of small islands and a rather large peninsula (Jutland) between the Northern Sea and the Baltic Sea. This position between two large water basins, guarantee the Nordic country a constant and relatively high wind speed of 4.9–5.6 m/s. However, in the Jutland and by the sea, this speed reaches even higher values (around 9.0 m/s). Moreover, the wind breeze is constant and present all year long, overall by the coasts. This renders Denmark a rather rich in natural resource country, when it comes to wind sector.

However, the most valuable and precious resource that Denmark owns is not wind itself. Chen (2009) acknowledged that the most relevant Danish assets in the wind industry are its high degree of innovativeness, the strong university and knowledge system and an incredibly high skilled and qualified labor force. The academic environment in Denmark is one of the main pillars of the success of the cluster.

The European Innovation System (EIS) set Denmark in the world's 4^{th} place in terms of innovation attitude. Furthermore, the Jutland peninsula has been considered as one of the global main core of wind energy research and studies. As we have seen before, in Denmark there is plenty of engineer and technical college and school, such as the University of Denmark, the Engineering College of □rhus, the Risø national laboratory, the Technical University of Denmark and so on[98].

Furthermore, Denmark is very well connected with transmission grids that links many Central and Northern European countries, such as Germany and Netherlands from the South and Sweden and Norway from the North. This means a limited grid connection problem because Denmark, in practice, does not need any additional peak-load energy farms to equilibrate the production wind energy. This is one of the reasons why Denmark's government has always been very optimistic in forecasting a 50% from wind power electricity consumption in the nation, by the end of 2050.

Finally the human resources of the territory, as it has been clarified in the first paragraph of this chapter, is particularly important, both in terms of number and in terms of qualification, know-how and skills.

[98] Z. R. CHEN, *Based on Triple Helix, the analysis of Danish wind power industry*, National Central University, Taiwan. 2009

The second important component of the Danish success is the peculiar composition of the Danish demand. As a matter of the fact, the usual connotation of wind energy demand is composed by large, public stakeholders that funds the projects. However, in Denmark the situation is rather different. In fact, together with the largest actors, such as the utilities, the grid owners, the public agency for the distribution and production of electricity, we can find a whole different subsystem of small and medium local unions, "*guilds and non-profit partnerships of wind turbine owners who pool their capital investment in local wind turbines. In 1999, 50% of Denmark's 3,200 turbines were owned jointly by 67,000 guild members, bringing significant economic benefit to Denmark's rural areas. The other 50% were individually owned*"[99].

The third force that is going to be considered before focusing on the industrial environment within the Danish wind cluster includes the strategic and structural features of the industrial environment. This means that we are going to understand the competitive and strategic system in which the wind industry actors operate.

Thanks to the governmental support, barriers to enter the wind industry are relatively low compared with the high initial investments to build turbines. As we have seen, the huge amount of subsides that Danish legislator and executive bodies have provided over the last 40 years, created a very favorable investing environment. Moreover, the politic action favored the emergence of many cooperatives and small and medium sized guilds.

After 1973, the Danish actors were the first in the world to innovate and create an investment environment which could have overcome the energy supply problem. Wind appeared soon as the most attractive alternative. It was in this period that the industry conformation started to take place and the present actors to rise. Examples were, as we have seen also in the previous paragraphs, Nordtank, that originally was a suppli-

[99] J. VESTERGAARD, L. BRANDSTRUP, R. D. GODDARD, *Industry Formation and State Intervention: The Case of the Wind Turbine Industry in Denmark and the United States*, Academy of International Business, Conference Proceedings, November 2004. p.19

ers of road tanks for industrial oils; Vestas, in its first days a blacksmiths factory and Bonus, active in the production of agricultural tools. In the Danish industrial structure, the know-how and the learning by doing and interacting are fundamental. All these first competitors applied their previous knowledge to a different field, reaching, in the following decades astonishing results, both in terms of economic returns and innovation and technology development. From this start point, the clustered configuration of Danish industry of wind power rendered the access to the competition easier. This was mainly due by the continuous and beneficial spillovers rising and operating all along the industrial setting[100].

This interchangeability of the wind industrial actors leads the investigation to its main theoretical core. Spillover effects are nothing but an effect of the clustering phenomenon. And a cluster is a "*geographic concentration of interconnected firms, specialized suppliers, service providers, firms in related industries, and associated institutions in particular fields that not only compete but also cooperate*"[101]. This means that within a cluster the presence of different industries is necessary. Nonetheless, these industries ought to be strongly linked with their respective activities. For example, in order to trigger a cluster phenomenon in the automobile industry, it would be very appropriate that, within the same geographical area, we could find steel suppliers, rubber processors, fuel refiners and so on.

In the wind industry this speech is particularly pertinent as well. Already in the first 1980s, the industrial environment of the Danish wind cluster started to assume a complex and multifaceted configuration. In those times, a network of blades, control system and gears producers was already set up. An example of the industrial interconnection within the Danish wind cluster is provided by the blades' supply system. Until the 1986 crisis of the wind sector in Denmark, given by the slowdown of the

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[100] J. VESTERGAARD, L. BRANDSTRUP, R. D. GODDARD, *Industry Formation and State Intervention: The Case of the Wind Turbine Industry in Denmark and the United States*, Academy of International Business, Conference Proceedings, November 2004. pp.7-8

[101] M. PORTER, *On competition*. Boston: Harvard Business School Press. 1998. p. 197

so-called "Californian rush", only Vestas and another competitor, Alternegy, were manufacturing their own blades. With the breakdown of 1986, Alternegy went bankrupt and its place was taken by LM Glasfiber. The history of this enterprise is quite emblematic to understand the relations among the industries in the wind cluster in Denmark.

LM Glasfiber was a famous sailboats' producers which emerged as the main Vestas' competitor for all the late 1980s and beginning of 1990s. Its high capability in dealing with fiberglass was one of the most important driver for the success of the firm. Working often side by side with Vestas, LM Glasfiber increased its production skills and, after the momentary collapse of Vestas in late 1986, it reached a monopoly position until the reorganization of the actual world leader in wind turbine production[102]. The history of LM Glasfiber is the typical example of how, in a clustered reality, firms operating within industries that are deeply different one from another - wind energy and sailboats - but that, at the same time, share some few elements in common - the use of fiberglass and the exploitation of wind as carburant, in this case - can become an effective and alternative model of development and business incubator.

The Jutland peninsula hosts an incredible complex wind industry. In the sole □rhus/□lborg regions almost 500 different firms operate in the wind sector, often intersecting their activities with ones of other industries - as it is clearly shown in the chart below.

[102] J. VESTERGAARD, L. BRANDSTRUP, R. D. GODDARD, *Industry Formation and State Intervention: The Case of the Wind Turbine Industry in Denmark and the United States*, Academy of International Business, Conference Proceedings, November 2004. p.10

Downstream		Middle stream		Upstream	
Business	N° of companies	Business	N° of companies	Business	N° of companies
Bonding and sea-lands	6	Transport & handling	18	maintenance	8
Metal processing	35	Electrical systems	45	Engineering consultancy	15
Plastic processing	5	Mechanical components	28	Energy software	20
Surface treatment	13	Blades	9	Project development	12
		Towers	12	Service	18
Total	59	Total	212	Total	115

Figure 3.11: □rhus/□lborg wind cluster supply chain[103]

Wind industry is a very complex reality, that hosts many different industries and activities within its range of competences. Chen (2009) stated that three different industrial growth models exist. This is very interesting because, whereas the first two models refer to an indirect production of innovativeness, the third deals with an actual creation of development and technology expansion. Going in depth, the first model is called “technology import model”. Spain is the classical example because it uses imported technology rather than developing new innovation within its industrial system. The second one is called “market-technology swapping model”. This is the example of the Chinese or Indian development. As a matter of the fact, this is an intermediate structure between a totally-dependent-on-import growth models and a totally independent one. Chinese government, for example, although allowing a large use of technology importation, impose to Chinese firm a 50% home-made manufacturing for many components in the wind energy industrial value chain.

Denmark is the most important representative of the third model, the “original innovation” one. In the Danish wind cluster, innovation, knowledge and technology originate from the active cooperation of private corporations and institutes of research,

[103] Z. R. CHEN, *Based on Triple Helix, the analysis of Danish wind power industry*, National Central University, Taiwan, 2009.

with the public institutions (such as the Risø Laboratory, the Universities, and so on). Other sources are: the coordination mechanisms between producers and users that allow a learning-by-interacting system; the synchronized industrial structure that guarantees a continuous supply of components and materials all over the value chain, and the technological and knowledge spillovers that increase the speed and the circulations of vital information all around the cluster.

This beneficial situation renders task specialization easier. In fact, in the wind cluster in Denmark we do not find just the typical, large producers of the whole wind turbine production process such as Vestas, Siemens and Bonus. We find minor and small components' suppliers as well - for example: LM Glasfiber, for the blades; Mita Tech. Company and KK for control and communication tools and so on. Even further we can find companies that work side by side with firms operating within the wind industry but that are definitely outside this industry itself. Examples are DWP, BTM Consultancy, Elsam, Tripod and many others which are active in sectors such as financial consulting, banking, legal consulting and so forth.

In conclusion, it is opportune to affirm that the presence of related industries in the wind cluster has always represented one of the main drivers to success for the Danish wind turbine industry. This is true as coordination and cooperation among different industries provide a wide range of supply differentiation; a spread out of knowledge and technology and the possibility for the firms, operating within one industry, to learn and evolve in new and more competitive ways.

IV. TRAJECTORIES AND PROJECTIONS FOR THE GLOBAL WIND INDUSTRY AND THE DANISH WIND CLUSTER

4.1. Methodology

In the last chapter of this paper, the future development trajectories and projections for the Danish wind cluster, both in terms of supply chain and productive system technology and R&D and government and private financing of the industry, will be finally analyzed. In order to do so, the vivid and concrete accounts of some people that actually work within the cluster and that I have personally interviewed during my period as a host student at the Århus School of Business, will be provided as direct account of my thesis and hypothesis.

My personal elaboration will mainly deal with the idea of a very likely opening of the Danish wind cluster towards new globalized markets, industrial dynamics and competitors that, as we will show during the chapter, will determine the disappearing of the Danish wind cluster as it is known nowadays. This analysis will be focused mainly on three different hypothesis respectively connected with the evolution of the supply chain, the technological and innovation system within the cluster and its financing system. On one hand, the first supposition will be that the Danish wind cluster will very likely conclude its dominant role as leading wind turbine productive force within the next 5-10 years. On the other hand, the second hypothesis will mainly focus on a deep conviction that the Danish wind cluster will keep on being one of the fundamental milestones of the global wind industry as far as regard the R&D system, the innovativeness and the technology point of view. Finally, I will try to demonstrate how the governmental financing system to the Danish wind industry - that has been one of the main hinges of the Danish wind cluster development over the past 40 years - will very likely cease to exist leaving space to a completely competitive market environment.

In my investigation I will try to answer in the most homogenous and consequential possible way to the guiding questions that make up the general skeleton of the interviews I have submitted to the Danish managers and academics, operating directly into the cluster. The questions have been sorted by thematic area.

a. Supply chain and productive system:

1. What are the specializations of your company within the Danish wind industry and which are the main technologies and products your company supplies? What were the main contributes your company provided all along the industry development? What are your strategies for the future?
2. What is the history of the company in the Danish wind cluster? How did it develop so far and which is the future growth forecasting for the next 10-20 years?
3. Where would you place your company and its production if you imaged to draw a theoretical supply value chain for the wind industry in Denmark? Is it embedded in upstream or downstream stages of the value chain? Is it active all along the value chain?
4. Would you characterize the Danish wind cluster supply chain as a centralized or decentralized one? Do you think it has always been like that or have you faced a sort of evolution all along the years?
5. How has the wind supply chain evolved in the past 30 years - basically since the introduction of the Vester turbine?
6. How do you think globalization is influencing the wind industry in Denmark? Which were the most important and noticeable shifts?
7. How has your company been affected by the entrance of new, foreign, powerful competitors such as the Indian Suzlon or the Chinese Sinovel, Don Fang and so on? What is the effect on the industry of these companies which are used to operate at lower level of fixed and variable costs?

8. How would you characterize the competition degree in the Danish wind cluster? How is that affected by globalization and which are the consequences on your company?

b. Technology and R&D system:

1. How important is the R&D system in such a high-tech industry as wind? How does your company deal with the R&D expenses? What is the share on the total costs of R&D expenses at your company?
2. How important is to act in a clustered industrial environment? Which are the advantages and disadvantages provided by the clustered configuration of the Danish wind industry?
3. How have your products developed in time? Which have been the most important innovations provided by your company and how have they affected the industry and the company's dynamics?
4. Kemp, in his paper called "Notions on learning applied to the wind turbine development in Denmark and Netherland", describes the concept of learning by searching and learning by interacting. In which category would your company fall when it comes to learning process? How do you think technologies have spillovered throughout the wind cluster?
5. Do you think that in the path of the Danish wind cluster growth, the R&D entrepreneurship has raised as a systemic, social accumulation of input and knowledge over time (distributed agency) or has it been the product of periodic, isolated genial invention by some individuals or enterprises? What about your company? How does it approach the R&D process? Does it seek a "bricolage" or a "breakthrough" (Garud, Karnoe) strategy when it comes to R&D?
6. How do you think the wind turbine technology is going to evolve in the next 20 years? Which are the perspective standards and the technological results you are willing to achieve?

c. Financing system:

1. Do you know which are the most important ways Denmark finances its prolific and efficient wind power industry? What is the share of public and private investment in the system?
2. Can you explain which are the drivers behind the paradoxical situation in which Denmark, although being world leader in the production of wind energy, has the most expensive electricity bills in Europe?
3. How do you think the financing system of wind industry has evolved during the last 30 years? Do you see any fundamental turning point on the merge of the first decade of XXI century?
4. Has globalization within the wind cluster affected the financing system as well? Is the Danish government still the number 1 actor in the cluster or are things slowly going towards a liberalization and internationalization of the market?

This typology of interview has been submitted with the adequate corrections and differences to the following people:

- Mr. Michael Degermann, Project manager at Eltronic A/S;
- Mr. Mogens Nyborg Pedersen, Global Source and Procurement Director at Siemens Wind Power A/S;
- Mr. Mads Hovmøller Mortensen, Industrial PhD Student at Vestas Wind Systems A/S;
- Mr. Jørgen Højstrup, Head of Global Wind&Site Competence Centre at Suzlon Energy GmbH.
- Prof. Poul Houman Andersen, Professional Training & Coaching at □rhus School of Business

It is possible to read the whole interviews in the following chapter of the paper.

4.2. Trajectories for the Danish wind cluster. The supply chain and the productive system.

The first part of this study concerns the shifts and the transformations that are likely to happen in the productive system of the Danish wind cluster in the near future. As it has been explained while studying the evolutional dynamics of the wind industry in Denmark, the Danish wind cluster has always been a fundamentally closed system. Taking into consideration the first 40 years of history of the wind industry in Denmark, the only considerable opening to new markets was the "California rush" in 1986.

4.2.1. Globalization, industrialization and innovation in the wind industry

Therefore, the wind industry has been identified with a Danish affair for many years. There are two reasons behind this tendentially closed structure. In first place, the development of the industry has always been strongly linked and connected with the subsides and the government support. The wind industry a relatively young one. During the first decades of life of the Danish wind cluster, the main trajectories that can be described regard mainly the huge technological growth. On the contrary, in terms of volumes of sales, the output has remained tendentially stable or it has grown constantly but slowly. The government subsides in the 1980s and 1990s became a substantial push towards an increase in terms of sales and output. However, being obviously totally directed only towards the national territory, they could not trigger an important growth rate. As a matter of the fact, Denmark is a small country with less than 5 million inhabitants. Thus, it is clear that the industrial total production level could not be that large in absolute terms.

The second reason concerns the global economic trends of the wind industry over the past four decades. As the first part of the second chapter of this thesis has shown, wind energy has been considered as one of the most valuable renewable energies since the 1973-1974 breakdown. Nonetheless, the very high R&D expenditures, the necessity to provide low cost turbines, the skepticism of many governments and the dominance of fossil fuels over time have strongly hindered this power source.

Indeed, the global market for wind power has grown very slowly until the first years of 2000s. However, in the last 7-8 years the wind industry has experienced a world-wide, vast increase in terms of overall output. As Mr. Mogens Nyborg Pedersen, Global Source and Procurement Director at Siemens Wind Power A/S, states: "*Now wind has turned into a real industry. Especially after the financial crisis, people have started to see into the wind industry a promising market. So we have three main drivers that drives the change in the cluster: globalization, innovation and industrialization*".

These concepts seem to be the key to understand the transformations of the wind industry, in general, and the impact that they will have on the Danish wind cluster in the next 10 - 20 years. Globalization is by far the main driver. Wind energy is the most important renewable energy in terms of installed capacity (159 GW in 2009). Wind is also the fastest growing power source with 27% per year. Offshore wind farm account a further 641MW installed capacity, with an astonishing rate of 72% increase per year. In Denmark, 20% of national electric demand is powered by wind; in Spain the 14%; in Portugal the 11.3%. Though, what is primary important to underline is that, nowadays, China has around 1/3 of the total wind power installed capacity, with a yearly increase of 13.8 GW in 2009. China is followed by USA (with 10GW added in 2009) and Germany (1.9GW added in 2009) [104].

The entrance in the industry of huge competitors has inevitably pushed the cost levels down. Comparing with the original, typical Danish wind cluster actors, new companies such as the Chinese Sinovel and Goldwind, or the Indian Suzlon, have a totally different, more pragmatic idea of how to make business within a globalized environment. Disposing of a gigantic amount of funds and incentives provided by their government or their being listed in the most important world financial markets, these companies can produce huge quantities of turbines with sensible cost reductions.

[104] AA. VV., *Renewables 2010. Global Annual Report*, REN21, Renewable energy policy network for the 21st century. 2010. pp. 16-18.

The main reason is that these new actors have just one aim when it comes to commercialize a product: make money, notwithstanding the quality levels. As Mr. Jørgen Højstrup, Head of Global Wind&Site Competence Centre at Suzlon Energy GmbH, says: "*Suzlon does not have any dominant model of components. Our technological philosophy is not to be a front comer in technology, but a second comer. The most important part for us is the commercial part, I mean, we want to make money. There are a lot of situations where you have competing technologies and best technology suppliers lost their challenge. That is why we are perfectly happy not to be front line*".

Suzlon, Goldwind and Sinovel, the three main Asian competitors in the Danish cluster but also General Electric (GE), the actual world number 2 in wind energy installed capability, seem to share a second comer strategy. This strategy allows these companies to save billions of euro of investments by pushing on quantity instead of quality. They leave to the large Western competitors such as Vestas and Siemens Wind Power, the burden of risking for spending huge amounts of money in order to increase the overall technological level of the turbines.

Therefore, globalization into the wind industry has determined the emergence of two different strategies. The former sees the late comer, global actors strongly challenging the industrial pioneers on prices and low cost turbine production; the latter, undertaken by the wind industry pioneers, that focuses more on vast R&D expenditure and protecting clauses in order to hold their technological advantage safe. The clash between such different strategies is another trigger event that has started what Mr. Pedersen called "*industrialization of the wind industry*". In brief, thanks to the entrance of new, powerful competitors within the wind industry and more specifically within the wind cluster as an incubator and experimental industrial environment, wind energy and its mechanic source - the wind turbine - have finally become a commercial and competitive product.

We can clarify this phenomenon by looking at the cost situation within the wind industry. The main costs of implanting a wind turbines are embedded in the fixed costs required to set up such a high tech and large machine, whereas fuel and maintenance costs are relatively low if compared to the capital ones. Of course, if we want to understand the price dynamics of such a particular, complex and specific product as wind energy, we have to consider many components such as: the building costs; the costs of transmission with the facilities; loans; the returns given to the funders; the annual production and the projection of these cost components on the life of the turbine.[105]

The following figure describes the cost composition of the world disposable energy sources in terms of estimated leveled costs.

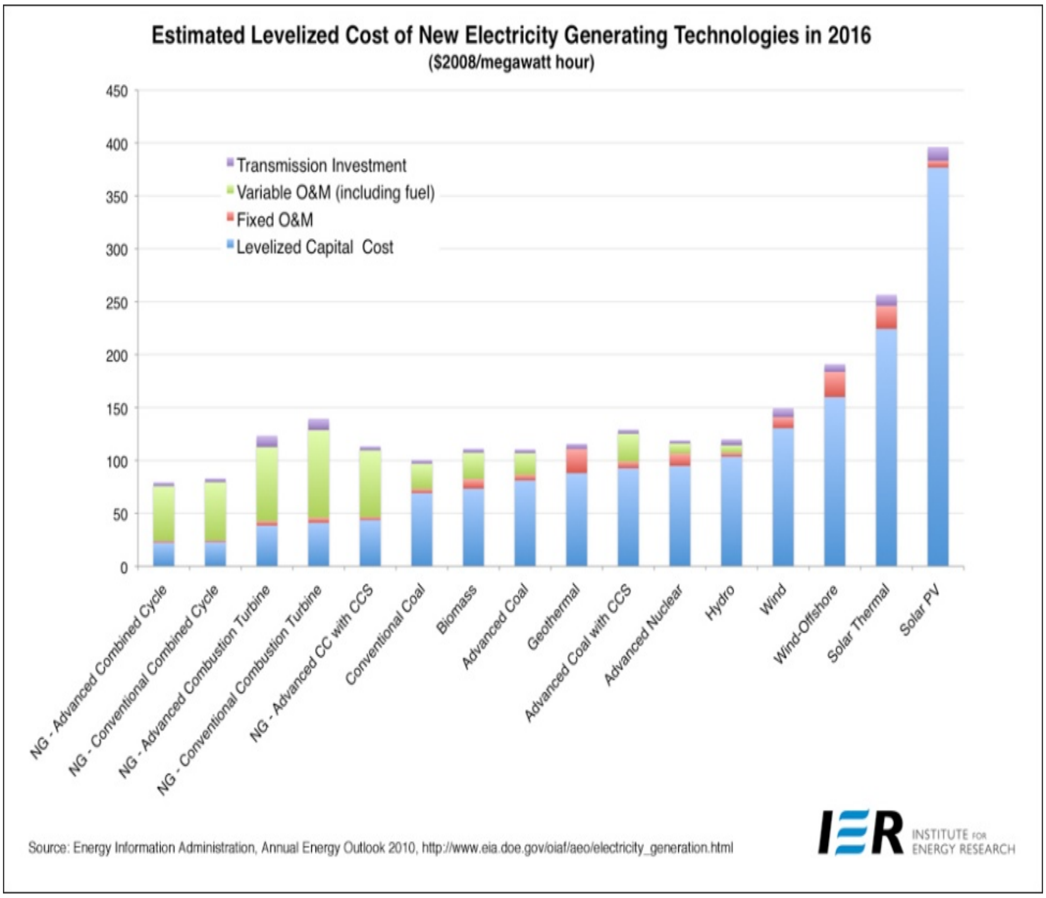

Figure 4.1: Cost composition of energy sources[106]

[105] EIA, *International Energy Outlook*, Energy Information Administration, 2006. p. 66.

[106] http://www.newinnovationsguide.com/WindEnergyBackground.html

Furthermore, these costs vary hugely from one county to another. Thus, we will consider a rather general measure of price per MW taking into consideration the overall global tendency. According to the Global Wind Energy Outlook for 2010 building a wind turbine is a rather large investment. However, capital costs have decreased sharply over the last 20 years as productive techniques have been enhanced and standardization and automation introduced. These improvements have activated economies of scale with a decreasing capital cost per KW of capacity installed and characterized by a high innovation rate.

In 2009, an average price of 1,350€ per each kW of installed capacity was reached. The global tendency seems to lead us to a hypothetical scenario where the price will decrease down to 1,240€ per kW in 2020 and 1,216€ by 2030 which means a standard investment of 2.7 million € for an average 2MW wind turbine in 2009; 2.48 million € in 2020 and 2.43 million € in 2030. Overall global investments in the wind industry are likely to increase from the present 53.5 billion € in 2010 to 79.1 billion € in 2015, 106.5 billion € in 2020 and €166 billion € in 2030. This analysis seems to show the degree of industrialization of the wind industry. Costs are sharply going down rendering wind energy a competitive and commercial source of energy.

Concluding this introductory sum up, the third driver that is transforming the wind industry is represented by the innovation level. Competition within the wind industry cannot be totally understood just focusing on volumes of sales and cost levels. It is simply impossible to have a clear idea of how wind industry is going to evolve if the strategic importance of technology, knowledge and information within such a high tech industry, is not taken into account. Vestas and Siemens Wind Power are respectively leader in the inshore wind turbine and offshore wind turbine production. It is not a case that Siemens and Vestas are the companies that are spending - and that have spent over time - the largest amount of money in terms of R&D and technology innovation.

Another demonstration of the overwhelming importance of innovation and technology within the wind industry is that GE, Sinovel and all the other competitors strongly rely on a vast scale production of small or medium turbines (from 1 up to 3 MW). Vestas and Siemens are involved in a fierce competition to produce turbines that go from 6 up to 10MW with energy output levels many times superior than the competitors. And, at least in the European market, where quality is set as a fundamental standard, the high tech turbines have always been the dominant model.

There is a very interesting example to understand the importance of quality in the wind industry productive system and it is provided by Mr. Mads Hovmøller Mortensen, Industrial PhD Student at Vestas Wind Systems A/S who makes a comparison between automotive and wind industry. According to Mr. Mortensen "*we are reaching a level in volumes where we can do mass customization and production. Wind industry is on the first phase of the growth lifecycle of the industry when it has not reached the tipping point yet. In fact, it is just 2 or 3 years that you have the possibility to choose among many suppliers. If you look also at the quality of turbine. If you take a car, […] you have a maintenance service after 40,000 km. If you see offshore turbine, it has a relative efficiency of 9 times more. But suppliers don't know these quality standards, so also Siemens, Vestas, have major quality problems with these suppliers. We cannot explain them how the quality is meant to be. This because we acquire the knowledge over time. In the automotive industry the basis technology has always been pretty much the same for the past 20 years. In the wind turbine ten years ago we had 0.6MW turbines while today we are trying to play with 6, 8 maybe 10 MW turbines. So you don't have the same learning curve. We have to experiment our new products, materials and so on. This means the investment is very risky*".

4.2.2. Transformation and trajectories of the Danish productive system

Once analyzed the three main drivers behind the expansion of the wind industry towards a completely global and commercial level, it is possible to notice that although wind industry from its very beginning has quite a long and remarkable story, it reached this outstanding development and substantial volumes in terms of production just around the first decade of 2000s. The wind industry in Denmark has been active since 1970s and Government has often pushed and subsidized the industry towards unique technological standards. Very likely Denmark is an exceptional case. The global wind hub has been in a quiescent state for decades and just after recent events, in early 2000s, it has become a real energetic alternative for the largest global powers.

In this section, the general attention will shift on the supply chain trajectories of the wind cluster in Denmark, without considering for the moment, the technological drivers. This multiple methodological approach will allow to focus merely on our first hypothesis - i.e., that the Danish wind cluster will disappear as a productive, geographical entity within the next 10 years.

It is rather impossible to picture the modern situation of the Danish wind cluster supply chain without considering globalization. In Denmark, this fundamental transformation driver has held a revolutionary role. The Danish wind industry remained a closed system for a long time. A significant and definitive data demonstrating how deeply and rapidly globalization has affected the wind industry in Denmark can be deducted by the two graphics below, representing the market share of the 10 main competitors in the wind industry in 2002 and in 2010.

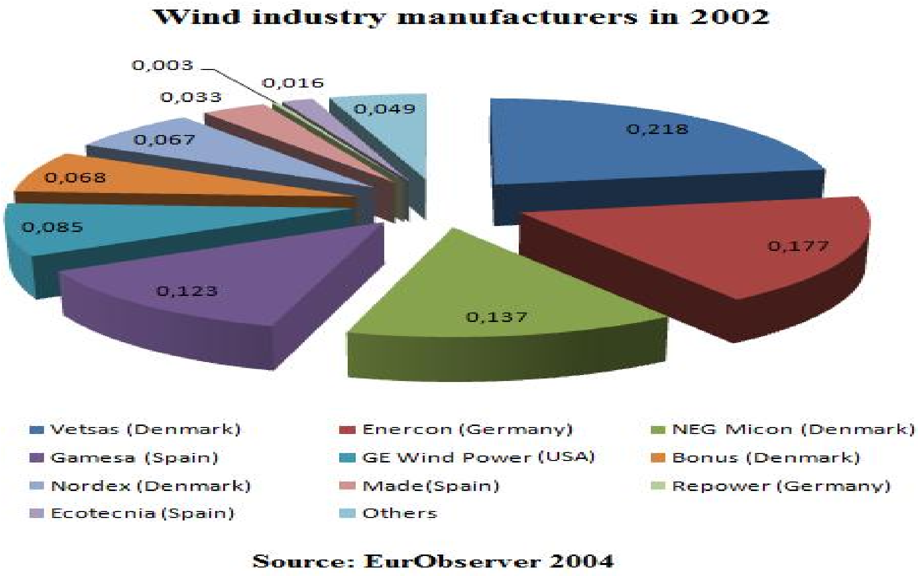

Figure 4.2: wind industry main manufacturers in 2002[107]

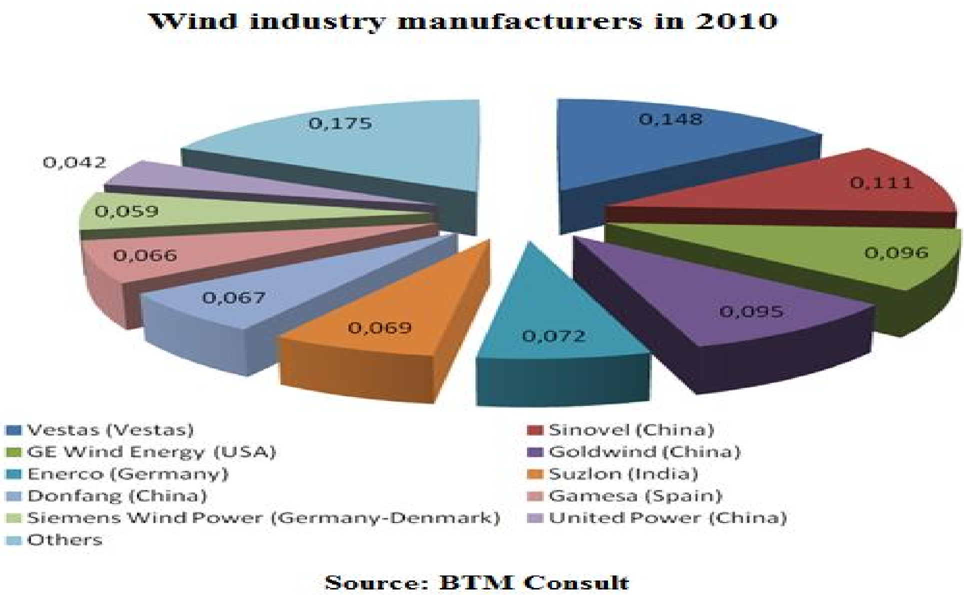

Figure 4.3: Wind industry main manufacturers in 2010[108]

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[107] P. LAKO, SPILLOVER EFFECTS FROM WIND POWER. *Case study in the framework of the project Spillovers of climate policy*, ECN-C--04-058, 2004. p.11

[108] http://en.wikipedia.org/wiki/List_of_wind_turbine_manufacturers

As it is easily noticeable in 2002 four among the largest seven wind turbine manufacturers were Danish. In 2003 Vestas merged with NEG Micon accounting an overall 35.5% of the world market share with an almost 18% share advantage on the second competitor (Enercon, from Germany). The explanation for this dominant role of the Danish enterprises emerges because of two different reasons. Firstly, the competitive and particularly favorable industrial environment in Denmark, as seen and demonstrated in the third chapter of this thesis. Second, and most important, the relatively small volumes of wind turbines production in the world wind energy market back in 2002. Danish companies could maintain an almost unbeatable leadership in terms of technological advantage and they could exploit this advantage until the production volumes remained low and the demand for wind turbines relatively small.

However, nowadays the wind energy installed capacity has raised vertiginously. The present world installed capacity is 197GW whereas in 2002 it was just 29.3GW. Denmark share in terms of installed capacity was 9.8% with 2.89GW installed in 2002 whereas in 2010 its 3.75GW installed capacity accounts a mere 1.9% of the overall world share. On the other side of the coin in 2002 China - just to make an example - could exploit just a 473MW installed capacity while nowadays it leads the global market with an astonishing 41.8GW, a world share of 21.1% and 4 among the planet's top 10 wind turbines manufacturers.

As it emerges from the various interviews, in *Addenda*, we can see a common confidence in setting the "boom" of the wind industry around 2004-2005 with a constant, outstanding growth since then. In brief, it is reasonable to affirm that wind industry has reached or it is about to reach its tipping point. From now on it is just expected to grow at 20-30% yearly rate at least since 2035.

However, it is still surprising to notice the profound transformations that occurred in the industry in just 8 years. The effects of this disruptive industrial growth have deeply influenced the configuration and the dynamics of the Danish wind cluster at all the organizational and corporate levels. Either if the object of the investigation are the small and medium local suppliers within the cluster - such as Eltronics; the large multinational enterprises coming from Denmark - Vestas - or having a long and deep tradition within the Danish territory - Siemens Wind Power; or the large global competitors that are challenging the old leaders overall in terms of prices - Suzlon.

The transformation of the wind industry is the product of a complex and interconnected mechanism that cannot prescind to take into consideration the relations and the modification dynamics of these three typologies of actors. Finally, the different impacts of globalization on these three types of competitors will be explained and a demonstration about why it is common belief that the manufactory system of the cluster will very likely move out from Denmark ,will be, hopefully, provided.

In the general Danish economic environment small and medium enterprises are one of the most important and valuable national assets. A large number of these type of firms exist, rendering the industrial structure of the country flexible and quickly adaptable to the fluctuation of the global market. However, the main problem with such a national business structure is that the rate of productivity is tendentially low overall when the volumes tend to increase sharply.

This general tendency seems to apply perfectly to the wind industry. Small and medium suppliers generally work as subcontractors or in concomitance with the largest wind turbine manufacturers in Denmark. They tend to specialize on particular components and pieces of the wind turbine and sell them to the firms they are connected with or in regime of free market. However, the market structure in the Denmark's wind industry is peculiar. Even though the Wind cluster shows the typical indirect and external spillovers in term of technology, knowledge and market information, there is still a large burden to the freedom of the spread of information in the system: the non-disclosure clauses. As it has been explained in the previous chapter, the largest and more innovative companies, such as Vestas and Siemens Wind Power, tend to impose hampering clauses on employment mobility or non-disclosure clauses in bilateral project contracts.

This is a big impediment for a concrete development of the small and medium producers. They obviously have not the same funds to invest in R&D activities and at the same time they cannot produce whole turbines on a vast scale. Therefore, globalization and the entrance of new, larger competitors within the Danish cluster, far from damaging these kind of firms, has actually enhanced their bargaining position.

As Mr. Michael Degermann, Project Manager at Eltronic A/S, says: "*for us [globalization] is just another opportunity to get in contact with potential customers. It's good to have new companies in that market segment […]. They [the large producers] […] still haven't understood how important it is to share knowledge. […] Little companies cannot face this huge demand and they would go bankrupt immediately, within a month. We wish an openness of the market in order to increase competition. I think in the next years we will see a consolidation of the market and big players going on the global market. […] Vestas or Siemens produce every part and components of the turbine, whereas they should simply outsource this production to small and medium companies which can specialize in those fields providing more competitive and cheaper products. […] It is important for foreign companies to go in Denmark and try to change this state of things. And they are doing precisely by looking at small companies. In other words, they cannot force Siemens or Vestas to provide them all the necessary tech needed to reach their levels. However, by working side by side with small and medium component suppliers, such as Eltronics, they can gain those expertise required to compete on a large scale level.*"

Two points emerge clearly from Mr. Degermann's analysis. On one side, globalization has enhanced the level of competition within the system pushing the large, traditional companies to reduce R&D expenses and to open to knowledge sharing. This creates a situation that somehow improves the condition of small and medium companies that are willing to compete over technological issues. As a matter of the fact, Vestas and Siemens Wind Power are already dropping some of their value chain activities and leave them to the most competitive subcontractors.

On the other side, the entrance of global manufacturers has improved the level of information flow in the system rendering the sharing of technology and knowledge much easier than in the past. As Mr. Højstrup says: "*We [at Suzlon] also have clauses but only on very key and high ranked people. My opinion is that competition clauses are very bad for the system because they prevent people from going to other companies and spread information and knowledge into other companies. And by doing that companies are losing knowledge and the whole industry level of knowledge is affected by this. I think it is stupid that we have very very knowledgeable people walking around without being able to work for years. It is actually crazy*". Global manufacturers have all the interests in keeping the flow of information as fluent as possible in order to keep their R&D cost down. They will seem to be to outsourcing the manufacture of the most high tech components to competitive subcontractors - better if they accept to be vertically integrated within their supply chain - and keep their productive costs down. The evolution and the trajectories of the spillovers' mechanisms will be discussed in detail in the next paragraph.

What is important to notice here is that these global competitors' strategies have strongly influenced the strategies of the third typology of actors: the large pioneer companies. In fact, they have been challenged from both the sides (small and medium firms and global manufacturers). These kind of firms have been active within the wind industry for decades - Vestas since 1968, Siemens Wind Power since 1980, Enercon since 1984 - and they have collected a considerable technological advantage deriving from their know-how, their experience and huge pushing on the R&D expenses.

However, as Mr. Pedersen states: "*wind has become a commercial product and we are looking for global sourcing. So, in the past, because of the competition within the cluster, we looked abroad seeking for low prices, lower costs, cheaper raw materials and so on. But nowadays because of the volume of the sales increasing, we cannot act anymore in terms of project specificity. But we had to change into a stock philosophy. So it means that we have the orders on long term bases and then we will have a* *more stable production. So producing not anymore for just the projects*". This means a shift of productive philosophy: from outsourcing just the roughest and heaviest components such us the tower, the wings and the nacelles, in order to decrease the transaction and transportation costs; to a different philosophy based on a large and vast scale decentralization of the whole productive system.

For many years, both Siemens Wind Power and Vestas produced the whole turbines in Denmark and then shipping them oversea. This strategy was mainly a protective shield in order not to spillover their technological innovation all over the world. However, nowadays this strategy is not applicable anymore to the global wind industry. This is true both because wind turbine global expansion has become larger and larger, implying increasing transportation and assembling costs and because global competitors are pushing the technological leaders with their back against the wall in terms of production costs, prices and volumes of sales.

Technology also affects the productive dynamics. It is clear that non-disclosure clauses is one of the few defensive measures these traditional competitors can use in opposition with the fierce competition of the global manufacturers. But, they appear not to be sufficient any longer to avoid the outsourcing of production. Technology is leaking quickly within and outside the cluster in Denmark and the global competitors will overwhelm the old leaders thanks to the new information beyond their huge availability of funds and liquidity. Moreover, companies such as Vestas and Siemens Wind Power have a much larger burden in terms of R&D expenses that arises from their first mover strategies and their involvement in the highest technological products - offshore turbines, large turbines. Hence, they cannot permit themselves to maintain a productive system in such a high cost country as Denmark.

Therefore, basing the analysis on the complete picture of the main competitors in the Danish wind cluster, it is straightforward to see that all the three different actors have a strong urgency to move their productive value chain towards countries where the productive costs are much lower than Denmark. The Danish productive structure has worked well for over 40 years because it was embedded in a regime of substantial global monopoly. Danish wind cluster has been the productive and technological center of the wind industry for decades, thanks to the technological advantage of the Danish productive forces and the massive governmental subsides. However, the actual situation imposes a critical change.

Wind as we have seen has become a commercial product with a lower and lower price per KW both in terms of installed capacity and in terms of electricity production. This implies a deep strategic revision and the seeking of productive methods and environments where the investment and the labor costs are lower and the availability of the widespread of raw material. Concluding this first section with Mr. Højstrup's words: "*I think the cluster itself will move to be not anymore a manufacture pool but just a sort of global HQ for R&D expenses and technology gathering. This is true especially if you see Vestas, Siemens behaviors. They are already, and I think they will produce almost everything outside Denmark. There are many factors pushing this phenomenon. One is price of course, another is seeking the availability of work force; there is also the question of transport. Wind turbines are becoming larger and larger so it will be more and more difficult to ship them from Denmark to other countries. So the companies will maintain their quarters in Denmark but shift the production bodies outside*".

4.3. Trajectories for the Danish wind cluster. The R&D system.

In this second section, the second study hypothesis - namely the fact that according to our findings the Danish wind cluster will continue to remain the technological hard core of the global wind industry - will be fostered.

4.3.1. Spillovers and non-disclosure agreement within the Danish wind cluster. A burden or a necessity?

In the previous chapter it has been shown how a clustered industrial configuration is able to strongly enhance the technological and knowledge environment both from an internal point of view and an external one. Technology, knowledge and information spillovers are one of the fundamental keys for the success of the cluster model of industrial growth. As Prof. Poul Houman Andersen, Professional Training & Coaching at □rhus School of Business states within a cluster: "*there are several benefits. One is the ability to have proximity in your learning process. In other words if you are very close geographically and also mentally, you might say your ability to interact, to learn, and exchange knowledge is strongly enhanced by the possibility of face to face interactions. The other benefit is that because of this interaction, trust building, specialization and division of labor become possible simply because wind turbine producers have been able to utilize, what I would call spare capacity, among suppliers. It is not that we have in Denmark a cluster of companies fully specialized in wind turbine industry. They typically have three, four fives industries where they are working*".

The technological system in Denmark is enforced not only by the typically "geographical and physical" advantage of operating in a clustered environment. In addition to that, the magnitude of the competitive advantage is empowered by a strong network of public and private knowledge institutions that makes the Jutland peninsula the unquestionable technological center of the whole globalized wind industry. In the sole city of □rhus we can find, apart from the Vestas' R&D headquarter, Suzlon and many other large companies general HQ, an incredible number of high level and internationally recognized institutions: the □rhus University, the □rhus School of Business, the □rhus School of Marine and Technical Engineering, the Engineering College of □rhus, the □rhus School of Architecture, the VIA University College, the Navitas Park, the INCUBA Science Park, the New University Hospital, Agro Food Park, and so on.

Moreover, the technological web in central Jutland is enforced by the strong presence of multiple, efficient and supporting industries such as boating, aerodynamics, and engineering. As Prof. Andersen explains: "*when you see the wind turbine cluster in Denmark, there are a number of companies that take part in wind turbine technolo-*

gies but another part that takes part in activities in other industries. So what typically happens in this semi opened cluster is the interactions among industries. For example, agricultural companies producing machinery, steel and iron industry import components and materials to the wind industry. So not just the presence of the activities is important within the wind turbine industry but also the connection with other industries that are reaching technological knowledge from a different industry into the wind cluster."

If we add the powerful and effective government incentives to the knowledge and academics institutions and the State incentive to the wind industry - overall the offshore one - we can easily understand how the □rhus-□lborg wind competitive environment is doomed to remain a technological pool; a lighthouse for the rest of the world.

However, there is a one of a particular that seems to affect the effectiveness of the Danish wind cluster and challenge one of the fundamental theoretical standpoints of the cluster theory. In the Danish wind cluster, as it has mentioned, non-disclosure and secrecy clauses seem to hamper the spreading and the leakages of both technology and competitive information. It is theoretically possible to divide spillovers into external and internal. In turn, the internal spillover can be categorized into direct and indirect. While indirect spillover seems to work perfectly in the Danish clustered configuration, the direct ones are strongly hindered by the non-disclosure policies of most of the what have been called "pioneer" companies all along this thesis.

However, it is difficult to analyze such a delicate topic without considering all the points of view. It is clear that small and medium firms, such as Eltronics and global competitors, such as Suzlon, perceive non-disclosure clauses and market obstacles as inefficient impediments to a real and effective competition within the cluster. As Mr. Degermann says: "*There is no much institutional spillover because you have to deal with disclosure agreements. It is difficult to share knowledge also in □rhus. We make an agreement when we make a project and we are not allowed to share it with anyone else. This is very common in the wind industry for the wind industry for the mo-*

ment therefore, it is very difficult to share knowledge outside the company so we need to do it from the inside. But again we need to be careful. That is why I think the in the industry is a little limited". The same goes for Suzlon.

However, not to mention the motivations of companies such as Vestas and Siemens Wind Power would be definitely misleading and unfair. It would be easy to demonstrate the inefficiencies of the non-disclosure clauses in terms of competitiveness of the market. As a matter of the fact, it would be enough to say that they are one of the most important source of barrier to the free flow of market information. And we know precisely that this is one of the main pillars of a competitive and perfectly efficient market.

However, there several reasons that is impossible not to mention in such a globalized industry like wind turbines. It could be harsh and perhaps politically incorrect to say but hinders to the spread and spillovers of technology, knowledge and information are vital to maintain the industrial technological standard at a high rate. This could sound as a very strong affirmation. However, let's consider a hypothetical scenario where non-disclosure clauses have been abolished by all the main actors in the market. As it has been learnt so far, pioneer companies, such as Vestas and Siemens Wind Power, base their competitive advantage on a strong R&D activity push, whereas global competitors tend to soak up the free flow of technology and information available within the market. Moreover, they have an availability of funds and liquidity to invest which is endlessly superior to traditional companies - overall the Danish Vestas.

This means that whenever the technology and information dams break open, the highest ranked competitors in terms of technology will be swept away, with a consequent loss in terms of technology standards. Sure enough, the rush towards the technological advantage would not have any sense any longer because all the technologies would be immediately available. Competition will shift towards mere cost advantage strategies with the huge, global multinational swallowing the entire industry in 5- 10 years' time. It is not a case if Prof. Andersen declares: "*the other thing is* *that with the globalization one of the debate is for a couple of years who is going to buy Vestas. Some think about some of the German companies (not Siemens but ABB; and so on). Vestas is in a situation in which they have to consider whether they want to be a specialized wind turbine producer and face the music as such or if they want to become part of a larger industrial conglomerate*".

Of course this is an extreme scenario. Spillovers exists already in the system and once again quoting Prof. Andersen, "*[…] until recently this was not a big problem. […] Vestas has been very keen[…]. But the issue is that when you start to set this kind of non-disclosure agreements, you take away part of the incentives to the most critical suppliers to participate. If a supplier can't really use what it has learnt during a design project when dealing with another customer. The supplier would start thinking that the manufacturing cost it is paying is too high and start to develop its owns. So this entire dynamic will change once the non-disclosure agreement will not be enforced. […] I believe there is this kind of non-written agreement in Vestas and Siemens also, that dealing with suppliers, there is this practice of treating the technological data confidentially, but still, the suppliers can use those ideas later on. Intellectual property rights are very hard to enforce. So it is more symbolic issues*".

In other words, it is true that non-disclosure agreements exist and somehow they enhance the technological advantage of the "pioneer" companies. However, thanks to the clustered configuration of the industry and the presence of wide indirect spillovers, they do not affect the cluster in such a way to hamper completely the information and technological flows.

4.3.2. Trajectories for the Danish wind cluster as world class technology pool

So, is it clever to think that the scenario - in which the actual world leader will be sold to the best bidder - is a mere theoretical speculation? Not quite. Perhaps, this particular kind of circumstance will not happen, or will happen with different and more moderate modalities. However, if the takeover of Vestas will not occur in the very next future, it is mostly because of the presence of different technological standards within the industry. This is the main core of the analysis and the main reason why it is common belief that the Danish wind cluster will continue to be one of the cornerstones of the wind turbine industry all over the globe.

Wind industry is moving towards two different kinds of production and technology. Global competitors are involved in a massive scale production of small or medium turbines. Suzlon 1.5MW turbine is the most spread model in the whole Indian market and one of the most common in the world. This is a cheap but rather effective prototype that seems to set the new frontier of low tech and low cost wind turbines. And it is rather secure that this Suzlon's archetype will become one of the most significant standpoints for all the developing countries willing to increase their energy capability through wind power.

Nevertheless, as Prof. Andersen says, whereas in the developing countries the main issue is exactly to increase energy installed capacity in the Western ones, the main problem is to replace energy capacity. This means the consideration of several aspects that at least in the short term, will be totally left apart by the emerging economies. It is the case of environmental issues, technological perfectionism, innovation and so on. This means that the Danish wind cluster will still remain the industrial élite center where research and even more development will reach the utmost in terms of effectiveness and technology. Indeed, it is in Denmark that the new frontiers of the wind industry have been experimented.

Examples are the present challenge that German companies are moving to the Danish ones trying to substitute the dominant model of turbines with a gearbox with another one which will lack of this component. This technology competition is mainly played between Vestas and Siemens Wind Power and it is then very well circumscribed within the Danish wind cluster strategic environment both in terms of production and R&D.

Furthermore, the Danish wind cluster is the most flourish environment also for some other kinds of experimentations which seems to represent the new horizons of wind industry. Nowadays, the attention in terms of technological and innovative development is shifting away from the productive value chain which has already reached a very high level. This is of course true for the onshore turbines whereas it remains a fundamental issue in terms of MW enlargement and developments for offshore turbines. Denmark remains the vanguard both in terms of production and innovation in this modern business whose frontiers present many opportunities but also many risks. As Mr. Mortensen says: "*Offshore is a very expensive investment so potentially this is more profitable but we have to be careful*".

For the more mature onshore industry instead the real new challenges are not productive ones any longer. Or, at least, they are no longer exclusively related with the increase of the turbines' productive capacity. Nowadays, facing wind energy consumption has emerged as the main industrial challenge. In the Danish wind cluster there are many projects going on which are precisely trying to do that: to face the consumption difficulties of the fluctuations of wind energy.

The first technological horizon concerns the topical objective to shorten as much as possible the time gap between the wind energy production and consumption. This problem, that has been explained talking about the grid connection, derives from the highly fluctuating character of wind power. Even with some adjustments through injections of energy coming from other countries - the Norwegian hydropower, most of all - the wind power remains a problematic source of energy, when it comes to consider the constancy and continuity of the energy stream. This is why the Danish wind cluster has recently become a huge and boundless experimental center for the building and the perfecting of a transnational super smart grid connected with both the Scandinavian NORDEL and with other Center Europe countries such as Germany, Holland, Northern France and UK. The main challenge is to cope with the large initial costs that by now have represented an insurmountable obstacle.

Moreover, to solve the problem of wind fluctuation, without getting stuck with humongous investments on the grid network, the entire R&D apparatus of the Danish wind cluster has been developing interesting and futuristic solutions. The first one can be perfectly summed up by Prof. Andersen's explanation: "*to convert wind energy on the spot in something else, heat for example. So storing energy will generate in huge tank and create heat and utilize later. For example in steam turbines and so on but you might lose some of it*".

The second one is even more fascinating. The main idea is connecting the electricity grid, the wind turbines and the electric cars "refueling points". Energinet, the Danish utilities owning the grid and Dong, a semi-public utilities owning many facilities in Denmark, in cooperation with a private company named Better Place are currently working on this pioneering idea that involves the almost 60,000 electric cars in Denmark. The project consists in connecting the household electricity system with the turbines. So "*when you are producing a lot of energy, basically when the wind blows hard and you have a surplus of energy, you can, through an intelligent net, ask your energy provider to charge your car. […] These batteries are connected so if I am in a situation of surplus of demand of energy I can actually borrow energy from this battery net. So, I can make an agreement with the car owner and take energy from the car and make the grid support the demand. These batteries work like a power plant and you can store energy. With this system you can reduce our conventional capacity of 10%*".

Therefore, within the wind industry, the technological focus is shifting away from the mere productive process and moving towards new and innovative horizons that are connected with interesting and demanding challenges related to the consumption and the usage of wind energy. Overall, from the interviews, it appears rather clear that Denmark will keep on being on the front line of the technological research within the wind industry. Indeed, it is within this country that the most interesting findings about possible utilization of wind power have been made and again, in these countries many of the most important global players have moved their R&D HQ in order to capture as much information and technological upgrade as possible.

Wind industry has started to walk in Denmark, it has learnt how to produce on a vast scale in Denmark and it has discovered its huge technological and productive potential in Denmark before boosting and spreading all over the globe. And, it is very likely that wind industry will understand how to manage and use the electricity and the energy deriving from wind again in Denmark. Sure enough the national R&D institutions for the wind power are the best in the world, there are plenty of related industries which seem to be able to face the difficulties and the complexity of the new challenges. As emerging from these findings, technological wind cluster is not going to disappear soon from Denmark.

4.4. Trajectories for the Danish wind cluster. The financing system and the political intervention.

When the financing system of an industry is taken into consideration one of the most important driver to analyze is the system of incentives, tariffs, policies and measures that guarantee that industry a certain level of funds and cash to carry on the related business. In the Danish wind cluster Denmark's State has been the main actor of this financing system for almost 40 years.

4.4.1. Feed-in tariff or green certificate?

Since the earlier years of its industrial development the wind cluster in Denmark has been strongly linked with the political intervention mechanisms and the system of incentives that the government was providing in order to favor the rapid technological and economic growth of the wind industry. The evolution of the financing system in Denmark in the last 30 years has already been described in the precious chapter. Thus, the focus of this paragraph will be explaining the present situation and the future trajectories.

Before providing some data it is fundamental to consider that except the brief parenthesis between 2000-2003 with the failure of the Energetic Reform and green certificates, feed-in tariffs have always been the most important way the political institutions have financed the wind industry. A full and complete idea of the relevance and effective value of the incentive measures in Denmark in the year 2008 can be forecasted thanks to this table provided by Renewable Energy Sources, one of the most reliable internet engine for renewable energies topic.

Turbines connected to the grid after February 2008	- premium price for 22,000 full load hours → 33,60 €/MWh (25 øre/KWh) premium + 37,62 €/MWh electricity price - additional allowance in the entire lifetime of the turbine to compensate for the cost of balancing → 3,10 €/MWh (2,3 øre/KWh) - private wind turbines below 25 kW → 80,60 €/MWh (60 øre/KWh)
Turbines connected to the grid from January 2005	- premium for 20 years→ 13.41 €/MWh - allowance for offset costs etc. → 3.08 €/MWh
Turbines connected to the grid in the period 2003-2004	- premium for 20 years → 13.41 €/MWh - allowance for offset costs etc. → 3.08 €/MWh (total tariff, i.e. premium + market price for electricity → must not exceed 48,27 €/MWh)
Turbines connected to the grid in the period 2000-2002	• Onshore - total tariff (premium + market price) for 22,000 full load hours 57.66 €/MWh - premium after full load hours are used up, until turbine is 20 years old → up to 13.41 €/MWh - allowance for offset costs etc. → 3.08 €/MWh (total tariff, i.e. premium + market price, must not exceed 48, 27 €/MWh) • Offshore - Total tariff (premium + market price) for 10 years → 57.66 €/MWh - Allowance for offset costs etc. → 3.08 €/MWh (total tariff, i.e. premium + market price, must not exceed 48,27 €/MWh)
Turbines acquired before end 1999	- 80.44 €/MWh until full load hours are used up; full load hour allowance is 25,000 hours for turbines of 200 kW or less, 15,000 hours for turbines of 201-599 kW and 12,000 hours for turbines of 600 kW and more - 36.20 €/MWh if the turbine is more than 10 years old but has not used its full load allowance up yet; total tariff must not exceed 80.44 €/MWh - up to 13.41 €/MWh if the turbine is over 10 years old and its full load allowance is used up, until the turbine is 20 years old; (total tariff must not exceed 48.26 €/MWh) - allowance of for offset costs: 3.08 €/MWh
Turbines financed by electricity utilities	• Onshore - 57.65 €/MWh if connected to the grid after 1 January 2000, for 10 years as from the grid connection - up to 13.41 €/MWh if the turbine is over 10 years old, but not older than 20 years; total tariff, i.e. premium + market price, (must not exceed 48,27 €/MWh)

	• Offshore - 60.73 €/MWh if connected to the grid after 1 January 2000, for 42,000 full load hours - up to 0.93 €/MWh compensation if production is subject to a grid tariff - up to 13,41 €/MWh after all full load hours are used up and turbine is not older than 20 years; total tariff, (i.e. premium + market price, must not exceed 48,27 €/MWh)
Wind turbines with removing certificates	- up to 16.09 €/MWh - for 12,000 full load hours for production covered by a removing certificate from a 450 kW or less turbine onshore, decommissioned between 15/12/2004 and 15/12/2009; total tariff, i.e. premium + market price, must not exceed 64.35 €/MWh
Household turbines	- 25 kW or less -> 80.44 €/MWh

Figure 4.4: the feed-in tariff system in Denmark in 2008[109]

All along the history of the Danish wind cluster feed-in tariffs have been the most important kind of subsides. However, since the definitive reform to the energetic system in the country, they have been slowly but decisively reduced. The evidence of this statement is clear if we compare the lasting of the feed-in tariff for the elder turbines - 20 years - with the ones that have been connected to the grid after 2008 – 22,000 hours (2.5 effective years of functioning).

Furthermore, all over 1990s the feed-in tariffs for wind energy were about 85% of the consumer price of electricity (around 0.03 and 0.05 €/KWh, depending by wind fluctuation). Moreover, independent electricity suppliers could get reimbursed from the payment of the carbon tax for another 0.036 €/KWh. To give a precise idea of these specific numbers it is enough to say that a producer, whose turbine was operating in a poorly windy geographic area and therefore enjoying the lowest possible feed-in tariff, was averagely earning around 0.08 €/KWh - i.e., almost 0.05 €/KWh more than the global average of 0.0325 € a year[110].

[109] http://www.renewable-energy-sources.com/2009/10/20/renewable-energy-prices-in-denmark/

[110] M. CERVENY, G. RENSCH, *Feed-in Tariffs and Regulations Concerning Renewable Energy Electricity Generation in European Countries*, Energieverwertungsagentur (EVA), Vienna. 1998

This decrease in terms of State incentive to the onshore wind industry has also been confirmed by many turbine producers. No wind turbine supplier have any kind of government subsides nowadays and the facilities producing electricity have seen their privileges and incentives being cut back all over the 2000s - namely when the wind energy started to become a relatively marketable and competitive product. As Mr. Mortensen says: *[…] I think that the cluster in Denmark has been shaped by the subsidy policy. It gave the industry a major boost and it gave us the competitiveness of developing a product before going abroad. Now we don't get any subsides while in the old days from 1 to 12KW you get like 0.6DKK [*0.08 €/KWh*] and so on. It rendered the investments a good practice. Today the subsides are mainly in the offshore sector. From the government there has been a policy of picking the winner and it worked quite good because it gave a stable industry and it boosted the industry before going abroad.*"

Another factor emerges as a driver of change. Globalization has affected the financing system of the Danish wind cluster enlarging the wind turbine market through the presence of many new global competitors; larger volumes of production and sales; more exports; and global specialization. This means that there are more investors willing to fund the wind industry in Denmark leaving the Government in a more neutral and passive position.

The astounding development of the industry over the last 10 years has set new standards for the wind energy which has become one the cheapest renewable sources and one of the most affordable source of energy in general, overall after the recent leap of the oil price. This is why with the amendment to the Reform of 2003 the Danish Government has been able to lower down the fiscal pressure over the taxpayers. In fact, most of the wind industry subsides have been financed through a deep enlargement of the public expenses over the past 30 years[111].

In 1998 Denmark spent 75 million € in the wind industry creating a strong fiscal pressure on the national balance sheet and the Danish citizens who pays one of the highest electricity bill in the world. This was the main reason that lead the Government to reform the feed-in tariff system. The attempt to introduce a market-based incentive mechanism - the green certificate - showed a new necessity to incentivize the wind energy market not through direct incentives but through mechanism of auto adjustment of the market without burdening the citizens with new taxes. Green certificates were a sort of tradable certificates issued to the producers of electricity deriving from renewable energies. This green certificates allowed the suppliers to receive a premium over the price of the electricity supplied once sold to whom wanted or had to buy electricity coming from renewable sources.

Nonetheless, the main disadvantages of the green certificate policy have risen clearly in a small, national market such as the Danish one. In first place they tend to incentivize only one and the most competitive technology (onshore wind turbines) leaving aside the development of new, innovative developments. In addition, the main problems were related with the fact that in order to create a significantly efficient incentivizing system, the national market had to be rather large whereas Denmark's one is particularly small.

According to the 1999 Reform the Danish electricity customers had to buy at least the 20% of their consumption from renewables and the green certificates were sold at an average price of a minimum of 0.10DKK/KWh and a maximum of 0.27DKK/KWh[112]. However, for the difficulties mentioned before, the Danish system was not ready to accept such a dramatic change, shifting from a totally publically

[111] P. E. MONTHORST, *Policy Instruments for Regulating the Development of Wind Power in a Liberated Electricity Market*, Contributions from the Department of Wind Energy and Atmospheric Physics to EWEC '99 in Nice France, Risø National Laboratory, Roskilde, Denmark, 1999. pp. 7-12

[112] N. MEYER, *Renewable energy policy in Denmark*. Energy Sustain. Dev. 2004; 25–35

incentivized system to a completely market based mechanism. The Reform execution was planned to be executed at the beginning of 1999. Even so, it was postponed continuously: before by January 2001, then January 2002 and finally January 2003. Because of the inefficiencies and the problems of adaptation to the Danish market in June 2002, the green certificate project was totally abandoned by the Danish Minister for the Environment and Energy who reintroduced a premium rate based on a less expensive feed-in tariff system as explained in the *prospectus* above[113].

4.4.2. Future projections for the Danish wind cluster financing system

What has been observed in the last years is a general privatization and liberalization of the wind industry, as long as wind energy becomes more and more a tradable and marketable industrial product. The new aim of the Danish authorities and industrial actors is to create a system in which the incentives are endogenous and not set from the external political environment. The green certificate experiment did not work. However, Denmark is trying to focus on feed-in tariff much less than in the past. Market quotas have always been present in the Danish wind market and they still represent a great challenge. Achieved with a large advance the aim of 20-20 by 2020 set by the EU, the new objective is to be totally CO2 free by 2050.

Even maintaining formally the classical feed-in tariff incentivizing structure, the 2003 Reform introduced some revolutionary principles and focus points for a formally social-democracy as Denmark. The first and most important is that there is no state ownership in the electricity industry. This means that nowadays, the almost 90 electricity utilities are owned mainly by privates or cooperatives although State remains the main shareholder in the most important ones. Secondly, a connection in terms of ownership between the distributing utilities and the main electricity generators in the country. Moreover, a continuation of a market quota policy which has been one of

[113] P. AGNOLUCCI, Wind electricity in Denmark: A survey of policies, their effectiveness and factors motivating their introduction, Environment Group, Policy Study Institute, London, 2005. p. 955

the most important tools the Danish government has used in order to push the wind and renewable industries since the Plan 1981.

Furthermore, another important issue set in the Reform regards the increasing taxation for electricity consumption. This is a very important fiscal tool because it tends to indirectly achieve motivating environmental objectives and it protects virtuous consumers by implementing the so called consumer generated values. In brief, this legal-political concept states that in monopoly regimes, consumers hold peculiar rights in the decisional process of management of electricity resources because they basically pay for the electricity investments.

The Reform shows a very important trajectory for the future of the financing structure of the Danish wind cluster and the renewable energy industry in general. This is true overall if related with some anomalies within the incentive system in the country. In first place, these incentives and the supporting mechanisms travel at a superior speed if compared with the objectives set in the EU's 20-20 by 2020 program. Moreover, Denmark has one of the lowest electricity prices before taxation in Europe. This means that this incentivizing structure could be an useless waste of government funds overall if we compare the cost of electricity after taxation - the highest in Europe.

The main reason why Denmark is not giving up this complex and expensive system is strongly linked with the evolution of the international market for electricity. Denmark is particularly attentive to maintain its competitive advantage in terms of technology and renewable source of energies for electricity against its main competitors. All the other Scandinavian countries introduced elements of competitions in the late period. Therefore, the Reform of 2003 was not simply an economic tool trying to sort out the main systemic inefficiencies of green certificates or to lower the amount of feed-in tariffs. Indeed, the Reform was a political step as well. The Danish Energy Agency and the Danish Parliament have opted for an opening and market based electricity production and distribution system but without revolutionizing what has been a winning model for more than 4 decades[114].

Concluding, the 2003 Reform for Denmark's energetic system has taken into account ambitious economic and political goals aiming to transform a State-incentive-based system in a market-competitive one revising the Danish historical development path. Focusing more specifically on the wind industry, the commercialization of the "wind product" seems to be direct proportional with the softening of the State intervention inside the cluster. As Mr. Pedersen says: "*Governments are no longer financing the industry like in the past because today wind is a commercial product so it is mainly financing just the utilities such as big companies owning the power plants in the transmission system, the grid owner, investors from abroad setting power plants*". The more the wind energy becomes a global and competitive goods, the less incentives it receives. The age of technological pushing through State incentives and subsides is over. Nowadays wind is ready to blow on its own wings.

[114] P. HOFFMAN, *The Danish Energy Reform*, Association of Danish Energy Companies, Frederiksberg, Denmark. 2004. pp. 65-67

V. ADDENDA

5.1. Eltronics. Respond to a survey form an Italian student

Part 1: Supply chain

1.1 Please describe which are the specializations of Eltronic and which are the main technologies and products your company supply. Can you make a brief description of what wind turbine control and Eltronic Track Device (ETD) are?

Eltronic specializes in developing customized manufacturing equipment and special equipment for specific tasks (often logistic), primarily for the wind turbine industry but also for other industry segments. Eltronic clients include Vestas, Siemens Wind Power, Grundfos, Danfoss, LEGO, Carlsberg and other Danish companies.

We do not produce anything physical ourselves, but are focused on design and development. In a typical project we are usually responsible for layout , construction design, PLC programming, robot programming, project management and installation of our solution. We usually choose our own suppliers, but our clients do have special requirements from time to time.

We very often have confidential agreements with our customers, which is why information about our projects is not released publicly (and therefore not found on the website).

An example of manufacturing equipment developed by Eltronic is an automatic bolt tightening cell for a wind turbine manufacturer. In this case, the client specified what they require (process knowledge) and the job for Eltronic is to design a cell that meet the requirements. This includes design of robot tool, hub manipulator, security system, control system and robot programming.

An example of special equipment developed by Eltronic is the Vestas Tower Crane. This project required close cooperation between Eltronic mechanical engineers and Vestas engineers. See these two articles for more information on the Vestas Tower Crane:

http://www.businessgreen.com/bg/news/1802434/vestas-pioneers-cost-cutting-turbine-spider-crane

http://www.scientificamerican.com/article.cfm?id=wind-tower-crane

The two products mentioned in the question are examples of special equipment to the wind turbine industry. They are pure control and software products.

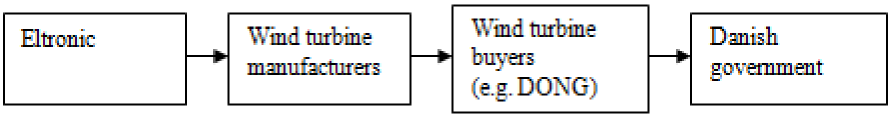
Wind turbine control makes it possible to retrieve status on wind turbines remotely. This makes a number of physical inspections redundant. The status is transmitted through Ethernet and can be accessed with a cell phone or laptop.

ETD is a software solution that makes it possible to track equipment handling automatically. ETD logs several key parameters that are linked directly to logistics of any product. ETD logs humidity, temperature, time without power supply, position at given time, G-force. All data is formatted directly into the quality system.

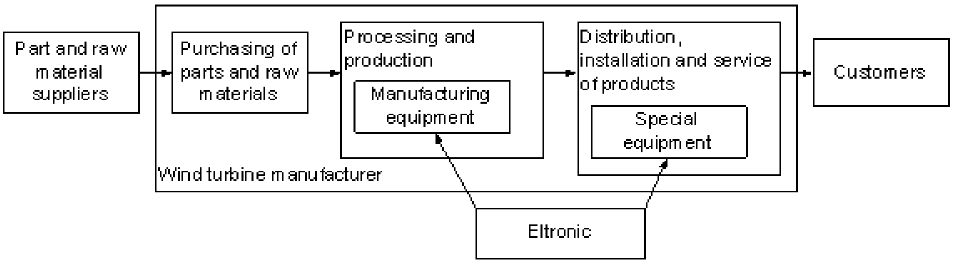
1.2 Imagine to draw a theoretical supply value chain for the wind industry in Denmark. Where would you place Eltronic and its products? Is it embedded in upstream or downstream stages of the value chain?

Upstream or downstream position depends on the point of view. From a wind turbine manufacturer’s viewpoint, our position is upstream, since we are a direct supplier to wind turbine manufacturers.

A very simplified model of how Eltronic positions itself in the wind industry can be drawn as below.



Eltronic provide manufacturing equipment and special equipment, and thus we are a side branch of the entire supply chain. The following model attempts to illustrate Eltronic's place in a typical wind turbine manufacturers supply chain:



1.3 Your web site states: "With Industrial Intelligence you can concentrate on market shares instead of wages". Can you describe what this Industrial Intelligence is and how does it round out your competitive-advantage strategy?

Industrial intelligence is the collective of engineering branches required to fulfill our client's requirements. This ensures that our clients can rely on our expertise within any manufacturing or special project they may have.

1.4 Would you please explain the history of the company? How did it develop so far and which is the future growth forecasting for the next 10-20 years?

- Year 2000
  - Establishing Eltronic A/S
  - Automation, Manufacturing IT og Electronics
  - Office at Spettrupvej 7A in Hedensted
- Year 2003
  - Expansion of activities to include construction and general project management

    - Design of customer-specific manufacturing equipment
    - Establishing test facilities
    - Year 2005
    - Electronic activities are moved to Eltronic Solution A/S
    - IT activities are expanded to also deal with OEE, Factory databases and system integration
- Year 2007
    - Establishing more test facilities
    - Extension of office facilities
    - Year 2010
    - Office at Kilde Allé 4
    - Positioning within 5 main segments

Eltronic is living of projects from clients, usually completed within 3-6 months. We are constantly trying to attract projects from our clients. In this light, it is very difficult to foresee the future for Eltronic. However, it is worth mentioning that Eltronic is currently expanding and working on opening local offices in India, China and USA.

1.5 In the last years the configuration of the Danish wind cluster has rapidly changed. How do you think globalization is influencing the general wind industry in Denmark? Which have been the most important and noticeable shifts?

As long as governments across the world and the world market continue to expand wind capacity and support the wind industry, globalization effects are generally positive. The upcoming Danish national test center in Østerild ensures that Denmark continues to be technology leader in the future. Technology and production is very dependent, so this only increases the benefits for Eltronic.

1.6 How has your company been affected by the entrance of new, powerful competitors such as the Indian Suzlon or Spanish Gamesa?

Eltronic is not owned or otherwise politically influenced by other companies, such as Vestas or Siemens Wind Power. We are an independent company and our expertise is not owned by anyone other than Eltronic (Lars Jensen). Therefore, any wind turbine manufacturer is a potential customer, including Suzlon and Gamesa.

1.7 How would you characterize the competition in the Danish cluster? Once again, how is that affected by globalization and which are the consequences on your company?

Competition within the Danish cluster is heavily reduced with only two large manufacturers left, Vestas and Siemens Wind Power. An indirect competitor is LM Wind Power who only produces blades for wind turbines. Vestas and Siemens Wind Power are responsible for most of the wind turbines in Denmark.

Vestas need new manufacturing plants at their outsourcing locations and still prefers Eltronic to design parts of the manufacturing equipment.

Siemens Wind Power have most of their production in Denmark and because of the high wages, they are forced to increase automation level in their factories. They also turn to Eltronic and buy our expertise.

Other large wind turbine manufacturers have also shown interest in Eltronics abilities and experience as a supplier of manufacturing equipment. So the consequences of globalization are generally positive.

Part 2: R&D system

2.1 "Create tangible, measurable and continuous improvements." This is the mission of Eltronic. How important is R&D in such a high-tech industry as wind? How does your company deal with the R&D expenses? Which is the share on the total costs of R&D expenses at Eltronic?

Eltronic is probably best categorized as a company that does research and development for the wind turbine industry. Research is done specifically for each project and is based on prior experiences and demands from clients. Every project is therefore an R&D project in its own extent, financed by our client.

2.2 It seems like the four main pillars of Eltronics R&D policy are: MANUFACTURING automation, engineering, intelligence and service. Would you please describe these four pillars more in depth?

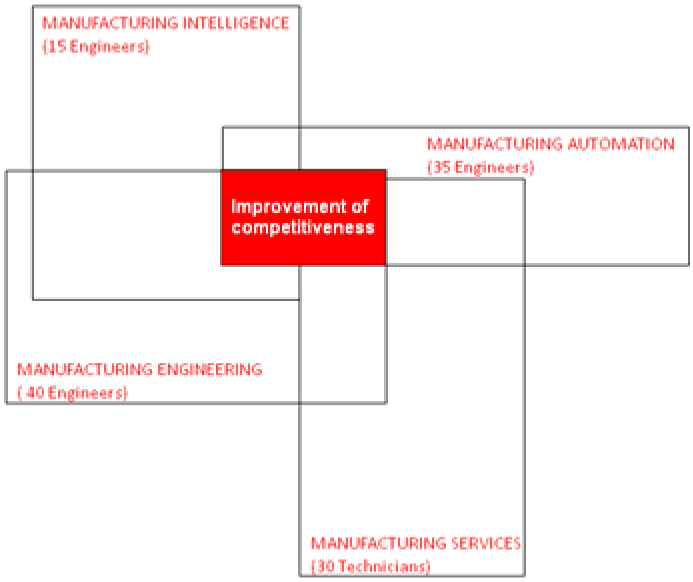
It is not the four pillars of our R&D policy; it is the four pillars of Eltronic.

Manufacturing Automation is the segment of Eltronic that deals with robot programming, PLC programming, HMI design and other design activities that are linked to control of Eltronics products.

Manufacturing engineering is construction design, layout design and drawing activities that very often is a part of our projects.

Manufacturing intelligence is software programming and development, MES, databases, SCADA.

Manufacturing service is installation and practical solutions to problems.



2.3 How have your products developed in time? Which have been the most important innovations provided by Eltronic and how have they affected the industry and the company's dynamics?

Since we act as consultants and developers for the industry, our products differ very much. Development within Eltronic is best seen on the expansion of engineering branches through Eltronic's history.

2.4 Kamp, in his paper called "Notions on learning applied to the wind turbine development in Denmark and Netherland", describes the concept of learning by searching and learning by interacting. In which category would your company fall when it comes to learning process?

Kamp's article describes learning applied on a national scale and the cooperation between state, wind turbine industry and buyers. The conclusions from the article are not directly applicable for a company, such as Eltronic. Eltronic is a relative new player in the wind turbine industry (founded in 2000) and has not been involved in the early stages of the Danish wind turbine development described in the article.

The article describes that the Danish wind turbine manufacturers acquired their knowledge through learning by doing, customer experience (learning by using) and by maintaining close relations with Danish researchers (learning by searching) – combined, this is described as learning by interacting. In this aspect, it is not possible to draw a direct parallel from the article to the learning process at Eltronic, since Eltronic is not directly involved with end users of wind turbines.

However, the learning process at Eltronic is best described as learning by interacting (but not on the same scale as in the article). Eltronic has internal interactions between several branches of engineering disciplines: automation design, manufacturing design & layout, control design, construction design, robotics, software design and project management. This creates a solid base of knowledge which we offer to our clients.

Projects are carried out in close cooperation with our clients. This is necessary, because the client usually possesses knowledge of the process itself.

In that manner, it is learning by interacting, since the client has the process knowledge (learning by using) which they share with us to a certain extent. Eltronic is the developer and is therefore both learning by doing and learning by searching.

2.5 Do you think that in the path of the Danish wind cluster growth, the R&D entrepreneurship has raised as a systemic, social accumulation of input and knowledge over time (distributed agency) or it has been the product of periodic, isolated genial invention by some individuals or enterprises?

In the aspect of Kamp's article, it would be the first. This is also seen in Eltronic, where several engineering disciplines are combined to provide the necessary know-how.

2.6 What about your company? How does it approach the R&D process? Does it seek a "bricolage" or a "breakthrough" (Garud, Karnoe) strategy when it comes to R&D?

We do not seek any of the two. This is defined by the project from the client, since the client defines the frames for the development project carried out by Eltronic.

5.2. Interview to Mr. Degermann, project manager at Eltronics A/S

This interview has been recorded on 28th April, 2011. However, in order to render it more readable and systematic for a thesis work, I have slightly modified the sentences and the structure of the interview, without, however, changing the contents or the idea of Mr. Degermann.

This is just a general introduction of what we are. We have a general company in Hedensted, and then we have a 20% share of the company called 20 solution, [dealing with the wind]; then we have another 20% part of the company that relays on the relations with the shareholders, then we have another 60% of the company dealing with general issues and our relations in Poland. What we are trying to do for the moment is to set up some business in India, USA, in China we already have something but not connected with Solution. We have to follow our customers and as they are more or less global, so establishing a quarter that is very important for our competitiveness. And because they have their large production size we need to be close to them.

We moved last year in a new quarter last July, we spent quite a lot on that, but as the size of the company is enlarging, we just needed to do something. Again, to be perceived by the market we also had to show that we have the facilities to show that we are able to deal with large customers. Companies like Siemens, Vestas look at where you are set up.

We set up close to the highway, and we have many employees coming from Århus, but also from all over the rest of Denmark. We have 130 employees. We want to be accepted partners for the industry in general, we want to improve customers competitors and what are we doing is the four people we talked about (in the interview). We have manufacturing engineering, that is all that has to do with engineering, that could be construction, projecting, … then we have service pillar, that deals with everything that is connected to the machines, both from a technical part and from an external point of view. The automation part is all that has to do with the automation *process of the machines that can be PLC programming for the machines, it can be the whole line [control]. You make a program that collects all the data and mostly to show the customers what has been done, database, statistics, process for the machines, how many parts of the machines we are able to use and whatever is able to put in an informatics system and it will show you everything you want to do.The IT part is more about ETS system which is a GPS used in the wind industry to check everything you have to know. You can also track the humidity, temperature, g forces, measures of the size. It is more or less up to you, what kind of data you need, you ask the device. It works with batteries but we also have a model running with solar cells so something that comes from the quality department in order to be sure that the process works fine. You can apply this device all over along the industry, on the turbine, or in the raw material site, it is more or less about what the customers really want.*

These four things we believe, can increase our customer relations. It is a question of what they do need. It could be one part or it can be all together. These two areas go together (engineer and automation), in order to solve the problems we face. We believe that the combination we have of these four things will be the best for us and for the customers. We have a consultancy part in order to find out what the customers want. How? I will look into the company and I would say "we have some project managers that are particularly strong on the technical assignments and then go look for the perfect documentation and all the things needed to be done. Then we have engineers that deal with the production part, next, there is a design step, and so on. The most important face is the control part. We have to be sure that things work exactly how the customers asked. We normally have two tests, one in the production step and one before handing the product to the project.

Most of our employees are engineers and we have just some economists dealing with accounting, HR and the documentation part that we need to ensure the customers on the security of machines, lifting devices and so on.

According to our organization structure, what we believe is that our managing directors and all the business units together with the project managers, are functions for the people working. So we believe that the most important values we have in the company is that employees are a valuable asset for the company, the most important part. There is a manager to every business unit that directs and controls if it is in line with what the board asks and there are periodical meetings to see that. There is however large freedom into the system, being an extremely flat and flexible structure, I would say despite being a small company.

The wind power section of the company is divided in two. One dealing with Vestas and the other dealing with the others (Siemens, Suzlon, …). That's because Vestas is the largest and it is very restrictive in disclosure measures. It imposes restrictive measures so even though we want to open and share our knowledge to other companies and clients, we cannot so, we divided the chain of productions.

We have also just started to operate in many activities. We have oil and gas, Danish industry for electronic devices, food and beverage and then we have a little part in pharmacy (mainly for insulin). Even though we have just started, for the moment, energy is the main activity. But again, given to the crisis some years ago, everybody turned down except the wind industry. But to play everything in wind industry is too dangerous. If we play 60% in wind energy we lose 60% of our share. So we are trying to share 20% for each activity, but we could not do it in the last years because of the downturn, even though it is the most dangerous path to follow.

One of the few products we have developed for first is the AST, we call it Automative System Treatment because some of the blade producers do a lot of rubbing out activities to smoothen the surface of the blade. We have patented a solution that allows us to rub the surface automatically instead of by hand. This is one of the feed products we have because we mainly work with customers and we do what customers ask us to do. Our products are mainly to do project work for the customers. This is the difference between us and many of our market competitors. For them the customers *come afterwards, while for us, we work in strict contact with the customers, we project what we are asked to.*

About the globalization in the system, for us it is just another opportunity to get in contact with potential customers. It's good to have new companies in that market segment, because frankly we and other actors of the industry are facing the same problems. If you take on the production side, everyone needs to have tower, blades, nacelles, so either they produce them by themselves or they need to outsource. They need to connect things. From that point of view they are still at very young age, and this is one of the main issues. They still haven't understood how important it is to share knowledge.

This goes in general. The market has consolidated in the past 10 years and I don't see space for small producers such as Eltronics. The main problem is the dimension of the demand, in fact the main buyers of wind turbine in Denmark are utilities and nationally controlled institutions, such as Dong (Dansk Olie og Naturgas), and so on. The problem is that little companies cannot face this huge demand and they would go bankrupt immediately, within a month. Eltronics wishes an openness of the market in order to increase competition. I think in the next years we will see a consolidation of the market and big players going on the global market and I think they are not doing it efficiently from my point of view.

If you look at the automotive industry, the market is much more competitive, for example there are more than five, six suppliers competing over the production of a single component. Large companies like VW, Peugeot, FIAT, whatever, are letting just few suppliers produce the components they need. The wind industry needs to focus on the fact that big companies should let others produce all the components. In order to be more effective, the wind supply chain should be more specialized. You do not need many competitors to produce a tower, you need just two or three in order to allow some checking and control mechanism. Vestas or Siemens produce all parts and components of the turbine, whereas they should simply outsource this production to *small and medium companies which can specialize in those fields providing more competitive and cheaper products.*

A distinction must be done. What component should the large companies produce by themselves and which one should be outsources and produced somewhere else? My belief is that they should produce the main areas (blades, generators, …) this is where you really make a difference and not competing for a tower or standard component. They are using a lot energy trying to avoid anybody else to use this stuff. I think it would be better for them to be open and share knowledge.

It is useless for example to increase competition over low tech components such as towers or blades, which, at the end of the day are always the same and easily replicable so favor a low specialized and opened market for these kind of tools. However, the competition should focus more on the main areas for example the production of the control system or the generator. Nowadays, these crucial components are subjected to the "duopoly" of Siemens and Vestas that often set disclosure impediment which freezes the market and where competition is impossible.

It is important that foreign companies go to Denmark to try to change this state of things and they are doing so precisely by looking at small companies. In other words, they cannot force Siemens or Vestas to provide them with all the necessary tech needed to reach their levels. However, working side by side with small and medium component suppliers such as Eltronics, they can gain the expertise required to compete on a large scale level.

This happens because the industry is still young. Just in the last 10 years people are using wind as a commodity. It could be good for them to look at other industries where they can really share knowledge.

I suggest that a greater official knowledge and tech sharing is required in the system in order to improve overall profitability. This can sound strange if we consider what we have said before about the tech spillover in a cluster.

There isn't much institutional spillover because you have to deal with disclosure agreements. It is difficult to share knowledge, also in Århus. We make an agreement when we make a project and we are not allowed to share it with anyone else. This is very common in the wind industry for the wind industry at the moment, therefore it is very difficult to share knowledge outside the company, so we do need to form the inside. But again we need to be careful. That is why I think the industry is a little limited.

However, practice, like sharing knowledge instead of technology is present in Denmark as well. We cannot share specific information about a project but we can share knowledge in order not to make the other make the same mistakes we have done. And then next time maybe you will do the same to me. Denmark has protected knowledge all over its history, but it is likely that it is going to open in future.

As a matter of the fact, there's plenty of disclosure agreements between the two companies. Not to share the knowledge arising from a project to third parts is a common practice within the industry for the moment, therefore is very difficult to share knowledge. This is a limit.

However, this is not completely true, because if the "official spillovers" are not allowed or hindered, the indirect spillovers are very widespread, so knowledge spreads anyway. In practice, even though the specific knowledge of particular projects does not spread easily, the geo proximity renders communication among employees, managers and directors within the cluster much easier. Informal conversation, meetings and so on make true that people talk about problems arising in the construction of particular pieces under non-disclosure agreements. Trial and error processes are shared and information flows.

Disclosure agreements have always existed all over the years of cluster development however, knowledge and tech have always spread. Keeping secret practices and tech in a cluster is not easy at all. Secrets are important for some particularly complex and strategic technologies, however, they become useless and they have been stepped *over all the time. Everybody knows how to build nacelles, blades, towers, so the disclosure is totally useless.*

The R&D parts in fact is strongly favored by the clustered conformation of the cluster. Although disclosure, people know each other, they come from the same universities, they had same teachers and they talk about similar problems. Denmark is the center of R& D system for wind industry, that is basically what the cluster is about. Because overall lately, outsourcing activities all over the world has become more convenient. As a matter of the fact transporting huge blades or generators overseas implies very high transportation costs.

According to Eltronics, this situation is useless also for the large companies, however the disclosure is just a past residual that has not even been questioned by the large suppliers. Therefore, according to Degermann, a change in the system,- with an even larger openness for new competitors, tech and knowledge sharing- is very desirable.

Globalization can change it, Chinese and Indian suppliers have money to invest in the industry and this will lead to cheaper products in the industry. They could be able to provide an alternative to the high tech turbine produced in Denmark. They could be able to prototype a new kind of cheaper and less long lasting turbine to push into the market and compete. They have a lot of money to invest so it does not matter if 20% of the turbines they produce will not work properly, they will just produce other at a lower cost. In the next ten years they will be able to produce a standardized model that will cost less. They will provide an alternative that nowadays there is not. Choosing between a turbine that lasts 20 years and works at a 90% efficiency rate, or a Chinese one that works for 10 at a 75% rate will become a matter of political and strategic policy.

Governments also have great influence on these strategic policies. Denmark wants to increase the amount of the wind energy. After Japan as well, governments are pushing even more on green energy. Germany closed 10-12 nuclear power stations.

Again, what will they do instead? England is another good example. In the Isle of Man they are putting a lot of offshore wind farms.

About the supply chain, the first step is to buy raw materials, steel components, chemicals, electronics, standard components and so on, you have them shipped to Denmark from USA, China, India because they are poor in resource then you have some factory activities for the tower and the nacelle so they are assembling the large components made with the materials coming from outside and for the blades, they buy the materials all around the world. The production of blades is similar to boats. You have material melt, then you put it into a model and then you just fill it up with a liquid that fills the spaces and keep on doing it. When you are finished you heal it up and you get the shape. So that is what you will find in the global market, you buy the resin and materials and you produce the blades in Denmark, then you put it in a stock or somewhere and then it depends when you have the order you have to transport.

So you have a series of services connected. Some of the parts are made by other suppliers so as engineering services, electronics and transportation. Next, you have to do some assembling service, assembling the small and more complicated parts. Then there is the problem of where to deliver. When the destination is too far, which is what is happening now, it is better to move the production outside. The components are increasing their size. It would not be efficient to ship them. A nacelle can weigh 200 tons, not even the generators, 6-7 meters so, in this part, there is a tendency to source all over the world and manufacturing the turbines close to the size.”

5.3. Interview to Mr. Mogens Nyborg Pedersen, Global Source and Procurement Director at Siemens Wind Power A/S

This interview has been recorded on 18th of May, 2011. However, in order to render it more readable and systematic for a thesis work, I have slightly modified the sentences and the structure of the interview, without, however, changing the contents or the idea of Mr. Pedersen.

Taken from the top level of the Danish turbine manufacturing industry, it is true that earlier it was the biggest in the world but it is declining down to something like 10, 12% of the total market. For example three large manufacturers have developed in China so far, Sinovel, Dong Fung and Goldwind. Other main competitors are GE, Nordex in Germany, Gamesa in Spain. Those are the major players. Due to their rapid development and innovation rates, it requires a lot of financing. This means that there will be less in the future that will have the strength in the wind power to develop new technologies and innovations.

When it comes to the supply chain, historically, for Vestas, Bonus and Siemens Wind Power has been a supply chain based on local and European scale. Now it has turned into a global supply chain, also due to other global development in US, China, India, Russia, Brazil, Canada, depending on the market size and also for cost reasons.

When it comes to supply chain into the cluster, former there has been mainly component suppliers but also system suppliers like petrolics, generators, coolers, gearboxes. The tendency now is that some of these suppliers have globalized and set up in other places in the world and new suppliers have developed as well. So suppliers have been following globalization and new suppliers are getting into wind industry.

Now wind has turned into a real industry. Especially after the financial crisis, people have started to see into the wind industry as a promising market. So we have three main drivers that drives the change into the clusters: globalization, innovation and *industrialization- the three main areas where we see the changes- and this is the tendency. We [at Siemens] have the strategy of having two core areas that we are doing in-hose production, overall of blades and control system. We also produce the towers, while gearboxes, generators and other system have been developed by the supply chain by suppliers based on our demand.*

About the globalized supply chain, we have to first identify the market size then, depending on the orders, we can start to calculate the size of production capability to set up. We can see: small scale set up or full scale set up. This is due by the component and the cost of producing there. For example tower, blades, nacelle production abroad makes sense, then we start to investigate if we have a local supply based or a clustered configuration there or if we have to start to import from the existent suppliers. We also identify, which one of these local suppliers can be useful also as a global supplier so not only for the local market but also local to global.

We cannot have a supplier in every country. The tendency is to create more integrated supply chains where we are looking to just some suppliers in order to deliver complete systems and integrate them with our components.

The globalization on the competition. Naturally over the years wind has become a commercial product and we are looking for global sourcing. In the past, due to competition within the cluster, we looked abroad seeking for low prices, lower costs, cheaper raw materials and so on. Nowadays, because of the volume of the sales increasing, we cannot act anymore in terms of project specificity, we had to change into a stock philosophy. This means that we have the orders on long term bases and then we will have a more stable production therefore not producing anymore for just the projects. A lot of projects are set up into the summer, for weather reasons, so it means that you will have a lower season during the winter to face.

The new competitors coming up does not directly affect the competition system. In fact, the most important thing in wind industry is to build up the turbine with the lowest price/KW rate. Of course the market demand innovation and the innovation *rate is important, overall in the cluster in Denmark. Historically you can see that wind turbine size double every 4 years so this is the innovation rate. Now we are moving into direct drive tech, it means turbines without gearbox, with multiple generators and convertors directly connectors avoiding the production of gearbox which is a very delicate and large component. This is not going to disappear completely, but in some projects, in the cluster, we believe that direct drive will be the future, reducing the cost production of up to 50%.*

Today wind suppliers are starting "beat-coal" projects for wind energy to become cheaper than coal energy production, which is a really industrial product with also large subsides from the government. However, large scale suppliers are not subsidized at all, but the customers are subsidized, by feed in tariffs.

The wind industry is booming right now, and in the next 5-10 years we will see a willingness to go renewables, also solar and so on. Plus, from the environmental point of view we see the lack of oil in some years so CO2 has to be reduced, and the nuclear also after Japan has become another issue to turn even more to renewable so now we can make it a commercial product, competing with the other power generation sources. There is a tremendous potential growth and we do see a major potential. Hydro will decline, nuclear will remain stable or decline and so the potential of wind is very huge. Also China and India have a huge interest into the industry.

Regarding the position of Siemens into the supply chain, we are actually producing the wind turbine itself. We also have quick gears and quick connection so we can offer the customers these two solutions. We are also number 1 in the offshore wind industry.

Moving to the R&D, in Siemens we have very high expenses on the R&D and we believe this is the core of our activity. The innovation rate of Siemens is very high, taking something like 20 patents a month. This speeds the innovation rate in the market. However, in order to support the costs of such innovation we need to increase the vo-

lume of sales and lower prices and become market leader. There is a trade-off between innovation and revenues.

About the non-disclosure agreement and spillovers. For some components we also have non-disclosure agreement, however, it is very rare that we put it in as a requirement and avoid them to work with the competition. We believe that we should allow them to work in the industry in order to create the synergies and the spillovers. We normally allow them, even though there could be some particular innovation that can create a very large competitive advantage (overall in the control system of the turbine).

Talking about government financing, Governments are no longer largely financing the industry like in the past because today wind is a commercial product, so it is just mainly financing the utilities, such as big companies owning the power plants in the transmission system, the grid owner, investors from abroad setting power plants.

Historically, in the cluster we have seen a bricolage approach to technology. If you go back into the 70s, there were a lot of companies trying to develop wind turbines all over the world but they were focusing on large turbines. Denmark was the one developing this industry because it focused before on small turbine and then, through learning by doing, developing practices, interacting and so on. New technologies followed the same path. Another important issue is learning by interacting. Even owning the best engineers, it is inevitable you cannot provide an innovation alone. In the wind industry, you need to have mechanical engineers, construction, chemical ones, and so on. You need to have a close cooperation with the suppliers, competitors, customers. Also our competitors have long lasting relations with other suppliers who have the core knowledge. This creates a system where innovation and cooperation work together in the R&D process. Innovation can come from other industries merging into the wind industry.

Today it is difficult to forecast new horizon for the wind industry technology because it is difficult to understand which will be the standards to achieve. This is because it *is a matter of cost/KW large component costs, logistic constraints, and so on. We are starting to look into speed blades, offshore and so on so there could be two horizons for inshore and offshore. Offshore costs are larger but the payback is high as well and you have less problems about environmental issues, noise, visual issues and so on.*

The situation that electricity bills in Denmark are the highest in Europe is just a matter of the taxation system. However, there is a small part deriving from the fact that if you built a turbine in Denmark in late 90s then you would have a security from the government and if this electricity was lower than 25€ per KW, they would be covering up to 10€ per KW, like security but this is just a minor part.

Finally, Siemens does not have a real prototypical project. That is because when we make a new invention, the innovation comparing to the competitors is very low. They are standardized products and customers want this so the setting becomes more competitive. Every turbine has very similar and standardized components and if you do not follow these patterns you get cut off: towers, three blade turbines, standard fiberglass materials and so on. This also applies to offshore blades. In fact the only relevant difference between inshore and offshore is not on components but in weather conditions. You need to have a higher coating, more heating devices, more humidity control so the only difference is on this peculiar component not on the larger ones.

About the grid connection, there are no problems, physically. The main issue is that there are many different types of grids around the globe and you need of course to have a program that fulfills the requirements of these grids so you need to prepare the turbine. If you have a fallout in wind you can affect the whole network so somehow you need to set the power in order this not to happen. In Denmark the grid system is excellent, it is a smart grid that also connects foreign countries (Germany, Holland, Sweden and Norway), on a State level but it depends a lot on the wind condition of the countries.

5.4. Interview to Mr. Mads Hovmøller Mortensen, Industrial PhD Student at Vestas Wind Systems A/S

This interview has been recorded on 30th May, 2011. However, in order to render it more readable and systematic for a thesis work, I have slightly modified the sentences and the structure of the interview, without, however, changing the contents or the idea of Mr. Mortensen.

We are the biggest firm within the industry and we have to be very careful to the shifts of the industry. If you look at the sales in China, they could actually support a whole industry in China. They could actually not go abroad, but they will do it. I know that Goldwind, Sinovel actually have tried to go abroad in US.

My background in Vestas. I have written a master thesis about the importance of the supply chain and this master thesis which was nominated to be the best thesis in Denmark. I won this and then I got an industrial PhD at Vestas. Afterwards, I started to work in Vestas and it wants me to look at why the supply chain is important in wind industry. When in an industry start you don't have a supply chain, then you have to set one up so you have to convince all the players in the industry to make items and products for you .If you look at Siemens, Vestas, most of the suppliers working with us come from other industries: agriculture, heavy industry, ship industry.

But as the industry matures, the volume also increases and the volume starts to build up the supply chain which, is what is happening in the wind industry right now. So now we are starting to see that many suppliers within the industry have started to merge. For example Vestas decided to be an active player in the market just 3- 4 years ago. Since the volumes are still very low, it is still heavy items. By active player I mean starting to look at other large suppliers in other industry. We are looking into the German automotive market. They have many board members that after the financial crisis, have decided to invest in the wind industry. They could see that the prospects of wind industry are very good at least until 2035.

Now we are reaching a level in volumes where we can do mass customization and production. Wind industry is on the first phase of the growth lifecycle of the industry, when it has not reached the tipping point yet. In fact, it is just 2 or 3 years that you have the possibility to choose among many suppliers. If you also look at the quality of turbine. If you take a car, you have a maintenance service after 40,000 km. If you see offshore turbine, it has an efficiency of 9 times more, but suppliers don't know these quality standards, so also Siemens, Vestas, have major quality problems with these suppliers. We cannot explain to them how the quality is meant to be. This because we acquire the knowledge over time, but the technology basis is always pretty much the same for the past 20 years. While in the wind turbine, ten years ago we had 0.6MW turbines, while today we are trying to play with 6- 8 maybe 10 MW turbines. So you don't have the same learning curve. We have to experiment our new products, materials and so on. This means the investment is very risky.

So what happened right now, Vestas was among pioneers of the industry. We have pioneers in the industry that applied a first mover strategy (Vestas, Gamesa, …). Then we have large industrials that set themselves in the industry (GE, Siemens, Samsung, …) and now we also have regional players increasing their sales and volumes (like Sinovel, Dong Fung, Goldwind, Suzlon). Both of industrial players and regional ones are challenging the pioneers from both sizes. They have great knowledge of the industry (Siemens) but they also have funds and they know how to set up a supply chain at an industrial level. Siemens can get a lot of resources from the HQ in Germany and so on.

All these players are following different business offshore Siemens models ,GE is the strongest on the medium small, 1.5MW turbines, producing more than 20,000 without upgrading but just mass producing. The model of American superconductors is taken into consideration. Basically, they build the supply chain for you so if you want to produce small turbines, it is not difficult to enter the market. However, the customers seek large turbines, so we can protect ourselves a little bit. Development is going very fast right now, also the customers are upgrading. Not only the utilities but *every customer is employing specialists from Siemens, Vestas, negotiating with us about quality and quantity standards. Dong is very active in this process.*

The cluster will move where the market is. If you look at the number of turbines in Denmark, it is actually very low. We can see that development right now is in Asia, USA, UK. We moved a R&D structure in UK. The strong cluster you see today will move towards other clusters in 5 years, overall in China and India, becoming competitive clusters for Danish ones also, which form a R&D and tech point of view. This is true because in the last 5 years all the biggest competitors (Siemens, Vestas, …) have moved some R&D departments abroad. China is purchasing a lot of knowledge from Europe, also buying the best engineers and employees. After 1 year they cannot work for competitors, for contract reasons [disclosure agreements], they will just go and hire them.

Right now we are in a very hard competition. We are active in towers, generators, blades, not gearboxes. If you take the history of Vestas, it started to produce agricultural equipment, then it started to produce small turbine (25, 50KW) and they are actually pretty similar than the one we see today. The political agenda of the Government, aiding the industry and the EU standards made it easy to set a wind turbine. If you look at the forecasting, they are very good if you look ahead, within the renewable energies. The wind is the renewable that is going to grow more.

In Vestas we have a lot of Danish suppliers and many are active within the global market. However, Vestas is structured with different PBUs producing different components, so of course we need to have a quite centralized structure. But what we are doing is to adapt to different market, also by placing and giving great freedom to PBUs and to the local markets. A lot of our past local suppliers have switched to more globalized suppliers. We have Bosch, ABB, trusting companies from Italy, electronics companies. The volume is so good right now that a lot of global suppliers are getting in the market and taking over. Wind has become very popular also after the crisis because it has lost little volume comparing to the market. The switching point of the industry has started in 2003-2007, but the best is still yet to come.

In 2003 Vestas had 4-5,000 people, now we are 23,000 over the world, and this is true all over the world. The regional players are challenging us on prices, not technology, but they are also learning fast from China, so their knowledge curve is quite steep right now. But if you look at them, many are focusing on small turbines, while ,we are more focused on large turbines. However, they are learning and large Chinese companies like Sinovel? Will they be number 2 next year and will they have very large growing capacity? Today we are number 1, followed by GE, Sinovel, Enecom, Goldwind, Gamesa, Suzlon and Siemens, focusing mainly on offshore. Offshore is a very expensive investment, so potentially this is more profitable, but we have to be careful.

Vestas is not focusing on competition in the wind cluster anymore. It is very important for the knowledge we have here, but if you look at the competitors you have to look globally. Competition is becoming global. If you look at R&D, it is different. In the cluster in fact, the knowledge is spreading very fast. If you look at the supply chain, it is carrying a lot of knowledge. If you also look at Siemens, it is placed no more than 200km from here [Århus], so knowledge spreads very easily. If I were fired, I could easily change company. Except for the disclosures, it is easy to move. In Siemens, if you come from Germany, you can change your position very easily. In Vestas you cannot do that, because we are from Denmark so this policy prevents a little bit spillovers. I have a 1-2 year contract where I cannot work for any competitors unless I am fired. In that case the close is 6 months so knowledge and information flows very easily form an indirect point of view, not official. Within some areas knowledge institutions have an important role in spreading the information.

I know that many of turbine manufacturing, at the beginning, could not deal with the customers. However, in the last years, many of the producers are trying to collaborate with customers and universities. At the beginning the cluster was very closed, more secret than now, without sharing basically anything. Now we have development all over, in terms of components and information flows. Before it was even more. If you have the most knowledge, you don’t have to share it. But now the situation has *changed. Within aerodynamics we have collaboration with Boeing nowadays and this is the sign of the expanding and openness of the industry.*

About how innovation appeared in the system, I think that it is a combination between breakthrough and bricolage approach. But I think we had some pretty good and important pioneers that at the beginning set up the first turbines. Seven or ten men going to the same school starting the main idea of the industry. The CEO of R&D in Siemens is actually one of those guys (Henrik Stiesdal). Also in Vestas we have some of this old guy pioneered. So in the past it was more with pioneers, while now it is more continuous. People say that the good thing of the industry is not the same. Ten years ago everything was new, so it developed more, while now we are just focusing on scale. The cluster is new talking about a supply side and not technological. In the beginning, in the cluster you could make large improvement on the wind technology, improving year by year performances by 5%, 6% of the output. Now instead we have to focus more in reducing costs and not increasing technology.

About the financing part, I think that the cluster in Denmark has been shaped by the subsidy policy. It gave the industry a major boost and it gave us the competitiveness of developing a product before going abroad. Now we don't get any subsides, while in the past , from 1 to 12KW you get like 0.6DKK, and so on. It rendered the investments a good practice. Today the subsides are mainly in the offshore sector. From the government there has been a policy of picking the winner and it worked quite goo, because it gave a stable industry, it boosted the industry before going abroad. Vestas has been the favorite target also from people because also a national pride.

Globalization has affected the financing system. Many countries nowadays finance wind industry (Canada, UK overall). I think that it is a chance to increase the wind industry. Vestas has also launched the Wind Made Logo, a logo you can put in the product and comes from wind. This is part of the next step strategy based on differentiation to market and advertising the products.

5.5. Interview to Mr. Jørgen Højstrup, Head of Global Wind&Site Competence Centre at Suzlon Energy GmbH

This interview has been recorded on 31st May, 2011. However, in order to render it more readable and systematic for a thesis work, I have slightly modified the sentences and the structure of the interview, without, however, changing the contents or the idea of Mr. Højstrup.

Suzlon started in 1995 and from 1995 onwards it got a large portion of the Indian market and then they wanted to expand. To do that they needed more expertise than they had already. So they decided to go where the expertise was which is in Denmark where they set up an office that started Suzlon international activity. Our job here was to assist and set up business units in different parts of the world to expand the market. That role has sort of been played now, in the sense that we have but all over the world, and they have become independent and here we have just a couple of them that serve as consultants.

The future trajectories for Suzlon in Denmark, is to collect more and more R&D in Denmark, but also elsewhere, in India and China. These are the main developments for R&D. Regarding the supply chain, the strategy is to make Suzlon vertically integrated which means making it independent from other suppliers. But the main reason is that we want to be able to expand, which is difficult when you are dependent on outside suppliers, you need to be independent and have full control on the production. Of course, it is also problematic when it comes to financial crisis but the strategy has not changed and we will get our suppliers from the companies that can supply us with both the best and the cheapest.

Basically Suzlon and associated companies produce most of the wind turbine so all of the main components are produced in house. Of course we get some from other companies but we mainly produce them in house, but just subcomponent, specifically components where we can find multiple suppliers but not strategic ones.

The main impact of globalization is that there are a lot of very well trained and capable engineers and academics in all the countries in the world. So you can go and get them at lower salaries than in Denmark, which is the main driver for Suzlon to go outside from Denmark. On the other hand, we know that in order to make best possible use of engineers and other people in low salary countries, we need to invest a lot more for management because it is so much more difficult to manage these people efficiently and get good results. It is not straight forward because of course ,culture differences make things difficult. The ideal management is internationally experienced management or managers that have regional experience and so on, but the combination of experience- local and international- is required unless it is useless. So there is a tradeoff between labor cost and management cost and availability, I mean, can you find the managers you need at all? In China, for example there are huge problems. Management skills are very difficult to find.

In India there is a big market and we have a special position there because of course, the company was born in India, we know the Indian market very well, we also have a knowledge advantage in India. Some of the biggest market players are becoming more active all over the world and when they come to India, they come with the same expectation and information of a normal market. But we have the advantage of knowing how the Indian market works. There is both a trust relation and we already know what kind of things they need there.

Also culturally, the situation is very different than in Europe. I mean, contracts, personal relations are looked differently; family relations are very important so you need to know somebody that has family in those places, and of course for western countries this is very difficult. As long as you are aware of the difficulties in dealing with a different culture you can adapt, but you have to be very, very aware of the meaning of communication in India. For instance, if I communicate, if I talk with an Indian engineer, there are some things that you cannot do. For instance I cannot ask him a question to which it can be yes or not, and the reason for that for Indian engineers is impossible to say not. You can only say yes. And this is because I am higher *ranked than him and his duty is always to say yes. So if I am asking him if he can or not do a particular task he will always say yes, even if he cannot. So you always have to be aware of screening information and find out the reality. Communication is difficult, but as long as you know, the situation is different. In fact when I have to hire people here to work in India, first I have to train them.*

We are using very few Danish suppliers. In the wind industry in Denmark main players are getting bigger and bigger, but there are still few suppliers forming a sort of a system in the industry together organizing themselves in order to supply large buyers. Also Danish manufacturers are having their production chain moved outside, because it is simply cheaper to do that. I think that in the next 5 years the situation will go towards this trend. It is difficult for the Danish suppliers because they are typically closed, but they are learning and also supporting each other in order to get accustomed better.

Suzlon came to Denmark in 2004, 7 years ago. Our entrance and the one of other external competitor has been based on the R&D activity. We are now seeing Chinese, Korean companies doing more or less the same thing we did at the beginning. It seems to be that Denmark has a lot of wind experience and if you need wind knowledge or people that have the experience in the industry, this is the place where you have to come. Our entrance is not focused on the supply chain part, but we are much focused on information. I think what the world is doing in the wind industry is coming here to gather the knowledge and the experience and the people with experience in the industry. Manufacturing of wind turbines, I believe, will disappear from Denmark at least in the next ten years. I think that Vestas and the Danish companies will be losing their leadership in a while. For example Vestas in the last 2 years has been very close to losing its number 1 position to GE and Chinese companies coming up very fast. I think that, as the things are nowadays, I would expect in the next 3 years not GE to be number one, but one of the Chinese Sinovel or Goldwind.

I think the cluster itself will move not to be not a manufacture pool anymore but just a sort of global HQ for R&D expenses and technology gathering. This is true espe-

cially if you see Vestas, Siemens behaviors. They are already and I think they will produce almost everything outside Denmark. There are many factors pushing this phenomenon. One is price of course, another is seeking the availability of work force; there is also the question of transport. Wind turbines are becoming larger and larger, so it will be more and more difficult to ship them from Denmark to other countries so the company will maintain their quarters in Denmark but shift the production bodies outside.

Regarding the role of globalization in affecting the competition, it is very difficult to answer this question because the market is very chaotic at the moment, after the financial crisis. There are many things that do not work correctly and basically there is a large extra capacity. It is difficult for the manufactures to develop at the rate they wish. It is also difficult to make money right now. It will change as the market comes up again. This is because there are customers that want to buy wind farm but it is hard to get financed. At the moment it is very, very bad, really cut throat. The main reason is the extra capacity.

Disclosures are signs of high competition. I think main Vestas put disclosers, overall clauses preventing engineers from working for competitors. We also have competition clauses but only on very key and high ranked people. My opinion is that competition clauses are very bad for the system because they prevent people from going to other companies and spread information and knowledge into other companies.By doing so, companies are losing knowledge therefore, the whole industry knowledge level is affected by this. I think it is stupid that we have very very knowledgeable people walking around without being able to work for years. It is actually crazy but some companies are totally convinced that their knowledge is so much more worth than other companies' knowledge that they think they have to do this. Vestas is the typical example. They think they do that for their own advantage, but they overlooked the fact that they need to get new knowledge.

What is happening now is that, instead of having a safe rotation of people working in the industry, some of the valuable people are simply hired by companies that have a *lot of money to invest, especially in the case of the Chinese companies. They went on the stock market recently, they have a lot of money, a lot of cash compared to the traditional ones in the wind industry and they are very actively recruiting the work force because they can afford that. For an "indirect spillover" part, originally, I worked at RISØ and for many years we were the knowledge base for the whole industry. This, when the industry was very small and research budget was really small and the main funds came from the government. This has completely changed now. Some of the bigger companies are collaborating with universities. I think the flow of knowledge is not totally and efficiently managed. But going back, I think it is a reason that companies are taking the good people and you get strategic advantage.*

The new globalized comers, like us and Gamesa (that do not exist anymore in Denmark) do not have non-disclosure clauses. I know for example that Gamesa have sort of delayed bonus payment. A more positive incentive, differently to clauses, negative incentives. But I also know that most of Gamesa people have been now hired by the Chinese companies, so in some ways it is a bad strategy for the information flow but it is rather good in order to defend your employees from the Chinese attacks. However, there is a difference between what they say and what they do. They say they want to keep the knowledge in house, but they actually want to keep the salaries down. Of course they do not say that, but there is a salary effect, of course.

Suzlon does not have any dominant model of components. Our technological philosophy is not to be a front comer in technology, but a second comer. The most important part for us is the commercial part. I mean, we want to make money. There are a lot of situations where you have competing technologies and best technology suppliers lost their challenge. That is why we are perfectly happy not to be front line. Of course we are spending quite a lot of money on R&D but our focus is not advanced technology, but to create reliable and robotic machines at the lowest, cheapest cost as possible since customers do not care about technology instead, they care about turbines that produce energy at the lowest price.

This is possible because, if you want to be in front line technology, you have big risk. There is a big risk that your product becomes too expensive. There is the risk that the failure of your product means to waste a huge amount of money. So if you go towards this technology strategy, you have high prices. High tech turbines give you a higher energy output, but the question is whether this additional output is covered by the extra costs. We are able to take prices down principally because we do not have all these R&D expenses.

Learning by interacting is a very important issue. But I don't think it is working as it should. It would be much better if companies shared the information without protection. If you want to have a synergic relationship with your customers, it means to share a lot of information and there is no willingness to do that. There is a tendency among some manufacturers of sharing the information.

It is difficult to guess how the technology is going to evolve in the next years. However, we can say that in general, energy prices are going up. Things are happening, like the Fukushima event and people are starting to really look at renewables as alternative sources of power. Now Germany is closing down all the nuclear power stations. This will for sure create once more a large market for wind industry in there. But in the long run, I think that the wind industry will take advantage of the going up of energy prices. Renewable energy prices are going down and thanks to the increasing competition it is rendering a quite competitive source. But it is difficult to predict the development in terms of price per KW.

Nowadays, in the wind industry, there are less financing aids. In the past there were a lot, also from a EU point of view but this is not the case anymore. If you look at new markets, like the Chinese one, there are a lot direct and mostly indirect advantages for the Chinese manufacturers. They have subsides that Eu manufacturers are complaining about, but of course, they had the same policy ten years ago. So what I see happening is that subsides will soon disappear, also because wind is becoming competitive and because of the increase of the general energy prices.

It is very important that political institutions are focused on long term objectives (like 20-20 in EU). People that are going to finance the wind industry can see long term payback. The American market, on the other hand, is a very bad example because they wasted a lot of time because they could not make an agreement on the laws to pass on renewables. In Europe it is different, there is a more continuous push from politicians and Eu went further and quantified how much they want in the grid by 2020, which is very important to the market, even more than subsides. Nowadays, feed in tariff is still the most widespread method of financing with direct investment in knowledge institutions.

5.6. Interview to Prof. Poul Houman Andersen, Professional Training & Coaching at Århus School of Business

This interview has been recorder on 10th June, 2011. However, in order to render it more readable and systematic for a thesis work, I have slightly modified the sentences and the structure of the interview, without, however, changing the contents or the idea of Prof. Andersen.

How important is R&D in high tech wind Energy? It is debatable whether we are dealing with an R&D industry or not. Typically, more development than research in Denmark, so it is more a D industry than R. One of the things the wind industry was able to benefit is actually research, but made in other area, such as aerodynamics, metal, components, in this sense the wind turbine industry has always been seen as an interesting test site. Because some of the situations are extreme, overall about the mechanical efforts but in itself, wind turbine is not really producing much. It was only until recently, actually in 2000s, that patenting really became an issue in the wind turbine industry. The thing is that it is not really driven by the urge to protect knowledge, but a way to deal with competitors. Research is important but development is still ruling the industry for the next years.

Cluster is more a theoretical process. There are several benefits. One, is the ability of having proximity in your learning process. In other words if you are very close geographically and also mentally, you might say, your ability to interact, to learn, and exchange knowledge is strongly enhanced by the possibility of face to face interactions. The other benefit is that because of this interaction, trust building, specialization and division of labor become possible simply because wind turbine producers have been able to utilize what I would call spare capacity among suppliers. It is not that we have in Denmark a cluster of companies fully specialized in wind turbine industry, they typically have three, four, five industries where they are working.

So when you see the wind turbine cluster in Denmark, there is a number of companies that take part in wind turbine technologies, and others taking part in activities in *other industries. So what typically happens in this semi opened cluster is the interactions among industries. For example, agricultural companies producing machinery, steel and iron industry import components and materials to the wind industry. So, not only the presence of activities within the wind turbine industry that is important but also the connection with other industries that are reaching technological knowledge from a different industry into the wind cluster.*

About how technological spillover in the Danish wind cluster are affected by disclosure policies of the companies? From my point of view, until recently this was not a big problem. I mean, there are specific problems, there some issues related to this phenomenon, especially Vestas has been very keen and probably Siemens as well. But the issue is that when you start to set this kind of non-disclosure agreement, you take away part of the incentives to the most critical suppliers to participate. If a supplier can't really use what has been learnt during a design project, when dealing with another customer, the supplier would start thinking that the manufacturing cost it is paying is too high and starts to develop its own. So this entire dynamic will change once the non-disclosure agreement will not be enforced. I think that one of the main issues that has been concerning Vestas during these years has been that they wanted to find a way to protect their knowledge, but not that much in technical solutions but knowledge concerning the future plans of Vestas in terms of new turbines and new designs to be freely available in the market.

I am not sure, but I believe there is this kind of non-written agreement in Vestas and Siemens also that dealing with suppliers, there is this practice of treating the technological data confidentially but still, the suppliers can use those ideas later on.. Intellectual property rights are very hard to enforce so it is more symbolic issues.

I am not sure that all the manufacturers will move out from Denmark but I think it is no longer the case. Now, I believe that there is more and more segregation in the system of developing of the wind turbine. Growth has been driven in the last years by the development of a dominant model in order to fill out the demand for wind energy and this supply for wind power in Denmark will be faced more and more by local *producers. So we will see, I guess, in the high value of the wind turbine chain, in values where activities are more specialized (offshore, extreme coatings, environmental tasks). I think in those areas, you will need specialized manufacturing, which is highly flexible and where you can combine and recombine. In this area, production will remain in Denmark because it is so hard to separate drawing and design of wind turbine. So, from my point of view, you will still find them in Denmark. Though, the truth is that the majority of activities located in Denmark will be from a particular segment, whereas the rest of the production will be spread all over. Manufacturing will be more and more a supportive function to the value creation than it used to be.*

About learning by interacting, let's try to imagine the opposite of Danish industry. Let's try to imagine an industry dominated by few extremely large companies that have like all the innovation going on within the value chain of the firms, like US automotive industry. In these areas we will have less plurality in terms of development and design, but more direction and faster growth trajectories . However, we may not see the same growth and diversity in the development and the same spreading of ideas in terms of design and ideas. This is one of the best answers to the cluster, a decentralized innovation system. This, of course, also means that growth,- if you look at the wind turbine cluster today from one point of view-, we have a huge concentration of employees, with Vestas dominance in the area. But looking at a manufacturing level alone, it does not tell us the real trajectories of growth of the wind turbine industry. And this is also why it is extremely hard to predict. To me it seems like there are two different models moving in different directions. Where there used to be a strong dependency of suppliers by Danish customers, nowadays they are not dependent anymore. Now they have a huge portfolio of customers outside Denmark, and they develop with these customers in different ways. So I guess the interaction thing has affected the growth by making it more diverse and let grow not just the top layer of the value chain but also in different layers of the value chain.

About technological standard evolution. Now we have a standard of 1.5MW turbines, which is the one Suzlon is producing big time. Suzlon is developing a turbine based *on Vestas design, hugely developed in India. In developing countries you need huge numbers of turbines and you need them very fast. So you do not need a very quality standard but a very effective one and suppliers are developing standard components. But there is another standard developing for other systems with different industries and energy system. I mean, the most important need in India and overall China is to supply and support the energy system. It not much a question of " be green" but a question of facing energy need. For that reason a lot of wind turbines are needed.*

In other countries, it is not much a question of actually increasing our energy capacity but replacing. So a lot of issues come to place: we want the wind turbine in places we can't see them, and so on. So a standard is arising from this point of view. Offshore, extremely large MW and so on. So it will be important to place and build turbines whose marginal environmental cost will be as low as possible. I think we will find this other segment trying to adapt to specific needs and manufacturers which will be specialized to this kind of activity. In this contest we have many challenges, such as the challenge of the gear and gearless turbines (the Danish and German design). I think the first will win the problem because the gearless need turbines of a certain size; you have really heavy turbines with a whole generator placed entirely within homogeneous nacelles, which is a large limitation. So we will have some standards, but we will see standards merging into product and component standard. In the low hand, we are already seeing it with Chinese, Indian and American trajectories. But then we will see the segment aiming to match all the things we have seen before and there, we will not see any shifting soon, and probably the production will remain in Germany, Denmark and so on simply because there will not be local demand yet.

They do not mind having 95% opt-time standard (wind turbine is working enough and sufficiently 95% opt-time over 22-25 years). The problem is that when you sell a wind turbine, you make the insurance that this is actually the case. This includes the fact that they will provide you all the service in order to this opt-time to be faced. This means a lot of money, overall if you are dealing with large turbines with 40-50 *components. In China and India you do not need to face a 95% opt-time, but you can deal with smaller standards and much larger tolerance for failures and less control quality. This is because they have a lot of money and liquidity to invest and also they have a different time perspective when it comes to energy policies.*

About the state financing, well, of course being a former state owned industry, when the industry started to be privatized, there was a need of a huge equity capital because lots of the machinery, installment, and the entire grid system came along with that privatization and of course, in some cases, when somebody had control over the grid network, also with a monopoly. Of course, a monopoly that by law you are supposed to share, but still Energinet, which is the name of the Danish owner of the grid, will never go out of business. Really there is no risk. These companies are private but State being significant shareholder but they are not allowed to have sheet deficit. So the State cannot intervene and help them, but of course, there are limitations to the "private" share.

Nowadays there is still feed in tariff, but much lower than in the past but of course the State is indirectly supporting the industry. Like test areas, research institution, engineers specializations and so on so the state is basically trying to enhance the knowledge system.

About the paradox of the bill, I think it is a question of economies of scale. The big problem is not production but consumption. Consuming wind energy is problematic for two reasons. The first one is that wind energy needs to be consumed at the same time it is produced. There is no storage. What happens is that you have to adjust on the load of power voltage for specific suppliers. The problem is that you cannot really adjust wind energy because of wind fluctuation so you have to keep a capacity level. Adjustment through hydro power from Norway or other source can help but to a certain extent, it is challenged in two ways: one way is that you place more and more turbines in several countries, Germany, Spain, UK and so on.

The more we get grid interconnection, the less is the problem. The problem is of course a matter of costs. Which development is faster? An interesting development concern is how to store wind energy. There are two interesting perspectives. One is to convert wind energy on the spot in something else, heat for example. So storing energy will generate in huge tank and create heat and utilized later. For example in steam turbines and so on, but you might lose some of it. Another very interesting way is to combine wind energy with the power grid and electric car. Energinet and Dong are working with a company called Better Place, and they are trying to sell the idea of selling rechargeable batteries for cars. They actually have this idea that you if you have 50,000 maybe 60,000 cars connected to the grid, the batteries could be loaded from home. So when you are producing a lot of energy, basically when the wind blows hard and you have a surplus of energy, through an intelligent net, you can ask and compute to your energy provider to charge your car. So actually the interesting thing is that if you have 50,000 cars and each of it has a battery, that will create a sort of a plant. These batteries are connected, so, if I am in a situation of surplus of demand of energy I can actually borrow energy from this battery net. So, I can make an agreement with the car owner and take energy from the car and make the grid support the demand. These batteries work like a power plant and you can store energy. With this system you can reduce our conventional capacity of 10%.

So at the moment this is the huge development. Focus is moving away from manufacturers, but it is moving towards a new system for scaling up, combining and improving storage and usage of wind energy connecting with all the other sources. So this demands not just improvement in the grid net but also in the wind turbine industry, but that is of course a wider perspective.

About globalization affecting the financing system of Danish cluster, it has affected it in 2 ways. The market is becoming of course bigger, and this is one thing. There are more potential investors. The other thing is that with globalization, one of the debates is for a couple of years: who is going to buy Vestas? Some think about some of the German companies (not Siemens but ABB; and so on). Vestas is in a situation in *which they have to consider whether they want to be a specialized wind turbine producer and face it as such, or if they want to become part of a larger industrial conglomerate. Wind turbine leadership is shifting from Vestas. It is not in a good situation also recently in the stock market. Despite they are actually selling more turbines.*

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