Danish Wind Power Energy Innovation System:

an Analysis of Industrial Dynamics, Learning and Policies

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Preface

This master's thesis was made in the period from April 2008 to October 2009 by Erzsebet Kerekes at the 10th semester of the study program in *Innovation, Knowledge and Economic Dynamics*, Aalborg University, Department of Business Studies.

The list of references in the report is organized according to the Harvard method. The references are thus stated with the author's surname and the publication year of the referred article, and also in case of two or three authors e.g. (Edquist, Hommen & Tsipouri 2000). Four or more authors will be stated with the surname of the first author followed by the "et. al" and the year of publication e.g. (Edquist et al. 1998) . In references where an author or publisher has published more than one text in the same year, and both text are used in this report, the references will be written with a letter after the year e.g. : (Danish Wind Industry Association 2003f).

The report's numbering of the figures and tables are done separately and continuously within every chapter. The numbers are given according to the chapters, so that Figure 1.1 represents the first figure in Chapter 1. The full list of references can be seen in the Bibliography at the back of this report.

The abbreviations with the explanations are organized in alphabetical order in the beginning of the report.

The appendixes A to I and can be found at the back of the report.

This report applies to anyone interested in the economics and political perspective of the Danish wind power energy and to anyone interested in using such a combined theoretical approach and framework, which I'd be glad to see improved.

I express deep appreciation to my professor, Birgitte Gregersen from Aalborg University, for her support and special contribution to this project. Special thanks go to my husband for his continuous support and to my son (who I gave birth during the period of this project), and who has brought a lot of laughter and happiness into our family.

ERZSEBET KEREKES

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Summary

This project, **The Danish Wind Power Energy Innovation System: an Analysis of Industrial Dynamics, Learning and Policies,** contains both theoretical approaches and an empirical investigation. The motivation for this thesis was discovering the reasons behind the drop in wind turbine installations between 2001 and 2007. The report is built around three main research questions, which are the following:

How was it possible for Denmark to sustain its global competitiveness in the wind turbine industry during the analyzed period?

How will the shift in energy policy after 2007 influence the wind power industry?

Under which conditions (social, economic, technological and political) can a country like Denmark maintain its competitive advantage in a continuously changing environment?

The approaches used to answer the above questions are: sectoral innovation systems, technological systems and industry analysis. These approaches are combined in order to offer the best framework to compare and analyze the Danish wind power energy system. The analysis is extended to the whole period of the wind turbines' history until the present day, and is split into three periods. The first period is calculated from the 1970s to 2001; the second period is from 2001 to 2007, and finally, the third period is from 2007 until now (2009).

The investigation of the problem area is realized through the application of a historical comparative analysis. The comparative factors are as follows: technological systems; institutions; organizations and industry analysis, where the most important factors are also studied: suppliers, buyers, substitutes and entry/exit barriers.

During the theoretical chapters, different innovation systems approaches (national, regional, sectoral, technological) are presented and finally, there is an argument on the reasons why the sectoral innovation systems have been chosen as the approach that best fits the analysis. (It is used, because it is a reasonable tool for understanding the dynamics and transformation of the industry, and also identifies the factors affecting the performance and competitiveness of the industry. The sectoral innovation systems

approach is also multidimensional and its border can stretch out to national or even global geographical boundaries; it is the sector's technology that defines the boundaries of the system.).

With such an evolutionary approach, the complexity of the wind power energy system can be studied (especially the relationships between the constituting elements). However, in order to quantify the investigation of the problems, Porter's diamond industry analysis has been used.

Since there is interest in the report about the impacts of the newly-established Ministry of Energy and Climate's energy policy, one chapter is dedicated to the presentation of the different policy matters, focusing on their overlapping and contradictory aspects. In order to do this, the innovation and competitiveness as notions have been discussed in the same chapter.

The historical analysis of the Danish wind power energy system is carried out within the theoretical framework. The results of the analysis are manifold: first, the parts entitled technology, institutions and organizations make the reader to feel the connections and relations between the three elements. Then, the industry analysis shows quantitative results in terms of installed wind capacity, energy production and use, energy intensity, market share and wind turbine sales. All these indicators contribute to the definition of the Danish competitiveness. Denmark's competitiveness during the analyzed period is in wind turbine manufacturing and its sale. In the first period Denmark was a leader in the wind turbine installations, but this cannot be said for the other two periods. Competitiveness, in the Danish case, was achieved and sustained by the following factors: economic efficiency, technological development (which constituted a huge amount of accumulated knowledge), demand, governmental intervention (support) and the last (but very important) factor: social acceptance. The industry's future is very optimistically presented in the new energy policy report issued by the Ministry of Energy and Climate, where the renewable energy technologies are promised to be subsidized. However, the wind technology, being an "old" type of renewable energy, will not get the most support. It is expected to do well in the market mechanism. Under these conditions, Denmark has to compete in terms of wind turbines and wind power technology with other countries, such as Germany, Spain, China, the US, the UK and India.

1 PROBLEM FORMATION

This part of the project is meant to explain why the project is important, and at the same time to give an explanation of the problem formation.

One century ago, some Danish people saw a possibility in the wind as a renewable energy source, and with hard work and perseverance they turned it into a worldwide industry. However, wind power energy has other important aspects. For Denmark, a country with strong and year-round winds, it represents a cheaper and independent energy source (the produced energy is cheaper, but the installations are still very capital intensive); it is without any kind of emission compared to other fossil energy sources, which are the causes of the climate change. Also, the wind power energy industry creates a large amount of jobs to active workers[1]. Why did it become so important? Because wind power energy was made available to everybody who wanted to be part of a clean energy production. Although the development of the Danish wind power energy industry was not as easy and straight-forward process as it seems in the writings, it still managed to reach out to the public and formed a large supportive community who fight for a common goal and share the benefits and detriments.

The specific problem of this project is the sudden drop in the installed wind turbine capacity after 2001. The project looks back in time to find out what the causes were of the sudden drop in wind turbine installations in Denmark. It starts by analyzing the wind turbine industry from the beginning by posing the following research question: **How was it possible for Denmark to sustain its global competitiveness in the wind turbine industry during the analysed period?**

Through this question it can be found out what could have had such a great impact on the industry in order to interfere with its previously competitive state. One of the reasons was the change in the Government and the attitude of the Government's representatives of that period (2001-2007). The project digs deeper to find other causes, too. It compares the more fruitful period of the wind power energy industry (1970s-2001)

[1] The number of employed people in the wind industry in Denmark was in 2008 over 28.000 people. However, due to the financial crises, a huge amount of people have been cut back in the first part of 2009 (Danish Wind Industry Association 2009a).

with the less ambitious period (2001-2007) and gives a prognosis of what could happen in the future (from 2007 onwards). Therefore, it poses the second research question: **How will the shift in energy policy after 2007 influence the wind power industry?**

By analyzing the two questions and searching for the answers, some lessons can be learnt. These lessons drive the report to the third question: **Under which conditions (social, economic, technological and political) can a country like Denmark maintain its competitive advantage in a continuously changing environment?**

This project sheds light over the development of the wind power energy industry; its strong and weak areas, and looks especially at the specific pattern that lies behind the country's success in the long term, as well as its lack of achievement in specific time periods. By providing answers to the research questions, the report emphasizes Danish success (or lack of it) in many areas, not only those generally related to the wind power energy sector. It breaks the industry into its building elements and discusses each of them separately, and then it forms a whole picture about the industry's development, changes within it and its future perspectives.

The specificity of this report lies in the fact, that the theoretical framework is composed of a combination of evolutionary approaches with a more mainstream economic approach. The aim of such a combined framework is to provide a full picture of the industry. It encompasses not only the two-dimensional cause and effect relationship between the actors in the industry, but also their co-evolution as a result of their mutual influence. More detailed presentation of the project's structure and methods are to be found in the following chapter.

2 METHODOLOGY

In the following chapter, the structure of the report will be described. The purpose is to provide the readers with an overview of how the project is built, how the required data is gathered, and which tools, methods and theories are used to analyze the data.

2.1 Structure

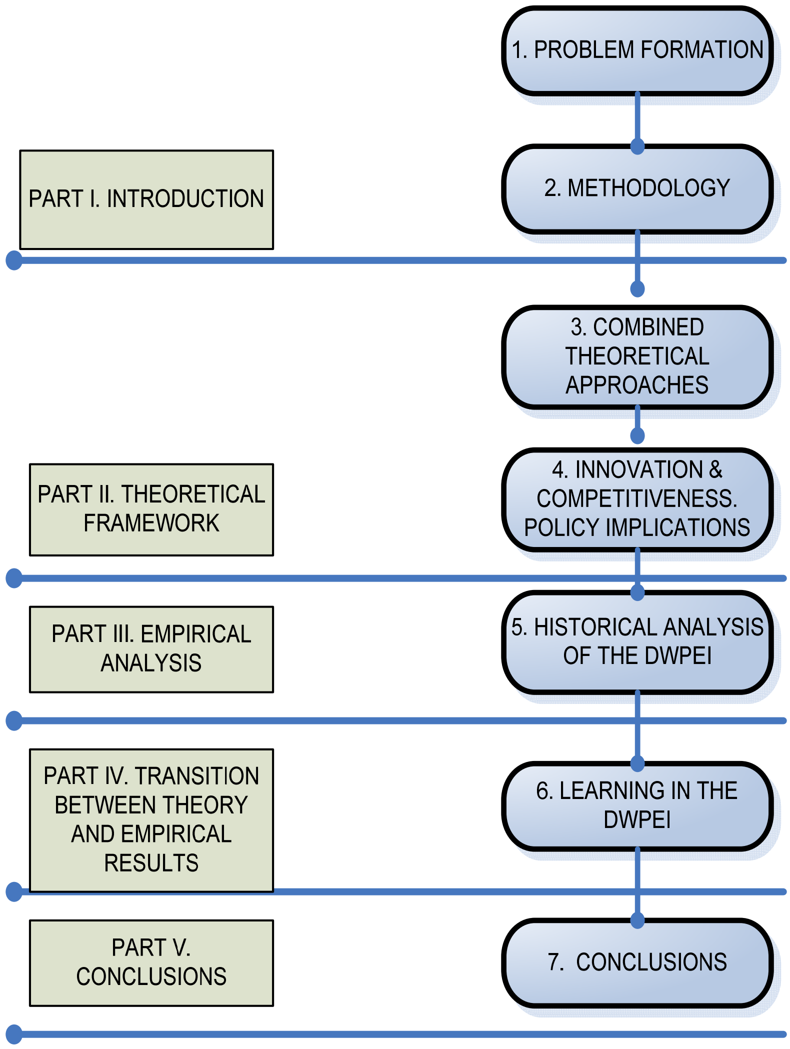


Figure 2.1. Project structure

The project is organized according to the structure in Fig. 2.1. It is based on both theoretical approaches and empirical analysis of the Danish wind turbine industry. As the structure design shows, the project consists of five parts; each part contains one or more chapters, containing seven chapters in all. **Part I** includes the first two chapters, representing the introductory section of the report. The first chapter outlines the problem formulation, while the second chapter discusses the theories and methods used to address the problem formulation, as well as the structure of this project. **Part II** includes chapters three and four and constitutes the theoretical framework of the report. Each chapter contains different theoretical approaches. Chapter three is a synthesis of the different types of innovation systems approaches. These approaches are the following: national-, sectoral-, regional- and technological systems of innovation, and finally a less evolutionary-approach: Porter's industry analysis. The chapter opens up to a detailed presentation of the previously-chosen approaches that are thought to be best suited to the research questions. Chapter four brings the topic of the project closer to the main research questions, by discussing the relationship between competitiveness and innovation, and relating them to policy perspectives. **Part III** represents the empirical part of the report. This part follows the story of the Danish wind turbine industry's development from the very beginning (late 19^{th} century) until the present day, with reflections on the future. The story is divided into three major periods. The first period is divided in two sub-periods, from the 1890s to 1973/74, and from 1974 to 2001. The second major period takes up a shorter interval: from 2001 until 2007. Finally, the last period is from 2007 forwards. **Part IV** joins the empirical part and the concluding part of the project. Chapter six is a synthesis of the "learning" approach providing examples from the empirical results. This chapter is halfway a concluding part with emphasis on the outcomes of the analysis, which represent the result of learning in the Danish wind industry. **Part V**, the concluding part of the report, contains the last chapter with a summary of the answers to the research questions. Specifically, it is argued the reason behind the competitiveness of the Danish wind turbine industry, some of the impacts of the new energy policy reform in the future are mentioned, and finally, a general formulation of the conditions under which a country like Denmark can sustain its competitive advantage in a changing and globalizing environment is given.

2.2 Research methodology

Due to the complex structure of the Danish wind power energy industry, the project is designed on more theoretical approaches: innovation systems approach, technological systems approach, some taxonomies about the industry and finally an industry analysis approach. The systems perspective has proven its virtue in the explanation of the dynamic changes at different levels of the economy (Bergek, Jacobsson 2003, Jacobsson, Bergek 2004). Since the report is focused on the wind power industry (which represents an important sector of the Danish economy) the innovation systems approach has been narrowed down to the sectoral systems of innovation (SSI) perspective. The contribution of the SSI approach to the project is very relevant, because it explicitly distinguishes both new and established products in its definition; it also emphasizes the fact that "for analytical purposes one could examine separately a sectoral innovation system, a sectoral production system and a sectoral distribution-market system" (Malerba 2002). The SSI approach also allows the analysis to go beyond the geographical borders of Denmark, which is the real case in the Danish wind energy industry. The role of these theories will be enumerated in the following. First, the system in general is an entity that comprises elements which interact with each other; therefore, it is a model of the reality designed for analytical purposes (Markard, Truffer 2008). According to the innovation systems approach developers, the concept is a good analytical tool in the policy making process. The technological systems approach has its role in providing an overview of the development of the technology in focus (here, it is wind turbines). The industry analysis has also multiple roles to fulfil within the project: it offers the most appropriate framework for analyzing the competitiveness of the industry, and is a tool for defining the borders of the system. To delineate the borders of the SIS (which is not an easy task), the technological system approach and Porter's industry analysis approach are used. In this way, the SIS can be stretched to national and even global dimensions on the line of the technology; and it narrows to the microeconomics of the wind industry through Porter's approach. Porter's diamond framework about competitiveness serves to explain the long-run development of a country's international competitive position, which is created on the basis of the individual nation's own unique characteristics. The model is probably the best-known analytical tool for understanding the development and the attractiveness of an industry and gathers those values which, according to Porter's research, are important in gaining a national competitive advantage (Porter 1990).

Figure 2.2 The graphical presentation of the combined theories

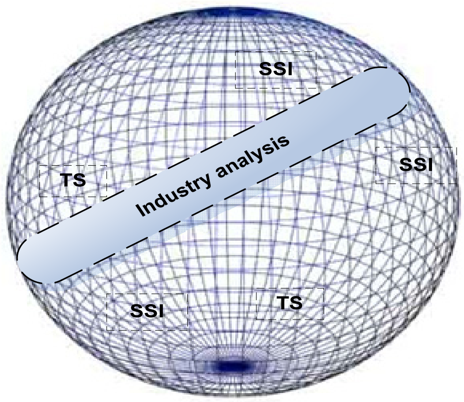
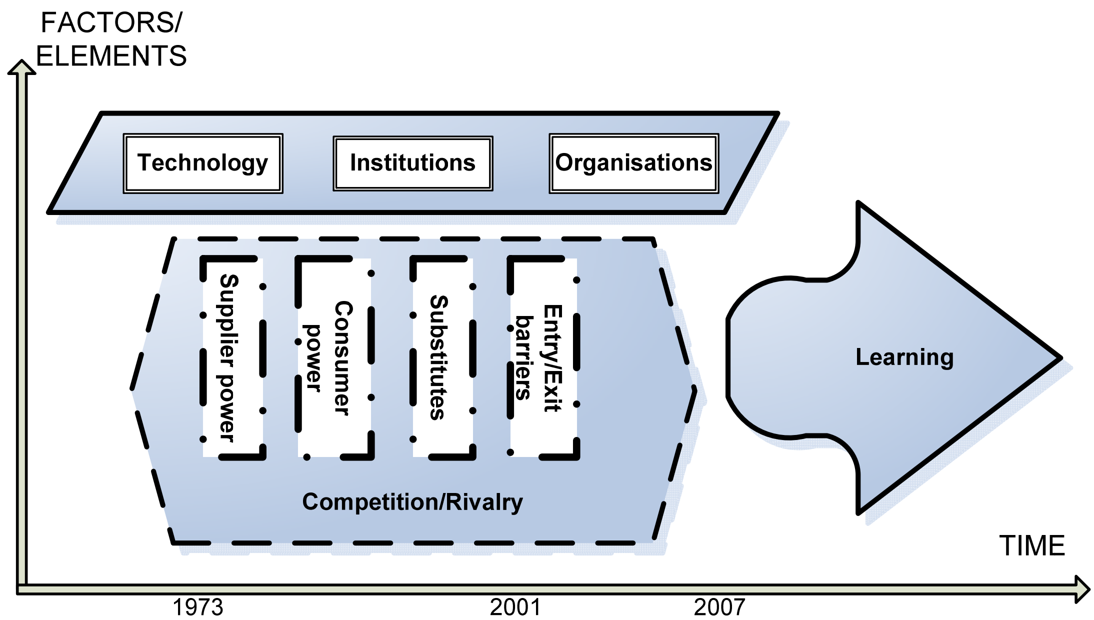


Figure 2.2 above is an attempt to visualize the theoretical framework through a geometrical figure which is going to be used in the analysis. The sphere represents the different kind of systems that complement each other and, in some part, overlap each other. The plane stays for the industry analysis. It has only two dimensions: data related to a certain time period, therefore it is presented as a plane of the sphere. Overall, the figure is a geometrical presentation of the way the evolutionary theory binds with the industry analysis. The theoretical framework is used in the empirical analysis conducted on the Danish wind power energy industry, as shown in Figure 2.3. The study that guides this project is a historical comparative analysis of the wind energy development in Denmark. The analysis is conducted in a historical perspective throughout three periods, comparing them according to a specific guideline (Figure 2.3).

The reason behind using the historical comparison perspective lies in the evolutionary characteristic, and path dependency of the innovation process. According to this definition, innovation (e.g. wind turbines; turbine wings; electrical grid support) can be best understood when the historical development is taken into consideration. Since the system keeps changing, it is possible that at one moment one system promotes the development of technology better than another system in a different time span (Kamp, Smits & Andriesse 2004).

Figure 2.3. The pictorial display of the theoretical framework applied in the historical comparative analysis



Thus, comparing the three different periods in the Danish wind power industry (each period had a different system, represented by different elements and links between the elements), resulted in some learning that is related to the performance of the industry (measured in its competitiveness) and the system that has promoted such performance.

2.3 Data collection

The primary methods for making this report are studies of literature. The literature used for gathering data for this report is primarily different reports from Danish authorities, energy plans and legislation, and various energy and policy related journals. The majority of the information is based on academic studies. These sources of information are considered credible and demonstrate great knowledge about the topics concerned. Articles from diverse magazines have also been used, and it should be taken into account that these are often influenced by the attitude of both the writer and the magazine in general. Other references are internetpages, which may have different levels of credibility depending on the company, organization and people behind them. Many web-references are from authorities, but others are from various interest groups, who may have underlying motives for the content.

Written material was used, because it seems that a great deal of academic research has already been done on wind energy development in Denmark. Therefore, I did not feel that it was necessary for me to carry out interviews.

3 COMBINED THEORETICAL APPROACHES

This chapter offers a comprehensive presentation of the theoretical approaches which have been chosen, and which represent the base of the empirical research. The discussion starts with the presentation of the national systems of innovation, followed by regional- than by sectoral systems of innovation and, lastly discusses the technological systems perspective. The theoretical part will also contain the industry analysis approach based on Porter's "five forces model". The aim of this chapter is to delimit those system approaches that suit the best the forthcoming analysis of Danish wind power energy sector.

3.1 Innovation systems approach

The innovation systems (IS) approach has been in focus since the mid '80s. A very general definition of the IS approach is given by the common understanding of the notion of the system of being built of some kinds of components and the relations between them. These two elements: the components and the relations between them should form such a "coherent whole" (Ingelstam 2002 cited in Edquist 2005) in which innovations can emerge. Such a broad definition of IS is given by Lundvall, and is also called the "Aalborg version" (Edquist 1997a, Lundvall 1992). "The structure of production" and the "institutional set-up" are the two most important dimensions that "jointly define the system of innovation". There are other definitions assigned to the IS approach, which have a narrow perspective[2], constituting of the elements of science and technology; however these do not suit the objective of this project the way the broad definitions do. Generally, the IS approach can be defined as "all important economic,

[2] Nelson, R (Nelson 1993) is considered the representative of the narrower IS' perspective, according to which the emphasis is on the nations' R&D systems; elements of science and technology are the driving forced behind innovations.

social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations" (Edquist 1997b).

The IS approach has ramifications in many different areas, depending on the scope of research. According to some authors (Edquist et al. 1998), "an IS can be "supranational" in several senses; it can be truly global, or it can include only part of the world…". A geographical delineation is between the national systems of innovation and then the regional, local and sometimes sectoral innovation system, which all together confirm that the border defining the respective system can be shifted towards the desire of the research topic. The "sectorally" delimited IS includes parts of the above mentioned systems, for instance the technological system is a very appropriate example. The most difficult method in defining the boundaries of the IS, is the one based on the activities (Edquist 2005).

"Innovation system" is considered the generic approach which groups the other system types (national, regional, sectoral). The difference among the variants is that "they co-exist and complement each other" (Edquist 2005). The IS approach "adopts a holistic and interdisciplinary perspective, which has the innovation and learning in the centre of focus. It employs historical and evolutionary perspectives, which make the notion of optimality irrelevant. It emphasizes: interdependence and non-linearity and the role of institutions. IS encompasses both product and process innovations and the subcategories of these as well." (Edquist 2005). The IS does not look as clear and transparent as it is presented. It has some "conceptual diffuseness" in relation to the definition of institutions and the exact components of the different system varieties. IS is considered a concept or theoretical framework rather than a theory, because it does not provide a causal relationship between a proposition and a variable (Edquist 2005).

While drawing the framework, the following research questions will be given the answers:

Q: Which theoretical approach can be best suited for the historical analysis of the Danish wind power energy system's competitiveness and why? How will it be used in the later analysis?

Q: What are the institutions and what categories they belong to? Who are the actors that constitute the "hard" part of the innovation system? What kind of relationship exists among them? What is their function and role within the

innovation systems? Beside the evolutionary approaches, what other theories are necessary to complete the framework?

In order to be able to define which systems of innovation are best suited to the project, a short presentation of each of the main types will be given (national, regional; sectoral, and technological), emphasizing the differences between them. Also, the constituent elements of the innovation systems approach (institutions, organizations and the relationship between them) will be discussed in the SIS part, because this represents the basic approach of the theoretical framework. Nevertheless, the elements are equally important elements of any type of the IS.

3.1.1 National innovation systems approach

The national innovation system (NIS) approach has different definitions, depending on the various authors. "The major differences have to do with focus and breadth of definition in relation to sectors, institutions and markets." (Johnson, Lundvall 2003). The national innovation concept is more useful for analyzing less-developed economies or small countries. Although Denmark is a small country, it has a relatively "complete" NIS. Therefore it is better to analyze a subsystem instead of doing a whole broad analysis.

> *"If there are adequate knowledge infrastructures and intellectual property rights and if there are good networking capabilities and high levels of trust, there is also a suitable basis for an efficient research and development system. It may then be quite possible* ***to analyse the details of this subsystem****, without worrying too much about the rest of the innovation system."* (Johnson, Lundvall 2003).

Taking into consideration the reasoning above (that is better to use in Denmark's case a subsystem), it has been decided that the NIS approach does not adequately represent the best approach from this project's point of view and, so it will not be used entirely in the analysis. However, the policy issues need to be discussed according to the national approach. Therefore, from the policy perspectives, the framework will be "stretched out" to the NSI.

3.1.2 Regional innovation systems approach

The concept of "regional systems of innovations" (RIS) was first developed and used in 1997/1998. RISs are useful when analyzing a specific region in one country or it can be shifted over the geographical borders of a country. RISs may be built by many other sectors, but most importantly it is built around a commonly shared feature such as culture, language or territory (Cooke, Uranga & Etxebarria 1997). Given all these definitions, it is hard to delimit the RIS from clusters[3]. *Synergy* is the key ingredient that creates a supportive condition for the innovation process to emerge, like the regional innovation led clusters of Silicon Valley or Cambridge in the UK (Tidd, Bessant, J. and Pavitt, K. 2005). However, in order to have a better understanding of these concepts, it is recommended that some of the works of the following major contributors to the cluster theory: Porter, Marshall and Maskell are read.

RIS is not the best approach for the analysis of the Danish wind power energy industry's competitiveness and the related policies, because, on one hand, it might have a too-narrow perspective in relation with the competition and policies. On the other hand, we can't talk about a regional wind power energy system in Denmark. Therefore, it looses its importance in this project.

3.1.3 Sectoral innovation systems (SISs) approach

Sectors are defined as "a set of activities that are unified by some linked product groups for a given or emerging demand and which share some common knowledge"[4] (Malerba 2005). Malerbas' point of view is that SISs approach complement the NSI. The main difference between the two IS is that the SIS may have local, national and/or global dimensions, while the NSI may have some national boundaries.

The SISs provide a multidimensional, integrated and dynamic view of sectors. It contains a set of products that are carried out by a set of actors through both market and non-market relationships. An SIS has a knowledge base, technologies, inputs and demand. The actors of the system interact through processes of "communication,

[3] According to Porter, "clusters are geographic concentrations of interconnected companies and institutions in a particular field" (Porter 1998).

[4] These are functional boundaries of the sectoral system of innovation.

exchange, co-operation, competition and command", and these interactions are shaped by institutions (Malerba 2002). The changes that the SIS undergoes in time are the result of the co-evolution of the elements within the system. Further in this project, it will be a presentation of the constituting elements of the SIS: institutions, organizations and the relationship among them; knowledge base; technologies; inputs and demand.

3.1.3.1 Institutions

There is a large amount of literature on the definition of *institutions* and there is a continuous debate among institutionalists and mainstream economists on behalf of institutions. Neoclassical economics defines institutions in a very simple manner as the "utility and profit maximization", which is driven "by a set of parametric prices within a context of exogenously given population, tastes and technologies" (Edquist, Johnson 1997). American institutionalism (represented by Thorsten Veblen) has at its centre the "institutionally unaffected Homo Economicus". Furthermore, in Keynesian economics, institutions were forgotten by the majority of theorists. However, there were a few European institutionalists[5], who contributed to the economic theory, taking institutions as well into consideration (Edquist, Johnson 1997). Oliver Williamson is considered to be responsible for the revival and the renewal of the institutional economics. From his point of view, institutions are defined as being related to the transaction costs. Williamson brings together the transaction costs and organizational forms on the levels of both firms and markets. In this perspective, institutional set-up is important, due to the fact that it affects transaction costs, and thereby the organization of firms and markets. According to North's definition, institutions have the aim to reduce transaction costs. *"Institutions are the rules of the game in society or, more formally, are the humanly devised constraints that shape human interaction. ... Institutional changes shapes the way societies evolve through time and hence is the key to understanding historical change"* (North 1991 cited in Edquist, Johnson 1997). Continuing with the definition of institutions, North offers another explicit definition: *"Institutions are the humanly devised constraints that structure political, economic and social interaction. They consist of both informal*

[5] Such theorists are: Gunnar Myrdal, who insisted on the importance of institutional and cultural factors and of cumulative causation and economic development; and Karl Polanyi, who proved the non-existence of pure markets and analyzed how market processes were embedded in institutions (cited in (Edquist, Johnson 1997).

constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)" (North 1991). The definition above has a more humanistic taste compared to the other definitions. The reason behind such thinking is North's educational background in political science, psychology, economics and humanities (www.wikipedia.org 2009).

The newest theory about the institutions discusses their evolution using game theory as a base of departure. According to this definition, institutions are considered as organizers of information. This is a very appropriate determination, since the volume of information has been increasing together with technological evolution; therefore future expectations are needed to be encoded in order to reduce uncertainty that arose from bounded rationality (Schotter 1981).

All these definitions of institutions indicate the common concept of basic behavioural patterns and ground rules (Edquist, Johnson 1997). Now, relating to the shape and form of institutions, they can be of different types: norms, routines, common habits, established practices, rules, laws, and standards. Many of them are national institutions, such as the patent system that may affect the sectors in different ways due to different features such as technology, knowledge and agents, while others are specific to different innovation systems, like, for instance, sectoral characteristics of the labour market. These institutions affect specific "spheres" of society, like economic institutions or political institutions (Edquist, Johnson 1997). Institutions can be more or less formal, and their effects are more or less binding on agent's actions (Malerba, Orsenigo 2000). Formal institutions are easier to notice than informal ones, because the latter must be observed through the behaviours of people and organizations.

"In a country such as Denmark with almost no large firms, relatively low levels of R&D, and no conspicuous technology policy, the relative importance of informal institutions in the system of innovation might be much greater than in a country like Sweden with many large firms and a considerable amount of formal R&D activity" (Edquist, Johnson 1997).

Still, the green energy culture is more developed in Denmark than in any other country, even those where the number of large firms is higher, and where there are obvious technology policies (for instance in the UK and the US)[6].

In some literature there is delineation also between the *"basic"* and *"supporting"* institutions. Basic institutions are identified with the ground or constitutional rules, while supporting institutions define certain aspects of the basic rules (Edquist, Johnson 1997). The same authors delineate between the *"hard"* or binding institutions and *"soft"* or perceived as ones, a rules of thumb. Making these delimitations is important when describing the Danish institutional set-up for the renewable energies.

History has shown that institutions (especially policies) play an important role in the development of a sector of the national economy. As a reminder of the research question, we should think about the Danish wind power energy case, where the changes in the government brought stagnation to the wind turbine installations after 2001. Institutions affect technologies, the organization of activities and, as mentioned before, the performance of the economy. The degree of impact of institutions upon the variables of the innovation system is hard to define or quantify. It is also hard to trace the direct impact of institutional changes upon the elements of the systems, because the interactions between the elements are very complex and so are their effects. In other words, there is a mutual embeddedness (Edquist, Johnson 1997) between institutions and organizations[7]. "The players follow the rules, but they also influence them" (North 1991 cited in Edquist, Johnson 1997). Institutions may develop spontaneously and are not characterised by a specific purpose, while organizations are created consciously, having a formal structure. Comparing institutions with organizations helps in the definition of the major functions that institution play in different contexts. They regulate the relations between the actors, thus influencing the interaction in the economy. They are the glue that keeps society together.

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[6] In this respect, it might be possible to think that formal institutions may have agreater impact in one country than informal ones and not in others. This would be a very interesting topic to discuss further; unfortunately it is such a complex phenomenon and there has been such a little amount of research done upon this subject, that it is impossible to make any concrete statement. However, it represents a very interesting topic for future research.

[7] In this section there will be no detailed discussion about the organizations. According to Edquist and Johnson, "organizations are formal structures with an explicit purpose and they are consciously created. They are the players or actors." (Edquist, Johnson 1997).

The function which is the most relevant for our topic, is the link institutions play between the governmental agencies and firms (Edquist, Johnson 1997). The role institutions play and the reasons why they are formed and used are multiple: reducing the uncertainty by providing information about the future activities, managing conflicts and cooperation among the actors of the context, providing incentives or obstructions in specific directions (Edquist, Johnson 1997). All these roles of institutions have been studied in relation to the innovation processes. Therefore, their role in reducing uncertainties has become the most important one, since the innovation processes are very uncertain activities. The uncertainty reduction by institutions is realized through the cooperation and control that institutions have upon the different actors involved in the process. This way, the bounded information asymmetry among the actors is aligned to a level, where for each party it is worth continuing the process of innovation. The incentive functions of institutions can be of many kinds. Edquist and Johnson (Edquist, Johnson 1997) groups them as: the pecuniary kind, the non-pecuniary kind and negative incentives. Since in the fight against the climate change, corrective measures to improve the energy efficiency and to become less dependent on conventional energies is a shared goal, therefore those institutions ought to be in majority, which would increase collective incentives. However, in the case of renewable energies, the policies and rules have become more stringent and binding, but, on the other hand, these offer incentives for policy users. There is much emphasis on the importance of incentives of the institutions, but not many theorists discuss the opposite effect that institutions can have, breaking the process of innovations because of their rigidity, stability and complexity or obscurity.

Institutions shape agents' cognition and action. Institutions may be imported or borrowed from abroad. These institutions might need changes or might not, when adapted to a different country; therefore this process has the names of "institutional adaptation", and "institutional imitation" (Edquist, Johnson 1997). Edquist and Johnson use the term "institutional drift" for the process where some institutions are brought through incremental changes and as a result they achieve different functions than before.

3.1.3.2 Organizations

The other most important components of the innovation system are the *organizations*. In the literature, there is a tendency to name some actors (organizations) "institutions". For instance, Institution of Science, Institution for Engineers, etc. are usually given to publicly-owned organizations, education-related or financial activity related organizations. What differentiates the organizations from institutions is that they have a "formal structure that is consciously created and has an explicit purpose", while institutions may have spontaneously emerged without having any specific purpose (Edquist, Johnson 1997). However, there might be also kind of institutions (such as laws), that have a formal structure (they are built according a standard scheme) and might be consciously creates, while at the same time having an explicit purpose; therefore we need a more precise definition of organizations and institutions. Thus, the difference between the two constituents can be observed when we look at both of them at the same time. Then we can tell which organization is the one related to the institution and which institution is the one related to the organization. So there is a mutual relationship between them, and to be able to differentiate between them, they must be analysed together. This fact deepens the relation between the two elements even more strongly than we have thought about before.

Organizations can be of two types: public and private organizations. Among the public organizations are those that formulate and implement different kinds of policies, regulatory agencies, standardization organizations and patent offices. Private organizations include industry associations, private research and development centres, and, most importantly, firms. As in the case of institutions, taxonomies may be considered in relation to organizations as well. Therefore, organizations can be distinguished according to the type of activity they perform: for instance, knowledge-generating, diffusing- and regulating-organizations (innovation oriented organizations) (Edquist, Johnson 1997); financial-activity performing organizations; or as North (North 1990 cited in Edquist, Johnson 1997) categorizes them: political-, economic-, social- and educational bodies.

Organizations and institutions form a very complex system; they both have different roles in the process of innovations, and this process builds up the relationship between them. However, relationships exit not only between the two main entities, but there are interactions between actors, supervised by institutions.

3.1.3.3 Knowledge base and learning processes

In SIS, knowledge is in the centre of the innovation process. It is the source of changes that fuels innovations by exhibiting new features (Arocena, R. and Sutz, J. 2003).

Knowledge differs across sectors in terms of domains, opportunity, accessibility and the degree of cumulativeness (Malerba, Orsenigo 2000). Knowledge is also related to the technological and learning regimes (Nelson, R. and Winter, S. 1982). Technologies incorporate different kinds of knowledge dimensions: tacitness, codificability, complexity, systemic features and the scientific base (Cowan, David, P. and Foray, D. 2000). For a better understanding, taking the wind turbines as an example, their development has been based on cumulative research and trials since the first models. These models contain tacit knowledge, which was transferred from the human capital that contributed to its development; and also contains codified knowledge, which is represented by the information that engineers usually know and use for further developments.

3.1.3.4 Technologies, inputs and demand

An enormous amount of literature on technologies and technological change has clearly shown how technologies affect the nature, boundaries and organizations of sectors (see, e.g. Rosenberg, 1976, 1982; Grandstand, 1994). The literature has shown that often, in a sectoral system, more than one technology may be relevant. Even on the level of firms that specialize in one product, they often have to master several technologies: and are labeled multi-technology corporations (Grandstand, Patel, P. and Pavitt, K. 1997). Also, differences in demand conditions play a major role in affecting sectoral differences in firms’ competencies, behavior and organization (Malerba 2002). And, when demand conditions are coupled with basic features of knowledge and technology, the effect on firms’ behavior and organization could be significant. A given technological environment or demand defines the nature of the problems firms have to solve in their innovative and production activities and the types of incentives and constraints to particular behavior and organizations (Malerba 2002).

Overall, SIS may prove a useful tool in various respects for a descriptive analysis of the Danish wind power energy sector. Specifically, it proves to be a reasonable tool for fully understanding its working, dynamics, and transformation, and also for the identification of factors affecting the performance and competitiveness of firms and countries and finally for the development of new public policy proposals (Malerba 2002). At the same time, SIS's perspective may help in identifying mismatches and may help to overcome vicious cycles that block the system in its growth, development and transformation (Malerba 2002).

3.1.4 Technological systems

Technological systems (TS), as defined in the previous chapter, are built by factors that shape the local innovation context (Carlsson, Jacobsson 1997). TS are networks of agents interacting in a specific technology area, within a specific institutional infrastructure, with the aim of generating, diffusing and using technology. TS can be transformed into clusters of technologies within an industry or a group of industries (Carlsson, Stanchiewicz 1991). TS are closely related to, and hard to distinguish from SISs; the common element between the two systems is *technology*. One kind of technology can go across more sectors or industries (eg. Telecommunication, computers, vehicles, etc.) and sectors can provide one or more technologies (eg. renewable energy sectors: wind technology, solar technology, wave, etc.). The notion of TS is interchangeable with the SIS when there is the same technology in the centre of a sector.

According to Carlsson and Stanchiewicz (1991), TS are built upon three elements: *economic competence*, *network* and *institutions*. By focusing on the building elements of the different systems, there are many common features among them that prove the affinity between them. TS are very similar to the different subsystems of the IS, since they are based on one specific technology area.

The *institutions* are common features of all systems, which demonstrate their important role within the system approaches. Within the TS, institutions represent important driving forces in the change of technology. Therefore, institutions either positively or negatively affect the functioning of the system in its objective of generating new ideas or creating diversity. Institutions change over time, and are reshaped (not always automatically or endogenously, but by many type of actors, especially firms and governments) (Carlsson, Jacobsson 1997).

The results that researchers came up with in terms of institutions are that they can be influenced by policies (Carlsson, Jacobsson 1997). The precise sets of policies that are needed to build a TS vary over its life cycle. Not only do policies influence the formation of TSs, but actors are involved too. Therefore, policy is not only a domain of the government; firms, universities, industry associations can all pursue policies, which all have an impact on the TS (Carlsson, Jacobsson 1997). According to the same authors, the policies should have different objectives in the different life cycles of technologies. For instance, at the infant stage, besides providing incentives, policies should focus on diversity creation as well, while in more mature stages, they should be more of the "market-failure" solution-type policies.

The *network* concept embodies the actors, institutions and the relationship between them, characteristic of the innovation systems approach. Within the network, the connectivity of the constituent parts of the system matters, and the amount of information and knowledge diffused may vary between networks. This role that networks play in the TS means that they form a well-functioning system, based on "strongly positive and reciprocal external economies, which tie together user, suppliers and competitors" (Carlsson, Jacobsson 1997). The positive network externalities are viewed as an integral part of economic organization. They lead to future risk reductions in decision making. Network externalities might also "contain a lot of inertia and path dependency, suggesting that a slow exploitation of technologies may occur, which are not shared by members of the network" (Carlsson, Jacobsson 1997) and this may be able to create diversity in the economy.

Finally, the third element, *economic competence,* is closely related to the innovation process. Economic competence is the ability to identify, expand and exploit business opportunities, according to Carlsson and Eliasson (Carlsson, Eliasson 1994), which might lead to innovations. Economic competence is unevenly distributed among firms, because of their different knowledge bases. Therefore, it broaches many issues for policy interventions: for instance, to what extent intervention should aim at improving the functioning of existing technological systems and to what extent it should aim at building new systems.

Technological change is very closely related to institutional change. A quickly or a slowly changing trend could cause disturbances in the innovation process. The change in technology is a gradual and cumulative learning process (Lundvall 1992). It is known from innovation-oriented literature that technological changes, in broader sense, are the consequences of innovation. The changes in technology occur within the TS which, according to definition, is a network of actors that interact in a specific technology area under a specific institutional infrastructure, with the aim of generating, diffusing and using the technology (Carlsson, Jacobsson 1997). TS are based on the knowledge that accumulates gradually during the development of the systems and is transformed into competences that flow within the network. According to this definition, the Danish wind turbine industry might be considered a TS. This system consists of dynamic knowledge and competence networks (Carlsson, Stanchiewicz 1991), whereas, in the case of ordinary goods and services the knowledge and competence flow is lacking in the system.

According to the authors, Carlsson and Jacobsson (1997), TS constitutes the "prime unit" of analysis when discussing policy; therefore it is important from the point of view of this project.

3.2 Industry analysis

One of the most famous contemporary economists, Michael E. Porter, developed a framework to study the competitiveness of an industry; however this framework has been successfully applied to firm analysis too.[8] His book, *"Corporate Strategy"* (Neumann 2001) was first published in 1980 and then came the *"Competitive Advantage of Nations"*, edited in 1990, for which the bases represented the first work. The two books provide a framework for understanding industries and competition better and thus formulating an overall competitive strategy. Porter's analysis is used to determine how attractive an industry is and the long-term profitability of a company versus the rest of the competitors in an industry.

Within this project, Porter's theory represents a useful tool for the description and analysis of the Danish wind power energy market on both national and international level, because Porter's five forces model incorporates supplier and buyer power, entry

[8] This makes us wonder if it could be applied to a global market analysis too. This may represent an idea for future research.

barriers, and the threat of substitute products. These elements can be analysed through an international perspective too. All these forces contribute to the estimation of competition in a certain industry on a long-term basis. According to Porter (Neumann 2001) the strength of each of the five competitive forces is a function of *industry structure,* or the underlying economic and technical characteristics of an industry. Structural change shifts the overall and relative strength of the competitive forces and thus, can positively or negatively influences industry profitability. Therefore, this approach is a beneficial tool in the forthcoming analysis upon Danish wind power energy competitiveness, from the 1970s, and its future expectations. In the following, a detailed presentation of the five forces that build up the structure of the industry will be given.

One of the five forces that contributes to the creation of competition is the **threat of substitute products** from other industries. The substitute products affect the product's price elasticity- as more substitutes become available, the demand becomes more elastic since customers have more alternatives. A close substitute product constrains the ability of firms in an industry to raise prices. The competition engendered by the threat of a substitute comes from products outside the industry. While the threat of substitutes typically impacts an industry through price competition, there can be other concerns in assessing the threat of substitutes. Continuously-changing technologies represent such a concern. These are products or solutions that basically perform the same function, but are often based on a different technology. Depending on the level of abstraction, nearly everything can be a substitution. In general, the only factor that really matters is a shift in technology (Arons, Waalewijn 1999).

Another factor of Porter's five forces is the **buyer's power**, which represents the impact that customers have on a producing industry. In general, when buyer power is strong, the relationship to the producing industry is near to what an economist terms a monopsony - a market in which there are many suppliers and one buyer. Under such market conditions, the buyer sets the price. In reality, few pure monopsonies exist, but frequently there is some asymmetry between a producing industry and buyers.

The third factor influencing competition is **suppliers**, if powerful ones can exert an influence on the producing industry, such as selling raw materials at a high price to capture some of the industry's profits. Suppliers are very much connected to customers. If the customers are weak, the suppliers are weak. If customers are concentrated, then suppliers also tend to be weak. For instance, the trend in the energy supply market shows a monopolistic industry structure. It is easier for a state to regulate one electricity company, for instance, or one petrol company, instead of a lot of them. Thus, the supply side of industry is very concentrated. In Danish wind power energy supply case, the energy is provided by a few utility companies. At least in this case, the oligopolistic energy supply market does not take to collusion as the usual oligopolies do.

When talking about the factors influencing competition, it is not only incumbent rivals that pose a threat to firms in an industry, the possibility that new firms may enter the industry also affects competition. In theory, any firm should be able to enter and exit a market, and if free entry and exit exists, then profits always should be nominal. In reality, however, industries possess characteristics that protect the high profit levels of firms in the market and inhibit additional rivals from entering the market. These are **barriers to entry** and they are compound of: *scale economies* (advantage of experience, learning and volume), *differentiation* (brand image and loyalty), *capital requirements* (new entrants will face a risk premium), *switching costs* undertaken by the customer, *access to distribution channels* and *cost disadvantages* (patents, location, subsidies) (Arons, Waalewijn 1999). Barriers to entry could arise from several other sources, including government regulations and asset specificity.

Barriers to entry are more than the normal equilibrium adjustments that markets typically make. For example, when industry profits increase, we would expect additional firms to enter the market to take advantage of the high profit levels, over time driving down profits for all firms in the industry. When profits decrease, we would expect some firms to exit the market, thus restoring market equilibrium. Falling prices, or the expectation that future prices will fall, deters rivals from entering a market. Firms also may be reluctant to enter markets that are extremely uncertain, especially if entering involves expensive start-up costs. These are normal accommodations to market conditions. But if firms individually (collective action would be illegal collusion) keep prices artificially low as a strategy to prevent potential entrants from entering the market, such entry-deterring pricing establishes a barrier. Barriers to entry are unique industry characteristics that define the industry. Barriers reduce the rate of entry of new firms, thus maintaining a level of profits for those already in the industry. From a strategic perspective, barriers can be created or exploited to enhance a firm's competitive advantage.

Barriers to exit work similarly to barriers to entry. Exit barriers limit the ability of a firm to leave the market and can worsen rivalry - unable to leave the industry, a firm must compete. The strongest forces become crucial from the point of view of strategy formulation. This framework identifies the relevant variables that must be taken into account in order to develop conclusions about a specific company or industry (Arons, Waalewijn 1999).

Overall, competition is influenced by the collective power of the above-mentioned factors, which constitute rivalry.

It is very hard to find a theory that best suits the empirical part of a project, especially in cases such this one, when the research question contains complex notions and elements that are not easily determinable. It seems that, what suits best the historical analysis of the Danish wind power energy is a historical **industry analysis embedded in a sectoral system approach, emphasizing the main research area with the technological system approach.** Porter's Five Forces framework completes the analysis by bringing more specific facts, relations, influences and results into the analysis. However all of these will be static. These three theoretical approaches offer some knowledge about the structure of the Danish wind power energy system, the actors constituting the system, the relationship between them and (most importantly) the rules that govern this system. The theories will help to identify those factors that contributed to the maintainance the wind energy competitiveness during these decades. Since the wind power system will be analysed from its infant period until the present time, with some future predictions, the evolutionary perspective of these approaches must be kept in mind. Taking into consideration that the analysis will focus on the institutions, and specifically, the policies that governed the wind power energy system so far, the assessment will be enlarged with reflection of the different elements and/or organizations that had some kind of effect upon the development of the policy system and subsequently, on the development of the wind power energy system to its present stage.

These organizations are: the Danish Government (Ministry of Environment, Ministry of Energy and Climate); European Commission and its organizations; research laboratories and departments, constituting the bridging organizations (eg. Risø-DTU, IPCC, UNFCC, Danish Wind Energy Associations (producers and owners)); financial organizations (which contribute to the promotion of the wind energy); NGOs; firms with activities such as supply, production and distribution of equipments; firms generating, diffusing and selling wind energy, and the consumer groups both for equipment and energy too. As we see in the list above, these actors occupy different geographical positions: they vary from international ones to local organizations. Therefore, it is a challenge to define the boundaries of the analysis and to choose the best-suited innovation system approach. So the challenge is to find a balance between the evolutionary approaches and concepts, and the static or neoclassical theory to try to fit this into the wind power energy system.

4 COMPETITIVENESS & INNOVATION; POLICY IMPLICATIONS

This chapter emphasises two important notions: competition and innovation. The aim of this chapter is to present the relationship between the two notions, which contributes to the performance of the economy in terms of growth. In order to answer the main research question, the policy implications of these terms need to be discussed.

4.1 Competition and innovation

This chapter will be based on the following research questions, which contribute to the achievement of the project's objective. The questions are the following:

Q: How can innovation and competition be defined, and what is their role and relationship? What is their role in the competitiveness of an industry/country? What are their policy perspectives?

Competition and innovation are two key features of the economy that are strongly related. Their relation also has been tested in the DISKO project, based on a survey on *"product development collaboration"* (Arons, Waalewijn 1999), which was conducted from 1997-1998 as part of the DISKO project by Danish researchers from Aalborg University (Kristensen, Madsen, and Vinding). Within the project, among many other factors, has been tested the relationship between competitiveness and innovation. The result has shown that innovative firms are more likely to cope with the increased competitiveness of an industry (here specifically the Danish manufacturing industry), than non-innovative firms. And it is also true that competitive firms are more likely to innovate than those which struggle to maintain their market position or struggle with day-to-day problems. The more innovative a firm is, the less it should experience the increased competition in its environment. So, it can be said that competitiveness can be achieved through innovation. There is a twofold or mutual relationship between these two important factors.

The relationship between innovation and competitiveness is, also accepted by the European Commission (European Commission 1995):

"Innovation in processes increases the productivity of the factors of production by increasing production and/or lowering costs. It provides room for flexible pricing and increased product quality and reliability. Competition makes this quest for productivity an ongoing activity: successive improvements are a guarantee of not falling behind." ""Innovation in terms of products (or services) makes for differentiation vis-à-vis competing products, thus reducing sensitivity to competition on costs or price…Since the life-cycle of the products and services is becoming ever shorter and generations of technologies are succeeding each other at an ever faster rate, firms are often under pressure to innovate as fast as possible. The time of entry into the market and the moment of introducing a new product onto it are becoming crucial factors in competition.""

In this regard, competition, just like innovation, can be projected in an evolutionary environment. The driving forces of innovations, such as knowledge (the part that represents a public good), imperfections of intellectual property rights (IPRs), and uncertainty, cannot be judged according to the equilibrium defined by the competition, but by a change in which competition is seen as a process. This view corresponds with the evolutionary approach to economic change, with its strong relations with the process view of competition (Metcalfe 1997). In this regard, competition is the source of the different firm behaviours, which comes from knowledge asymmetries among companies. In the long term, competitiveness can diminish due to the fact that some firms manage to take the customers from their rivals, thus increasing their market share, but the result of such process is in the reduction of firm numbers among the competitors, which could end up with a single firm dominating the market (monopoly). The changes in competition can be sensed by the evolution of an organization's market share. Competition as such is quantifiable on different levels of aggregation: firm level, and industry level, national and international levels. In order to protect competitiveness on a long term, continuous technological and organizational innovation is indispensable. As the author argues, (Metcalfe 1997) "Innovation drives competition and competition drives innovation as those who have fallen behind seek to protect and improve their market position". Thus, the innovation mechanism is the primary process that can recreate the competitiveness among firms, if it is eroded by the decreasing diversity in firms' behaviour. Diversity is created (among other things) by technology policies. In this regard, general support by technology policy instead of specific support will make policy-makers focus on the question of which technological opportunities are more promising (Metcalfe 1997) for diversity creation.

Since Danish wind power energy became a competitive industry on a global level, the analysis has to broaden its viewpoint and discuss the international competition in this respect. In a global economy, international competition needs to be understood as the interplay of the different national markets (Zysman 1994) within the same technological systems. Dayasindhu (2002) defines global competitiveness in a dynamic theoretical framework as the result of the economic, sociological, knowledge management and industry clusters' collective effort in increasing productivity, focusing direction and quicker pace on innovation and achieving growth. The reason for choosing this definition of competitiveness is because it contains the societal factors that contribute to the achievement of global competitiveness and it complements the previous definitions based on the economic theories. These factors are the following: embeddedness, knowledge transfer and industry clustering.

Embeddedness is considered an important determinant of competitiveness, and refers to the fact that economic behaviour is affected by the social relations and the network structure of these relations. Also, embeddedness is considered a continuously changing process of the relations between the different constituents (Dayasindhu 2002). In this respect, this kind of definition is very close to the one given to institutions, as components of innovation systems.

Knowledge transfer is a key process both in innovation dynamics and global competitiveness. It improves performance by "purposefully modifying the behaviour of new knowledge" (Dayasindhu 2002). The different knowledge types have all importance in the achievement of competitiveness. Through the explicit and individual knowledge, actors provide technical expertise; the explicit and collective knowledge are the rules, regulations and laws (Baumard 1999 cited in Dayasindhu 2002). This means that knowledge is considered a constituent part of institutions. Tacit and individual knowledge constitutes intuitiveness, while tacit and collective knowledge constitutes the wisdom of social practice (Baumard 1999 cited in Dayasindhu 2002). The previous statements can be attributed to the innovation systems approach and associated with institutions and social capabilities. So, knowledge and learning, in a way, constitutes the changing institutional set-up and contributes to the formation of social capabilities too. In this regard, institutions are following the path of learning and knowledge transfer.

Industry clusters are considered important forces in the enhancement of competitiveness. They are formed by the relations between the suppliers, producers, customers, labour markets and training institutions, financial intermediaries, regulatory institutions and bodies of law and government (Dayasindhu 2002).

This framework complements the well-known Porter's diamond framework on competitiveness, because it emphasizes the relationships and their impacts on the productivity, innovation and the growth of new organizations.

Porter (1990), on the other hand, takes into consideration more the mainstream economic factors and focuses on the positive impact of the domestic market in order to determine the international competitiveness of a country. According to him, the traditional supply factors are important in the early development phase, but they don't represent the primary determinants of "competitive advantage" in more advanced countries, where growth is assumed to be innovation driven. Fagerberg (1995) tested this hypothesis, in 16 countries. The empirical analysis' results have shown that for five countries (Japan, Denmark, Finland, Norway and Switzerland) the relationship between the suppliers and buyers was very strong. This means that countries, in the long-run, tend to develop comparative advantages in areas where there are many advanced domestic users. This emphasizes the fact that competitiveness relies on the strength of domestic demand. Another result of the same empirical measurements shows that the relationship between the buyers and producers seems to be stronger when domestic markets are exposed to international competition (Fagerberg 1995). Porter (1990) suggests an approach which can be used by public authorities to improve the quality of domestic demand and so improve national and international competitiveness. These are the factors that matter: "regulation of products and processes", "buyers industry structure", "stimulating early sophisticated demand" and "technical standards" (Porter 1990). Under the regulation of products and processes, Porter distinguishes between the regulations relating to standards and those relating to competition.

Standards are considered as very positive rules of the economy. They can "pressure firms to improve quality, upgrade technology and provide features in important areas of customer (and social) concern" (Porter 1990). The positive effect of the standards is related to social (ie: the environmental or health) concerns that firms cannot be expected to set independently. Tough standards will require the buyer firms to be demanding customers in technology procurement. On the other hand, those standards that are beneficial will not be "laggard or anachronistic". Such standards should be anticipated by the regulations and, in this way, give a nation's firms a head start in the international competitiveness (Porter 1990, cited in Edquist, Hommen & Tsipouri 2000). There are, of course, opinions against this positive perspective about standards. According to this view, the most important issues should be negotiated among private economic actors (Edquist, Hommen & Tsipouri 2000, cited in Rankine 1995)

In regard to competition, the regulation is approved only in the case when it supports domestic rivalry and new firms (ibid.:). In terms of competitiveness, Porter states that firms should be under competitive pressure in order to promote "innovation at home". In other words, the development of domestic suppliers produces more sustainable advantages than the use of foreign suppliers (Porter 1990). Porter also discusses the existence of a "vigorous domestic rivalry", which has its starting point in strong anti-trust legislation, the avoidance of policies that support the creation of "national champions" and strong policy against "horizontal mergers, alliances and collusive behaviour" (Porter 1990). With this statement the chapter opens a new vision about the policy perspectives in terms of innovation and competitiveness.

4.2 Policy perspectives

Policies, as part of the institutional framework of the innovation system approach, can be attributed to each activity that is performed by the actors. In other words, each step taken within the innovation system is governed by institutions. Usually, one institution (policy) governs two or more activities and one institution is usually related to various activities. This fact causes serious conflicts and can lead to the uncertain and ambiguous state of the decision makers. Furthermore, it makes it more difficult to separate the different institutions into categories. The boundaries are impossible to draw. Therefore, an overlap is created among the different institution (policy) types. For instance, science policy relates mostly to the research activities performed in laboratories, research institutes, universities, etc. and their funding, which overlaps with financial policies belonging to the economic policies category. According to the following authors, Lundvall and Borrás (2005), science policy is part of technology policy, while the two policies are integrated into the innovation policy. Innovation policy, in its broad definition, is comprised of all the processes that contribute to the incremental or radical development of a new product, process or organization from policy perspectives.

If we want to look back a little bit to the generation of innovation policy, we bring the notion of economic growth into the picture, and specifically, the slow-down of this process. The reason behind the sluggish growth of the 1970s still has not been clarified, but there is a strong belief that the ability to exploit technological opportunities was lacking at the time (Lundvall, Borrás 2005). Therefore, the "objectives of the innovation policy are economic growth and international competitiveness" (Lundvall, Borrás 2005). A secondary objective of innovation is to cope with problems related to "pollution, energy, urbanism and poverty" (idem). In my opinion, the second objective of innovation policy has already taken a more prominent place in the agenda of policy-makers in comparison with to the first objective of innovation policy.

According to the same authors, innovation policy has developed on two strands: one the laissez-faire and the other the "systemic" version. Behind this divergence lies the simultaneous existence of the two theoretical approaches: older, neoclassical economics and the new, evolutionary economics.

The laissez-faire version commits to the non-interventionism and focuses on the "framework conditions" rather than on specific sectors or technologies (Lundvall, Borrás 2005). In this version, the market and competition are the predominant prerequisites for innovation and, in principle, a single institutional design is recommended for all countries (Lundvall, Borrás 2005). It seems that there is not too much focus on the institutional design, nor is importance accorded to the differences between countries.

The "systemic" version, which refers to the innovation system, implies those policies that contribute to innovation. Within this version, the competition also occupies an important place. However, the close co-operation (both vertically and horizontally) between users, producers and competitors, gains much more importance. The name of this policy type suggests that national innovation systems represent a starting point in the design of the institutional set-up, which eventually differs across national economies (Lundvall, Borrás 2005).

Overall, both of these policy approaches cover the whole innovation process (diffusion, use and marketing of new technologies), and in this regard they are a part of the "economic policy", where the focus is on innovation rather than on allocation (Lundvall, Borrás 2005). Competition policy is also part of the "economic policy" category, which provides the continuous debate about which activity should earn more focus: innovation or competition. But, before we start coming up with solutions to the dilemma, first there will be a short presentation about the origin of competition policy and its objectives.

Competition policy dates back to the last decades of the 19th century, when it was implemented in the US and later, in the 1950s in Europe (Neumann 2001). Competition policy could very well coexist with the free market mechanism of that time and was considered an enhancement to the economic welfare. In the neoclassical economy, competition was considered to be the perfect attribute. However, this theory is obsolete, in modern evolutionary economics (and I think that the "perfectly competitive" market structure has been never achieved) where it is known that competition can be influenced by many factors, especially through the elements discussed above. Therefore, the rules and laws protect competition, and try to dissociate it from the distortions. In this respect, competition policy gains a huge significance. It has two kinds of roles in a market economy. First, it enhances economic welfare by “favouring an efficient allocation of resources and technical progress” and, secondly, it aims to maintain a competitive order within the market economy, thus becoming an important part of economic and social policy (Neumann 2001). This then brings up the dilemma of to what extent market forces should be relied upon or, alternatively, Government regulation should be used to shape economic development. (Neumann 2001).

The general view about this, is that governments play an important role in the provision of the conditions that support innovation and competitiveness (Edquist et al. 2004). Competition may be influenced by the government through strategic actions in an oligopolistic industry. This does not mean that the government will gain growth advantages for such an action (Zysman 1994). However, a government can intervene and influence the balance of gains between its national firms and others, either in a positive or negative way. “The government’s ability to influence outcomes in specific markets to its national advantage does not inevitably create longer term growth advantages and conversely its failure to generate advantages does not automatically produce disadvantage.” It all depends on the character of linkages among the actors of the economy. If there are strong linkages, the loss of an industry, can destroy the positions of others (Zysman 1994). This is also true in the opposite case. Therefore, it cannot be said that the government intervention will automatically lead to protectionism and corruptive mechanism or diminish the competitive advantage of a nation. The two can exist alongside each other; the important thing is to know exactly what interests and objectives need to be achieved, and to use these mechanisms in their support.

The ISE empirical work has shed the light upon formal institutions designed by policy-makers, indicating that these types of policies have a “too great emphasis on “perfect competition”, which can undermine competitiveness” (Edquist et al. 1998). However, protectionist policies might have the same undermining effect with relation to competitiveness. Therefore, neither “perfect competition” nor protectionism should be promoted at all costs. The issue has to be viewed in a different way. A country’s institutional structure should have the capacity to “allocate the gains and pains effectively” among the winners and losers of a certain policy effect (Zysman 1994). Otherwise, the problem that has been cured with a certain policy may raise other issues that could lead to conflicts. Therefore, it can be said that solutions to new problems must always involve a new match between tasks and capacities (Zysman 1994). Thus, policy-making process has to go beyond the simple goal of reaching economic efficiency; it has to become a learning process that involves economic, social and political solutions to the same problem.

When the objective of state intervention is to improve market functions, it usually increases competition rather than increasing the rate of innovation. This kind of policy is called “general” or “horizontal” in the sense that it tries to achieve the same objective all over the market (Edquist et al. 2004). In case of the “specific” policies, these are characteristic to specific sectors or products. “In these cases the degree of competition has to be estimated, and if ways to increase it are needed they must be appropriately designed and implemented” (Edquist et al. 2004).

There is no concrete recipe to solve the dilemma, although history has shown that in some areas (the environment, education, social security, research, radical innovations, etc.), market mechanisms are not able to fulfil their functions or they may not even exist. Therefore, there is a need for public intervention or other regulations. The authors (Edquist et al. 2004) define two simultaneous conditions for public intervention in a market economy. The first condition exists when the **self-organization** of the system **fails** to happen. In other words, a **problem** cannot be solved by the market mechanism. The second condition is based on the state and its public agencies **ability** to solve the existing problem. With the ability rises the problem, that ex ante the public agencies do not always know if their intervention will have the desired results, especially in innovation-related cases, where the outcomes are uncertain. Therefore, a detailed analysis of the problem and its causes may be necessary (Edquist et al. 2004).

The policies used to solve or mitigate problems are of two main kinds: non-market mechanisms and tools that “improve the functioning of markets” (Edquist et al. 2004). The former relies on subsidies, tax allowances or technical standards, while the latter one includes all those activities that have an impact on supply or demand. The grey surface in the following part shows some information about the most-frequently used policy instruments.

The first instrument (a non-market mechanism), **government aid,** can be of different kinds, for example: subsidies or tax allowences, sale of real estate below the market price or an increase in the equity of a public enterprise (Neumann 2001). The most regularly used aids concerning the Danish wind power energy are subsidies and tax exemtions.

The other type of public policy, which influences the market-mechanism, is the **public technology procurement** (PTP), which is a well represented topic in the innovation research and policy related literature. PTP occurs when a public agency places an order for a product or a system that does not exist at the time, but which could probably be developed in a certain period of time (Edquist, Hommen & Tsipouri 2000). In some writings, PTP is considered an instrument of industrial policy (Edquist, Hommen & Tsipouri 2000). This policy instrument may favour certain regions or industries and, at the same time, has a discriminatory effect on foreign competitors. On the other hand, it has many positive effects that lead to a win-win relationship among suppliers-buyers-public. However, due to the great benefits it can provide, there are some problems associated with it. First of all, there is the possibility of corrupt practices, since the volume of purchase achieves gigantic amounts, and since the wage of the person making decisions on behalf of the company which should supply is very small relative to the amounts within the business' operation there is a high probability of a "bribe" being offered. On the other hand, the competing suppliers may collude. Therefore, as a control mechanism in such activities the submission and auction procedure was adopted (Neumann 2001). Auction theory is very well suited to the regular public procurement[9] activities, while in case of public technology procurements; auction might not be such an efficient approach (Edquist, Hommen & Tsipouri 2000). However, if we take a look at the PTP relationship regarding innovation, we might find that is the most important innovation policy instrument, which the enhanced capacity for innovation and therefore makes firms and nations more competitive (Edquist, Hommen & Tsipouri 2000). In the previously mentioned work, at least five instrumental uses of the PTP as a policy tool are collected. First, the procurement (not necessarily PTP) was considered to be a tool for increasing demand, which enhances economic activity, and as a result, creates

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[9] Regular public procurement refers to the action of a public agency placing an order for already existing goods and services and basing this decision upon the winner of an auction, based on price and performance. On the other hand, public technology procurement relates to technology demands from public agencies under the uncertainty condition, which means that the technology is not finished by the time the offer is placed.

employment. Second, PTP can be used to protect domestic industry from foreign competition. Third, public technology procurement has been used to protect the competitiveness of an industry by assuring the demand for the produced goods. Fourth, it has been used to decrease regional disparities. Lastly, it has been used to create jobs for marginal sections of the labor force (Edquist, Hommen & Tsipouri 2000). PTP, from the EU point of view, remains an area, in which national governments and public agencies continue to enjoy considerable autonomy. EU policies are focused on strengthening the competition through the reduction of protectionism. Therefore, the EU disregarded from the PTP, excepting some sectors: water, energy, transport, and telecommunication (Business International Ltd. 1991 cited in Edquist, Hommen & Tsipouri 2000).

Since the PTP is a demand side policy instrument, the arguments in its favour are more closely related to the nature of demand, rather than that of supply and investment. The generally favourable view related to PTP is that public agencies are more capable of placing a demand for technological solutions on a problem that private actors are either unable or not motivated to address, especially in the case of a common social problem. The most frequently cited arguments in favour of PTP are those which refer to "specific characteristics of demand: strategic importance, largeness of scale, high risks and high costs (Rothwell, Zegveld 1982 cited in Edquist, Hommen & Tsipouri 2000). Furthermore, a newer work demonstrates that "under certain market conditions, in sectors of significant technological content, the high concentration of public demand early in the product cycle acts as a potential catalyst for innovative activity" (Faucher, Fitzgibbons 1993 cited in Edquist, Hommen & Tsipouri 2000). An example that has other objectives beside economic ones was the NUTEK activity in energy-saving, through which the object of procurement was the new refrigerators using less Freon.

This instrument (PTP) links two actors of the innovation system: public agents with suppliers and producers of technology. The point of departure of such PTP action is always a socio-economic problem that cannot be solved through the private market actors. The public agency can be either in the position of a final user of the demanded technology, or as an intermediary, co-ordinating the demand towards a different actor. There is a close interactive learning process between the two actors that is allowed by the rules and laws. Although, PTP is considered to be the most important driving force towards innovation, it is viewed as "necessary evil" by the European Union's policy-makers (Edquist et al. 1998). The risk that is always associated with the PTP is the development of protectionist relationships between the respective actors. However, this cannot represent a cause to diminish the power of PTP. Therefore, the regulations should be changed in such a way that they "stimulate and spur interaction between procurers and suppliers in fields where public technology procurement is appropriate" (Edquist et al. 1998).

As has been already mentioned, the buyer industry needs to represent strong demand in order for the technology procurement to be effective. In this respect, Porter (1990) suggests that, especially in the electric power industry, the procurer acts as a more "sophisticated buyer with more stringent and advanced needs". These buyers require particularly high levels of competence and learning. In this case, the learning from the buyer's side happens in an earlier phase of the innovation process, than in the "technology-push" case.

The demand-oriented policies are the kind of market drivers that induce companies to innovate. They set targets and provide rewards (Lundvall 1992). Companies can innovate due to demand in cases when this demand is very sophisticated. An immature market is a handicap for the producers (Borrus 1993 cited in Zysman 1994). Examples of demand side policy include public technology procurement, laws, regulations, standards and other institutions (Edquist, Hommen & Tsipouri 2000, Edquist, Hommen & Tsipouri 2000 cited in Zysman 1994).

Buyer demand is also required to be strongly present in the early stage of the technological process. In this way, buyers perceive the risk that concerns mostly the producers that the demand will fail to materialise. Assurance of future demand is required to encourage a sufficient investment in R&D and production (Edquist, Hommen & Tsipouri 2000). But, of course, the shift of the risks towards the buyers needs to be counteracted with some incentives to them. In this respect, Porter suggests that subsidizing buyers instead of the producers is more beneficial to innovation and competitive advantage because in this way, suppliers have to meet the buyers' demands, which stimulates the competitive rivalry among producer firms (Porter 1990).

Measuring policies is not an easy and straightforward process. By evaluating their impacts on different subjects we gain more insight into the efficiency of the policy that has been created and it is easier to see whether that specific policy has reached its goal or not. However, it must be emphasized that innovation policies are designed in a phase when the output of their object is in an unknown state, so ambiguity is impossible to overcome. The other problem regarding the policy measurement is related to its time perspective. Usually, innovation policies have long-term objectives, so the results that these policies produce need to be evaluated on a very long time scale, during a continuously-changing economic-, social- and political environment.

The authors (Lundvall, Borrás 2005) suggest some ideas for the analysis of innovation policy. First of all, the analysis has to start with specific insights into the characteristics of the national innovation system, or other levels of this. Then, the system can be assessed according to some parameters: "specialization, institutional set-up and insertion into the global economy". Through a SWOT benchmarking analysis, the missing link (or the links representing a lock-in effect) may be located and rectified. Last, an analysis of the innovation policy in international dimensions should not be forgotten.

An empirical way to assess energy policy programmes has been used by a group of researchers in a European Commission funded project called EXTOOL. Their analysis tool was the *experience curves*[10] (Neij, Andersen & Durstewitz 2003). The group analysed the impacts of energy policy programmes in the wind power sector. Among the many results gained through this assessment, the overall conclusion was that experience curves are not appropriate for cost efficiency evaluation of wind power measures, but they do constitute an aggregate tool for describing cost reduction (Neij, Andersen & Durstewitz 2003). The same research stated that experience curves do not represent an efficient tool for assessing individual policy measures, but do analyse the effect of combined policy measures in terms of installed units and cost reductions (Neij, Andersen & Durstewitz 2003).

The evaluation of policies should be included in daily political processes, when public administrations try to elaborate conclusions from the past performance in order to become better in the future. So far, there are as many methods of policy evaluations as evaluators (Lundvall, Borrás 2005). Therefore, this area would need some standardization but keeping the specificities of each evaluation in regard to different context. Several authors emphasized that the evaluation of STI (science,

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[10] An experience curve provides a measure of the performance of a system, which (continuously) produces certain products (Neij, Andersen & Durstewitz 2003). Experience curves can be used either for historical evaluations of energy policy measures or a decision to support new energy R&D programmes (Neij, Andersen & Durstewitz 2003).

technology and innovation) policies presents a lot of difficulties because of the wide-spread effects throughout the system. It has been also argued that “micro-level evaluations (program-specific) are more reliable than macro-level evaluations where issues such as whether a specific program or policy enhanced the competitiveness of an economy are almost impossible to determine” (Luukkonen 1998, cited in Lundvall, Borrás 2005).

Over the years, there have been other attempts to measure innovation performance or productivity. Nevertheless, these measurements are not capable of perceiving or sizing the qualitative impacts of the innovation. This means that these measurements are necessary when analysing innovation policy impacts, but they are far from sufficient (Lundvall, Borrás 2005). The authors suggest that, in order to support the design of innovation policies, indicators need to be built that represent the diffusion of process innovations, innovation in services, organizational innovations and their diffusion. Beside these quantitative indicators, some qualitative information is welcome in the measurements (Lundvall, Borrás 2005).

This chapter has given a presentation on the most important facts regarding innovation and competitiveness: it has defined both notions with their objectives, it has presented how they interrelate with each other, and presented the dilemma that builds up between the two situations when it comes to policy intervention and government objectives.

There should not be a debate on which is more important (innovation or competition), because both are extremely important and are indispensable for the growth of an organization or the whole aggregate economy. Also, as presented at the beginning of this chapter, innovation and competition mutually reinforce each other’s performance. It is hard to determine which one is more important, because this depends on the environment where innovation and competition do or do not take place.

Innovation policy embodies not only economic but also social processes, due to its willingness to understand the complex innovation processes. It also pays attention to the institutional and organizational dimensions of innovation systems, focusing mostly on competence building and organizational performance (idem).

What has been previously said for innovation policy is appropriate for competition policy too. It is an economic policy that overlaps social policies in that it tries to maintain a fairly competitive environment for social purposes. The competitiveness of the labour market, for instance, is one example. Although the asymmetry is quite high between the number of employers and employees, competition policy somehow provides the certainty in the contractual relationship between the two kinds of actors. A very univocal example represents the antitrust character of competition policy, which has also a positive impact on the social layer, since it tries to hinder monopolies from asking for monopolistic prices from their potential customers.

Throughout this chapter, there have major steps in the process of policy design been followed. There has been discussion about the determination of a problem or "system failure", and then the discovery of its causes, the dilemma of which type of governmental intervention should be applied in ameliorating and solving the problem, and what capabilities of the policy-makers are needed, and finally, the assessment of policy effects through various methods.

4.3 Conclusions of the theoretical chapters

The project initiated the theoretical discussion from the innovation systems approach and then the approach has been separated into different levels: national, regional, sectoral and technological. Among the approaches lies a specific one that best suits the analysis of the Danish wind power energy sector's evolution, and this is the sectoral innovation systems approach. It is considered the best framework for policy design so far; however, it is far from being perfect. Also, the results of academic research on the innovation policies have been just the different frameworks for analysis and evaluation rather than success in formulating a universally-applicable policy. These frameworks still have a value in providing the tools for an analysis of policy objectives and instruments (Edquist et al. 2004). According to these authors, the sectoral system approach is "the most appropriate unit of analysis for examining industrial conditions and the behaviour shaping innovation performance" (Edquist et al. 2004). Sectoral systems perspective leads to new insights into the innovation policy area by defining the principal role of the policy maker, which is the coordination of the innovation systems in such a way that they will self-organize themselves within a certain policy domain (Edquist et al. 2004).

The fact that shines through all these discussions is that the sectoral systems approach emphasizes that innovation and technology policies affect and are linked with other types of policies, such as science policy, industrial policy, policies related to standards and IPR, and (most importantly what interest us), competition policy. A sectoral system approach highlights the interdependences, links and feedback among all these policies, and their effects on the dynamics and transformation of sectors.

However, the research question of the present project has a second important issue to solve, which is the competitiveness of the Danish wind power energy industry. In order to find out what the driving forces behind the Danish competitiveness during almost four decades were, the framework of analysis needs to be extended with more specific, almost mainstream economic theories, without losing sight of the evolutionary perspective of the wind power energy industry. Therefore, the extension is brought in by Porter's industry analysis. Since in the centre of assessment rests a technology driven industry, the technological systems approach seems to be appropriate to fill in the gaps in the analysis.

These are the different policies' effects upon the technological system presented very briefly. The strength and good functioning of the technological system depends on the constituents and the linkages among them. In this respect, policies have the role of assuring the healthy operation of the system. By assigning such roles to policies, the focal point will be on the conditions and processes instead of on "picking the winners in the form of individual firms" (Carlsson, Jacobsson 1997). This view was proper to Porter's framework, which "underestimates the power of technical change to transform industrial structures" and overestimates the entrepreneur's power to decide and implement innovation strategies (Tidd, Bessant and Pavitt 2005).

When relying on the innovation systems approach, some general policy issues can be derived from it as a sign-post for the existing system failures, which ultimately can be turned into solutions. Nevertheless, this does not contain sufficient knowledge for innovation policy design. The issues revealed through the sign posts do not tell the policy makers exactly what to do in order to improve the functioning of the system.

Neither do the market-failure[11] type of problems. The market failure approach is not a comprehensive base for policy design. One of the reasons is embedded in the "idealistic" nature of failure recognition, which is not compatible with evolutionary economics. Its other weakness lies in the fact that it cannot provide policies with detailed specification upon certain topics. For instance, it cannot tell where subsidies or other aid should go, or what the amount should be. Therefore, it is not a practical tool for policy-makers (Edquist et al. 1998). It does not indicate how large subsidies or other interventions should be or within which specific area one should intervene (Metcalfe 1995). In order to develop policies that would fit to the different system specificities and could solve the "problems" within the system, policy designers ought to develop their analytical and methodological skills. The best way to identify "problems" according to the authors Edquist et al. (1998) is through empirical comparisons between existing systems over time. Therefore, such a system-failure method will be used in this report, according to which two existing innovation systems are compared and conclusions are drawn from the problems identified through the differences between the systems. The innovation system approach has better odds of providing policies with a more specific context (Edquist et al. 1998), due to the character of the system, where if one problem is recognized, it is possible to detect the other rules or players in the system that might be affected by this problem. In this way it provides a wider and more naturally complex view for policy-makers. However, the system perspective is a demanding policy design approach due to the complex linkages among the elements of the system.

Furthermore, a system approach suggests that for policy co-ordination, it is vital to develop information systems, which can only be achieved through the dialogue between policy-makers, researchers, business leaders, unions, etc. and thus, it is a key policy challenge arising from the system approach (Edquist et al. 1998). The communication must exist between SMEs, large firms, universities, public research institutes, financing organizations and public organizations in order to design policies with exact purposes. The interactive character of the innovation process

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[11] "market-failure" is the notion of something malfunctioning in the market system. In order to recognize the failure within the market system, there is a need to compare two markets related activities or factors. On the one side of the comparison is the actual market situation; while on the other side is always an "ideal" situation. The deviation from the ideal state represents the failure.

makes the linkages and the quality of interaction extremely important in relation with the outcomes. This is why some innovation policies which focus on just one part of the system (e.g. suppliers-subsidies) are incomplete; users need to be brought into the focus at the same time. This represents a part of the innovation policy learning process (Edquist et al. 1998).

A very general conclusion that has been formulated during this report is that each country has a different institutional set-up that derives from the different innovation systems that a country relies on. Therefore, there is no rule that can be applied identically in the case of different countries. To be more precise, from the CIS (Community Innovation Survey) results show that each member state of the EU has major differences in their innovation structure. Therefore, the policies designed on the European level cannot be fitted to all member countries' innovation systems. This is the reason why the EU should provide just general framework for the different policies, and leave it to the member states to make the specifications according to their innovation structure. However, this would contradict the fact that the European Parliament can exert its legally binding power upon the policies designed on national level.

5 HISTORICAL COMPARISON OF THREE PERIODS IN THE DANISH WIND POWER ENERGY SYSTEM

In this chapter, every theoretical approach that has been concluded as being appropriate for the assessment of the Danish wind power energy system's competitiveness and its policy related issues will be applied.

The objective of this chapter is to compare three significant periods in the Danish wind power energy system's evolution, from the beginning to the present day. Throughout the comparison it is hoped that some important indications of the fact that the Danish wind power energy sector is among the most competitive industries in the world will be found. In order to do this, the project focuses on the driving forces of competitiveness both from a more static economic to a more evolutionary point of view. Also, it is known, that government intervention has played a major role in the development of this industry. Therefore, answers in the political systems that have been in use during the years should be sought. Leaning our analysis on historical comparison; some conclusions upon the future of this industry can be drawn, taking into consideration the present political state of Denmark and the world economy.

Before jumping in the middle of the analysis, we first need to identify those three periods that represented important milestones in the development of the wind power energy industry and to summarize the Danish national systems of innovation. The first period is split into two sub-periods: from the 1890s to 1973 and from 1974-

2001 (the growth period), the next period is the stagnation period in Denmark, marking the years 2001-2007 and, finally, the period after 2007 will be analysed.

Denmark's NSI is characterized by: high income and high wages, high taxes, a large public sector, an export specialization in low-tech products and a relativly low proportion of more highly educated people, especially in science and technology. There are many small companies and a few large, international firms. In general, these firms are innovative in the form of incremental changes. The firms' competence is built up by the experienced and more highly educated labour employed and, at the same time, by the strong inter-firm, firm-university collaborations (Christensen et al. 2008). Because of these attributes, Denmark survived the changes that occurred because of international market pressures, but more than that, it has stayed competitive and wealthy for decades.

Different authors have different opinions about Denmark's NSI. According to Zysman, the interesting thing about the Danish economy is that the country has a small amount and few types of raw materials, "a vulnerable strategic position and is in all sorts of traditional, supposedly slow-growing industries". At least, this was the case until 1994. In spite of such parameters, the country was able become a very rich country, with very high income levels due to the strategies of creating value in market niches. The Danish strategy is one of importing low-value input commodities and, in the case of grain, feeding them to pigs and cows to create a dairy farming and food processing industry and in the case of semiconductors, putting them into hearing aids and exceptionally-expensive consumer electronics.

The line of argument so far is that there are "national institutional foundations of market systems that generate quite particular logics and dynamics in each case" (Zysman 1994).

Others say that the specificity that lies in the Danish welfare state is related to the informal institutional system, the "egalitarian belief in society", and the trust that forms strong relations (Christensen et al. 2008). This type of economy, called the "village economy", together with stable macro economic conditions and a qualitative public service sector, have managed to keep Danish industry very competitive even without much input from formal R&D (Christensen et al. 2008). However, recently, there have been some changes in this "village economy" in terms of social cohesion and globalization. The social cohesion is politically pressured by neo-liberal tendencies, which are common to most capitalist countries, while the globalization issue impacts on the changes in the international division of labour and innovation modes (Christensen et al. 2008).

5.1 The Danish wind power energy system

The real Danish wind power energy industry dates back to the 1970s, when the welfare state model was characterized by social cohesion and a relatively equal distribution of income. Economic policies were created and implemented in a cooperative way, the so called "corporatist system of interactions between the state, the trade unions and the employers" (Christensen et al. 2008). The period before the 1970s represented a preliminary experimental period. Therefore, it wasn't a system behind the wind power energy that could be analyzed.

The aim of this part of the project, is to apply the theoretical framework that has been built in the theoretical part of this project. The periods of the Danish wind power energy system will be described according to the sectoral system approach, with insights into the technological sub-system and the Porter kind of industrial analysis framework, which contains five important driving forces. Therefore, the subchapters will be the following: technological systems, institutions, organizations, and the wind turbine industry will be broken down into the five forces: suppliers, consumers, entry/exit barriers, substitutes and all these forces contribute to the rivalry of the industry, which is going to be integrated in the concluding part of the industry analysis. At the end of the discussion and analysis, a small summary of the results will be given and a view of the whole energy system of that period will be given.

5.2 First period (1890-1974-2001)

5.2.1 Technological systems (TSs)

The first period takes up a very long period of time, from the emergence of the idea of building windmills, to the maturity stage of the modern wind turbines. For the sake of the analysis, it is therefore better to split up this long period into two sub-periods. The first sub-period dates from the 1890s until 1973/74, when the first oil crisis hit the world. The second sub-period is set from 1974-2001.

Despite the vulnerable strategic position of Denmark and the small amount of raw-materials, available wind power represents a major potential. Initially it was used only for sailing, but soon Danes started to think of wind power as an energy source. The reason behind this thinking was the first energy crisis from the same year, when Denmark decided to produce electricity independently of oil and other raw material supplies from outside the country (Tranaes 1997).

Wind energy was not a completely new technology for Denmark; windmills of the so-called Dutch types had been used for centuries for milling grain. At the end of the 19th century and the beginning of the 20th century the classic multi-blade windmill or "wind-rose" appeared. This kind of windmill was more modern in those days than the "klapsejler", a windmill with adjustable narrow vanes and a further development of the Dutch windmill. Instead of the canvas sails, Danes used adjustable wooden sheets. Thus they could control the effect of the wind. Beside their being used in the grain milling, windmills were used to power agricultural machinery, and to pump water, often to huge containers. In 1931 there were about 30.000 such windmills all over Denmark (Tranaes 1997).

During this time, Poul la Cour, a teacher at the Folk High School Askov, started a series of experiments in 1891 with the aim of finding a methodology for transforming wind power into electricity.

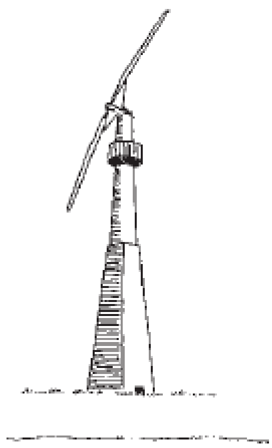
Figure 5.1 Poul la Cour's wind turbine at Askov

Source: (Danish Wind Industry Association 2003e)

He was the first person in the world who carried out systematic experiments with artificial air currents in a wind tunnel (Tranaes 1997). Poul la Cour received subsidies from the Danish state to build a trial turbine at the school, where he taught. The turbine (Figure 5.1) was a wooden house with a tower. In 1897, a new and larger trial turbine was made, providing direct current (DC) for the school and later for the Askov community (Carlson, Madsen 2007). As a result of his experiments, he established some taxonomy concerning the elementary laws of aerodynamics, and he developed a number of windmills and blades, which represented great progress in the design of windmills (Tranaes 1997). His dream was to supply the Danish population with energy produced in small local power plants. He took his dream step by step, and first he had taught "rural electricians". Around the country approximately 30 small village power plants were built (Carlson, Madsen 2007). The development of the electricity-producing wind turbine was advancing in periods of crisis, especially during the two world wars. However, when coal and oil began to be imported to Denmark in gigantic quantities, the interest in wind power dropped considerably, because it could not compete with the cheap alternating current (AC) produced by huge power plants (Tranaes 1997 cited in Carlson, Madsen 2007).

> "During the First World War there were approximately 250 wind turbines producing electricity, 120 of them were connected to power plants. After the war, in 1920 only 75 small power plants used them and in 1940 the number was down to 25. In the years 1940-45, during the German occupation of Denmark, the wind turbines with the wooden lamellas were popular again and many of those, which were privately owned were bought by the power plants.
>
> During the Second World War there were approximately 70 electricity producing wind turbines with a diameter of 14-18 meters and a maximum power of 30-40 kW." (Carlson, Madsen 2007).

Figure 5.2 Wind turbine with two aerodynamic wings and a concrete tower

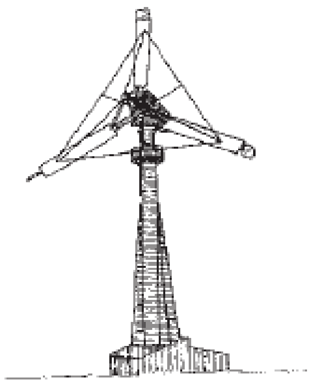


Source: (Danish Wind Industry Association 2003f)

At the beginning of the Second World War, the cement company F.L. Smidth and the aircraft producer Kramme & Zeuthen, developed a wind turbine which produced DC current and had aerodynamic wings (two or three of them). These turbines had a higher capacity, around 40-70 kW. One of these turbines was placed in shallow waters, outside the Bornholm Island. Therefore, it was considered the first offshore wind turbine (Carlson, Madsen 2007).

The first wind turbine that is called the father of the present turbines is the “Gedser-mølle”, constructed by a student of Poul la Cour, Johannes Juul (Carlson, Madsen 2007). This turbine represented the “prototype” for the later turbines produced in the 1970s’ energy crises. The “Gedser-mølle” was in operation from 1957-1967, when it produced some exceptional results.

Figure 5.3 The “Gedser-mølle”

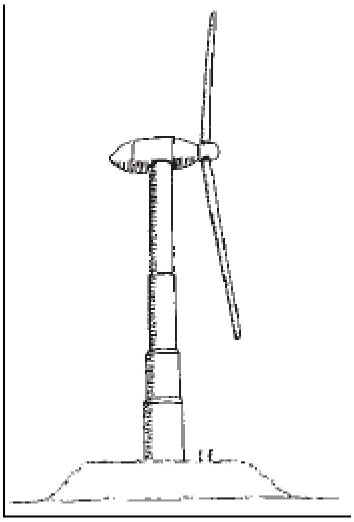


Source: (Danish Wind Industry Association 2003e)

The maximum power it could produce was 200 kW, much stronger than the previous rivals, and it produced 400.000 kWh per year. Although it had high performance for that period, the only thing that mattered then was pure economics, taking into consideration only the price of electricity generated by this turbine, compared to the electricity price generated by the oil power stations.

Unfortunately, nobody took into consideration the environmental benefits of the wind turbine, and since the electricity price was double that of the electricity price produced by the oil platforms, the “Gedser-møller” was stopped. This thinking has upheld until 1973, when the first energy crisis arrived. Everything that seemed to have been forgotten over the years suddenly had to be reanimated. Some proposed wind power, but others were against it, arguing that the past experiments were a loss, and not an improvement. Nuclear energy came into focus at the time. However, public opinion could not be suppressed (Tranaes 1997). Students and teachers of the Tvind School continued believing in wind power as an alternative energy source in the period of first oil crisis. Therefore, over three years, from 1975-78, they built the largest wind turbine of that period. The maximum power of the “Tvind-mølle” was 960 kW, almost five times larger than the one built ten years earlier. This turbine was built mostly by volunteers, and some expert knowledge related to the wings and design was offered by engineers (Carlson, Madsen 2007).

Figure 5.4 The "Tvind-mølle"



Source: (Danish Wind Industry Association 2003h)

The wings of this wind turbine were changed in 1993, and the turbine is still running today, so far having produced more than 70.000 hours and over 12 million kW hours energy (Danish Wind Industry Association 2003h in Carlson, Madsen 2007).

Then came the history-making turbine that was developed by a carpenter, Christian Riisager, from whom the turbine received its name. He experimented with a 22 kW turbine made of glass fiber blades, using the "Gedser-mølle" as a point of departure. During the experiment he had failures as well as successes, but he finally managed to create a prototype, which he asked the local electricity distribution company to approve for connection to the grid.

Figure 5.5 The "Riisager turbine"

Source: (Danish Wind Industry Association 2003h)

This experiment came out so well that the "Riisager turbine" was marketed. The customers were a number of "idealistic visionaries" of the Danish population. By spring 1978 the number of Riisager type of turbines had grown to 30 pieces installed, plus a number of electricity producing "wind roses", which had a power output of 10 kW.

After the first oil crisis, interest in wind energy was rekindled and Denmark wanted to produce large turbines like as the other countries were, namely: Sweden, Germany, the UK and the USA (Danish Wind Industry Association 2003g). In 1979, Danes built two 630 kW wind turbines, called the "Nibe turbines". Unfortunately, these turbines had the same fate as their predecessors: they were very expensive and the price of the energy produced was very high. However, the 1980s presented a new decade in the production of the first commercial wind turbines, which was of 30 kW. The producer was initially in the agricultural machinery business, but he saw a new market and a new product and switched his company's production orientation.

Figure 5.6 The "Bonus" turbine

Source: (Danish Wind Industry Association 2003h).

The company's name was Bonus Energy. Today it is Siemens Wind Power.

In 1980-81 a 55 kW wind turbine was developed by NEG Micon A/S (now part of Vestas) and it became the industrial and technological breakthrough for modern wind turbines.

The cost per kilowatt hour (kWh) of electricity dropped by about 50% due to the appearance of this generation of wind turbines, and also because the wind industry became much more professionalized, and the parallel development of the European Wind Atlas Method by Risø National Laboratory was extremely important in lowering kWh costs.

Figure 5.7 The "Nordtank 55 kW"

Source: (Danish Wind Industry Association 2003h)

Thousands of these machines were delivered to the wind programme in California in the early 1980s. Having started series manufacturing of wind turbines about 5 years earlier, Danish manufacturers had much more of a track record than companies from other countries. About half of the wind turbines in California are of Danish origin. But, the market for wind energy in the United States disappeared overnight with the disappearance of the Californian support schemes around 1985. After that, only a tiny trickle of new installations were commissioned, although the market seemed to pick up.

Just to have an idea of wind farm's size of that time,[12] by the end of 1986 there was around 16 MW capacity of real wind farms installed in which the biggest was 3.75 MW (Madsen 1988). The wind farms consisted of 20-25 wind turbines, and the majority of these were installed by private Danish individual groups. This has a natural development of the so-called "co-operative wind turbines" of which had several hundreds were installed. The "co-operative wind turbines" are based on 1-4 wind turbines installed together and connected to a common grid and these turbines are owned by 50-100 families (Madsen 1988).

Table 5.1 The advantages of wind farming

Advantages of erecting wind turbines in "farms":
optimal utilization of sites
larger capacity of wind turbines spreads the costs of a grid connection, which is rather expensive
possibility of more rational and time-saving supervision and maintenance
gathering of wind turbines in large groups gives the utility companies better opportunities for regulating wind power effect on the electric system.

Source: (Danish Wind Industry Association 2003a) in (Madsen 1988)

The following years represented a significant development in terms of installed wind power capacity, as a new plan to increase to 100 MW capacities in the period of 1987-1990 by the Danish utility companies was ordered (Madsen 1988).

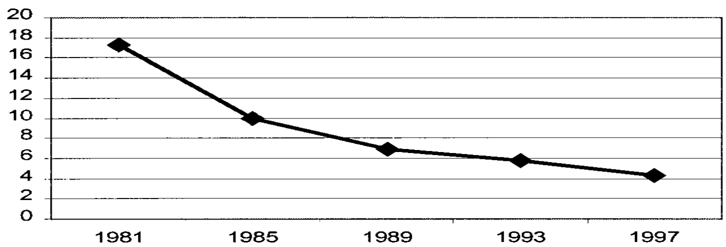
In 1995, the most common sizes of wind turbines reached 600 kW, while in five years time they had increased their capacity to 750 kW (Danish Wind Industry Association 2003c). However, there were even bigger turbines in 1995 that reached the megawatt size. The prototype of the Nordtek 1500 kW was commissioned in 1995, which has two 750 kW generators working. One year later, Vestas came out with a 1500 kW turbine working with one generator. Slowly, the megawatt market

12 In Denmark the definition of a wind farm is 5 or more wind turbines installed together (Madsen 1988).

took off and since then the market trend has been for bigger turbines and bigger projects. These megawatt sizes turbines are extremely important for areas where the site for placing them is small for offshore projects (Danish Wind Industry Association 2003b). By 1999, Bonus brought out a new prototype of a 2 MW wind turbine, while only one year later, the Nordex 2.5 MW turbine was commissioned (Danish Wind Industry Association 2003d).

The figure below shows the technological development of Danish wind turbines in terms of production prices (Lund 2000). As a result of the learning process, the capacity and efficiency of wind turbines has increased, dropping the electricity prices by significant levels.

Figure 5.8 Wind power production prices (in US $ 0.01 per kWh)



Source: (Lund 2000)

The belief is that further technological changes need organizational changes, and, therefore, independent public regulation is needed, perhaps now on an international scale, especially if public issues like climate change and sustainable development are considered. Moreover, public participation is a condition for further improvements and, therefore, should be promoted and developed (Lund 2000).

5.2.2 Institutions

This part of the project emphasizes the informal and formal institutional set-up of the Danish wind power energy industry, focusing especially on rules, laws and regulations related to the development of the industry.

The first sub-period of the wind power energy industry was characterized mostly by an informal institutional set-up. At the very beginning there was just the enthusiasm of Danes to build windmills and then wind turbines. By the time the crises struck, there were still no national energy policies. The crises showed that there was a need for planning, and energy planning was set on the political agenda. The plan was to build new plants when and where they were needed (Carlson, Madsen 2007).

The first Danish energy plan was made in 1976, and it focused on the production of energy by means of coal and nuclear power. Its aim was to restructure the energy system in such a way that it could reduce Denmark's oil dependency and stabilize energy consumption. Besides this plan, Denmark also looked into exploring oil and gas in its North Sea territory and also identified renewable energy, energy efficiency and energy savings as important steps towards a more independent and secure energy supply (Lund 2007). However, strong nuclear resistance was raised in Denmark, and in 1976 with this aim two NGO's fought against nuclear power plants.[13] They presented a draft for an alternative energy plan for Denmark, focusing on renewable energy, energy savings and co-generation, and spreading knowledge about the risks of the nuclear power. This plan was mostly made by people from universities. The plan was not completely accepted, but it opened up the opportunities for discussion of future energy production (Carlson, Madsen 2007).

First taxes on electricity were introduced in 1977. They were later followed by other negative incentives. Because of the oil crises the taxes were increased drastically – especially on gasoline and diesel due to the fact that the price of oil had tripled in the period 1979-1980. In the coming years the taxes increased on a regular basis and in 1982 a tax was introduced on coal, but not for the production of electricity. (Energitjenesten 2007 in, Carlson, Madsen 2007).

The first state support, was offered to experimental activity, which resulted in the "Gedser turbine"; the support was offered by the state of Gedser, in the south of Falster. More project-oriented subsidies for building renewable energy plants were introduced by law in 1979, and a few years later the first energy plan was born. The law stated that the Danish state would cover 30% (or 50%, according to other sources (Madsen 1988)) of the expenses of buying a wind turbine. This action gave a boost to the Danish wind turbine industry for settling in this new market (Carlson, Madsen 2007). Another law in 1981 was introduced regarding subsidies for the use of renewable energy (Law title: Lov om statstilskud til udnyttelse af vedvarende

13 More information about these NGO's will be offered in the "Organisations" section.

energikilder mv). This law made subsidies for erecting wind turbines and installing other renewable energies possible (Energitjenesten 2007 in, Carlson, Madsen 2007).

The next step in the evolution of the institutional system was the formation of the first Ministry of Energy in 1981; in the same year the Danish government made a new energy plan, called “Energy 81”. This plan focused on coal power and renewable energy, but it still left open some gates for potential nuclear power. The plan has shown an aimed to cover 10% of Danish electricity consumption by biomass and wind power, which would require 60.000 small wind turbines. (Just as a reminder, in that time period, the “Nordtank 55 kW turbine” was the popular one). Furthermore, it became a goal to detach financial growth from energy consumption, which later became a big success for Denmark (Lund 2002in Carlson, Madsen 2007). Very soon (in 1983) another alternative energy plan, called “Energi for Fremtiden – alternative energiplan fra 1983” was put into place. The role of renewable energy supplies increased within this energy plan and there was also a discussion on how to further decentralize the energy supply (Ing 2004 cited in Carlson, Madsen 2007). At this time, the questions surrounding nuclear power were still open but, with the adoption of the 1983 energy plan, the Parliament finally decided in 1985 (taking into consideration public opinion too) to give up all plans on nuclear power ((Lund 2002 cited in Carlson, Madsen 2007).

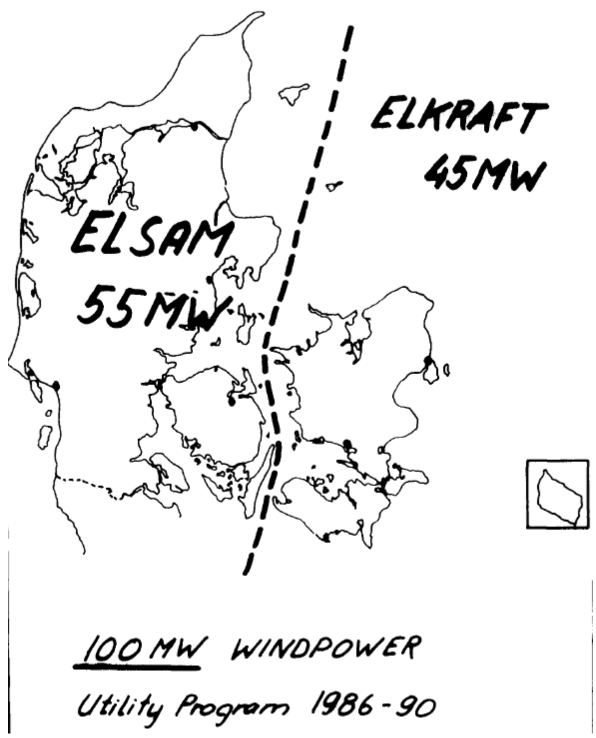
In the next period, the power companies were feeling the approach of the countdown towards the Law for Wind Turbines, which had already started at the beginning of the 1980s. Therefore, they harassed turbine owners with various financial charges.

> “For instance a supply company introduced a surcharge fee for wind turbines in their area. It was a duty normally imposed on large electricity consuming installations, and it was clearly unreasonable on installations like wind turbines, which supplied the grid with electricity… Other companies deducted 10 % from the normal payment for the electricity produced by a wind turbine, or they considered wind turbines as electricity consuming apparatus with subsequent extra duties… A particularly clever company made up and collected some unreasonably high connection contributions for wind turbines” (Tranaes 1997).

DV (Danmarks Vindmølleforening-Danish Wind Turbine Owner's Association) appealed to the committee for electricity prices for the first two cases and won. In the last case, DV could not intervene, because it was considered an internal matter. ((Tranaes 1997).

But it didn't take much time until the power supply companies realized there was nothing else they could do to stop the wind turbines spreading. There had been continuous debates on the installation of wind turbines by the utility companies. The Danish decision not to use nuclear power was probably part of the reason for a contract in late 1985, between the Energy Ministry and the two biggest utilities on installing 100 MW of wind power in five years (Carlman 1988). The 100 MW goals were to be realized by two utility companies: Elsam and Elkraft. In the following, there is a figure showing the distribution of the turbines.

Figure 5.9 The Utility Program 1986-1990 of installing 100 MW wind turbine



Source: (Madsen 1988)

There were some conditions for this enlargement: it needed to be based on well-tested wind turbines already in commercial production, but at the same time the enlargement should encourage further development of existing turbines resulting in bigger wind turbines which were better adjusted for the electricity supply systems demands. At the same time as this 100 MW agreement was put into practice, limitations for private people establishing large scale wind turbines were introduced. Furthermore, it was a part of the agreement that the enlargement by the utility companies should not receive any subsidies from the Government neither on the construction nor the operational side (Madsen 1988).

DV played an important role in the public relations area, especially through the association's magazine, *"Natural Energy"* and this gradually led to a phase where politicians as well as the public opened their eyes to the fact that the electricity companies "used their self-appointed right of determination to carry through their own energy policy apart from government and parliament" (Tranaes 1997). Hard pressed by the political situation and fearing legislation, the DEF (Dansk El. Forbund) agreed to negotiate a national agreement about connection conditions and setting prices with DV (Danish Wind Turbine Owner's Association) and FDV (the Danish Wind Industry Association).

After long and tough negotiations, and under the direct threat of political intervention, the parties - DEF on one side and DV and FDV on the other - entered intoa 10 year agreement about conditions for grid connection and settlements. The main points of the agreement are shown below:

> The costs of connection to the grid should be shared, with 1/3 being covered by the state, 1/3 from the turbine owners and 1/3 from the power companies (when the State's support for wind turbine projects was dropped a short time later, the payment from the state disappeared, and after that the turbine owners paid 2/3 and the power stations 1/3).
>
> The price paid for the turbine electricity was at the rate of 85% of the electricity price paid by the larger power users (they paid a slightly lower price than the ordinary users), and at the rate of 70 % of this price to turbine owners with turbines in their own installation. (The reason for the lower price to individual turbine owners was that having your own turbine, you had a bigger chance of using your own electricity, and the utility was meant only to be available as purchaser of surplus electricity, but it had to be the supplier of total consumption, if the wind was not blowing). The 15 % reduction in price paid to the turbine guilds was payment for use of the public grid (Tranaes 1997).

A cooperation committee was formed between the three associations, and their activity went quite well on the whole. Not until now did uncertainty start to spread. DEF clearly expressed that when the agreement expired, the wind turbines would have to manage on market conditions. Many were nervous of going into new projects, when they did not know what would happen after 1994. When development almost came to a standstill, the energy minister stated: "The parties should negotiate a new agreement, which should remain in force right into the next century." The negotiations were protracted. The electricity companies demanded that the connection costs should be doubled and the settling prices reduced to a fixed, but lower, amount. DV and FDV were not quite pleased with the conditions, because this would meant that the development of wind power would come to a halt. Encouraged by the energy minister and others DEF stuck to their ideas - and DV and FDV on the other hand, broke off negotiations, because to the wind power people, it was everything or nothing (Tranaes 1997).

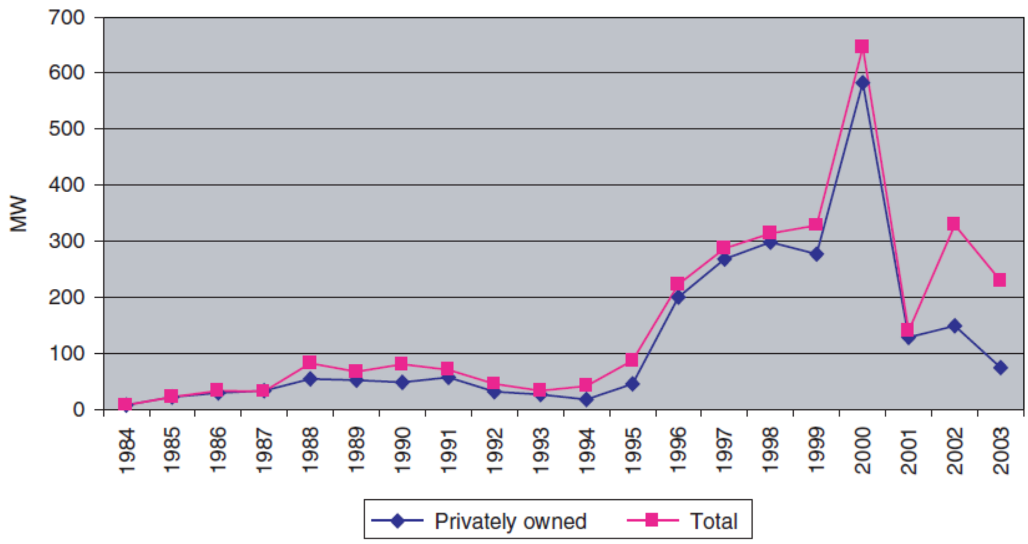
During some hectic political negotiations the agreement was replaced with the legislation. The energy minister was forced by the green majority to introduce a bill for wind turbines.

"In the future the power companies should pay all expenses for reinforcement of the grid in connection with the erection of wind turbines, whereas the expenses for the grid connection all the way to the public grid should be carried by the turbine owners ... In the future there should be only one tariff for electricity from wind turbines, i.e., 85 % of the price paid by the larger power users." The 70 % settlement disappeared. DV produced the proposal to let the electricity supply companies be responsible for and pay for the reinforcement of the grid, taking into consideration that this was the only solution, which could prevent eternal disagreement or negotiations.

In connection with the Law for Wind Turbines, something quite new in the Danish history of electricity was established: that the utilities are under an obligation in the future not only to distribute electricity, but also to collect electricity from decentralized power stations and renewable energy plants. This was as far as the electricity companies were forced to go, and has a dent in their political credibility. But they were frustrated and disappointed in the circle of power stations. At their general meeting in 1992, when the Bill has been passed, the chairman of the DEF said: "It has created certain bitterness in electricity companies' quarters that the collective electricity consumers still have to be punished economically for the wind turbines of the individualists!" (Tranaes 1997).

The official name of this law was the feed-in-tariff, introduced in 1992. Utility companies were against the tariff, because the price of the energy produced by wind power was more expensive than the energy produced by other resources (mainly gas and oil) and they had to buy the wind energy paying 85% of the price instead of the old 70%. The industry was disappointed, because the tariff of the wind energy was set lower which represented lower incomes for the energy producers. The result of this tariff can be read from the following figure.

Figure 5.10 Wind additional generating capacity



Source: (Danish Wind Industry Association 2002).

According to Figure 5.10 above, the additional generating wind capacity decreased from its pre feed-in levels (Agnolucci 2007). There are several reasons behind this trend.

The delay of the increase is believed to be due to the expectations on the stability of the policy. The law should have proven to be stable, because the government had a stake in both utilities and generators of wind power. On one hand, it wanted the generators to build more turbines so as to meet the targets in the energy plans; on the other hand it wanted the utilities to be financially healthy in delivering electricity to the customers. The fact was that the future of the feed-in law and therefore of the tariffs paid to the generators, was far from being certain.

According to Lauber, the hesitation of the utility companies to implement the new law created insecurity among potential investors (Agnolucci 2007, Lauber 2002 in). The expected result of the policy was delayed until 1995-1996, when the additional generating capacity multiplied. The change is believed to be due to the election of the new government in 1993, when the environmental and energy ministries were merged and a minister with "sympathetic views to renewable energies" was appointed (Lauber 2002 in Agnolucci 2007).

Others, like Christensen, have a different opinion about the delay of the expected results. According to them, the delay was due to the fact that the "tariffs initially did not live up to the expectations of windmill owners, as the retail electricity price, to which the tariffs were linked, did not rise as much as expected" (Christensen 2004 in Agnolucci 2007). He is doubtful about the fact that only this cofactor influenced investment decisions and the substantial decreases in the following years of the feed-in law, because the feed-in tariffs were in fact as high as the rates paid by utilities under the previous voluntary agreement[14].

A different opinion comes from Holst, who points out that the planning constraints which have been really challenging until the beginning of the 1990s. Then, a new planning regime mandated local governments to indicate zones for windmills and made the sites for erecting wind turbines much easier (Holst 2004 in, Agnolucci 2007).

The next energy plan arrived after the feed-in law was introduced in 1990 as "Energy 2000", as a response to the highly-debated problem of CO_2 emissions and the green house effect. At that time, Denmark was lagging behind in the CO_2 emissions level per capita. Only the US and Canada had higher emission levels than Denmark. This energy policy proposed to increase energy efficiency and local co- generation to 12-14% of the renewable energy share in the supply. The new plan also included a 20% reduction of CO_2 emissions in comparison to 1988 levels by 2005, and the introduction of CO_2 taxes (Inforce 2006). Figure 5.11 shows that during this 10 year period, the CO2 emissions declined more than 10% in comparison to the 1988 levels. So, half of the target was achieved in almost half the time. Still, in 1993, when the

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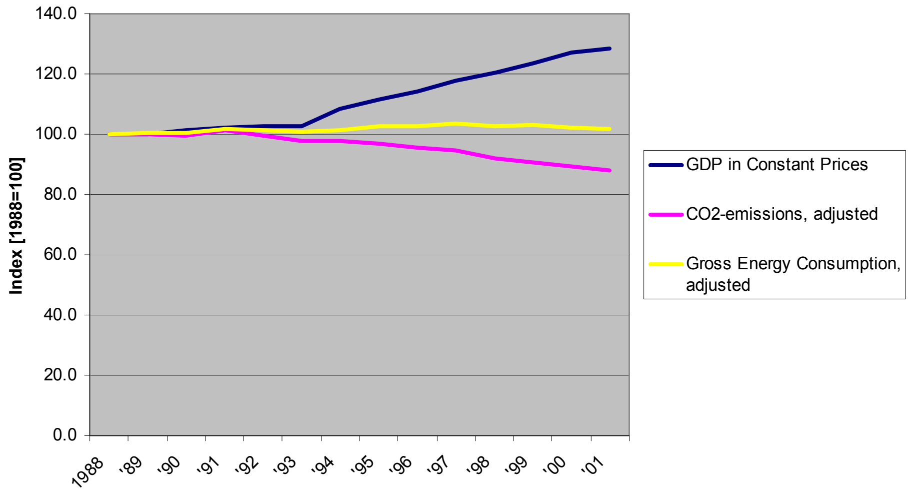
14 In the voluntary agreement wind generators received 70-85% of the retail electricity price while the tariff in the feed-in law corresponded to 85% of the retail electricity price.

government performed an analysis entitled the *"Follow up on Energy 2000",* it showed that the outlined targets would not be attained by several million tonnes by 2005. Therefore, they introduced reactionary measures to keep these targets in sight. The government introduced green taxes in all sectors of the economy and they agreed to increase the use of biomass-based energy production (Energy in Denmark: Development, Policies and Results).

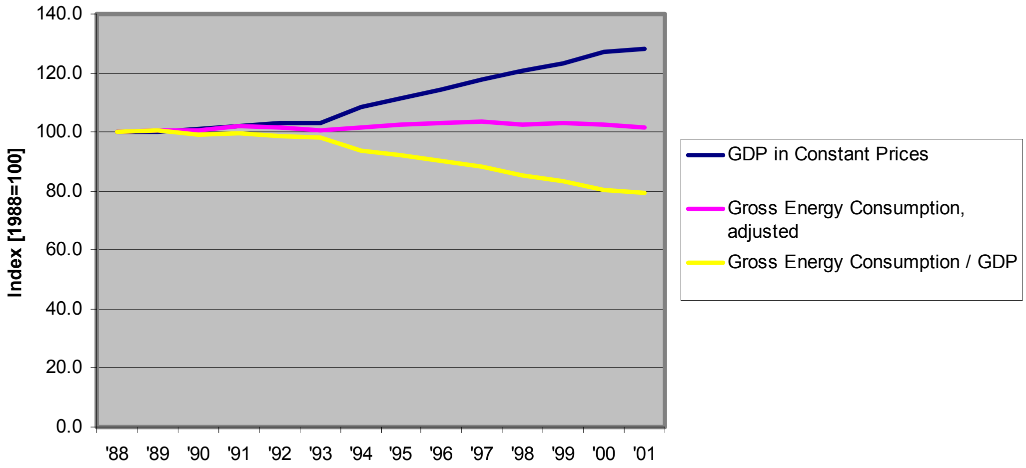
Figure 5.11 Development in GDP, CO_2 emissions and Gross Energy consumption



Source: (Danish Energy Agency 2008a)

According to this policy the transport sector, had a subordinate target to reduce its CO_2 emissions, while the other sectors had to reduce their CO_2 emissions by 25% by 2005 (Energy in Denmark: Development, Policies and Results). According to the same source, the main sources of CO_2 emissions were power plants and transport, accounting for 50%, and 20% of emissions respectively in 1994 (Energy in Denmark: Development, Policies and Results). This energy policy had the result of virtually stagnating the consumption of primary energy for 10 years despite the growing economy; oil consumption was reduced in the first few years of the 1990s and there was stagnation in the use of fossil fuels (Energy in Denmark: Development, Policies and Results). This is shown in the following two figures, where the pink line is assigned to the gross energy consumption, and is quite stagnant during the 10 year period.

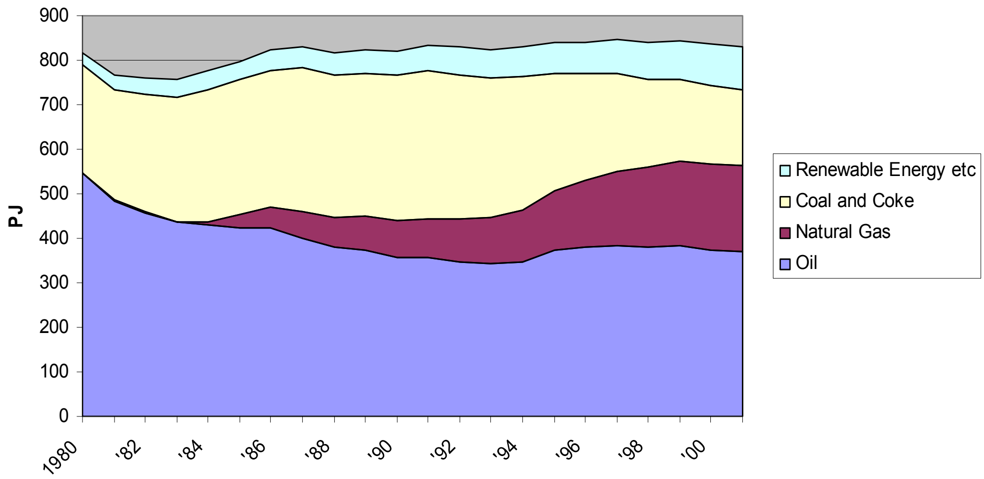
Figure 5.12 Gross Energy Consumption and Energy Intensity



Source: (Danish Energy Agency 2008a)

A further figure shows the same total energy consumption distributed by fuel type used in Denmark during the analyzed period.

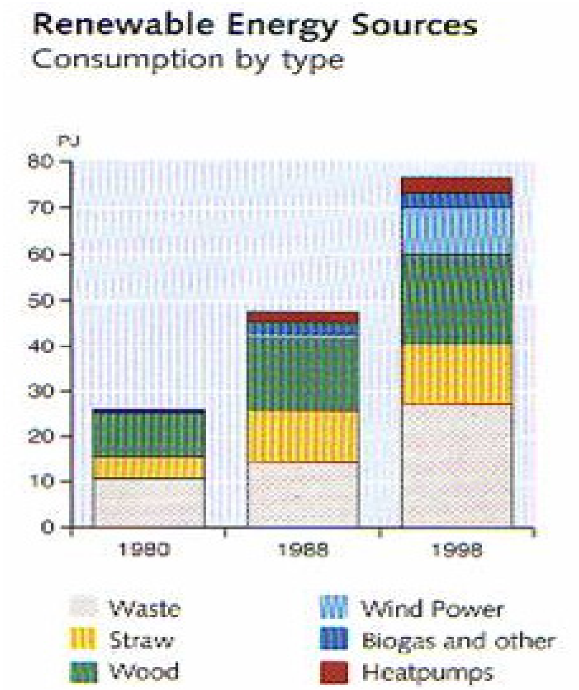
Figure 5.13 Gross Energy Consumption by Fuel Type



Source: (Danish Energy Agency 2008a)

Figure 5.13 shows the reduction of oil and other fossil fuels' consumption with the increase of the renewable energy share in the use of energy. A more detailed presentation of the different renewable energies, specifically the wind energy, is shown in the next figure, where it can be seen that in the 1980s wind energy hardly existed as an energy source, but 10 years after that, it had increased its share enormously.

Figure 5.14 Renewable Energy Sources – Consumption by type



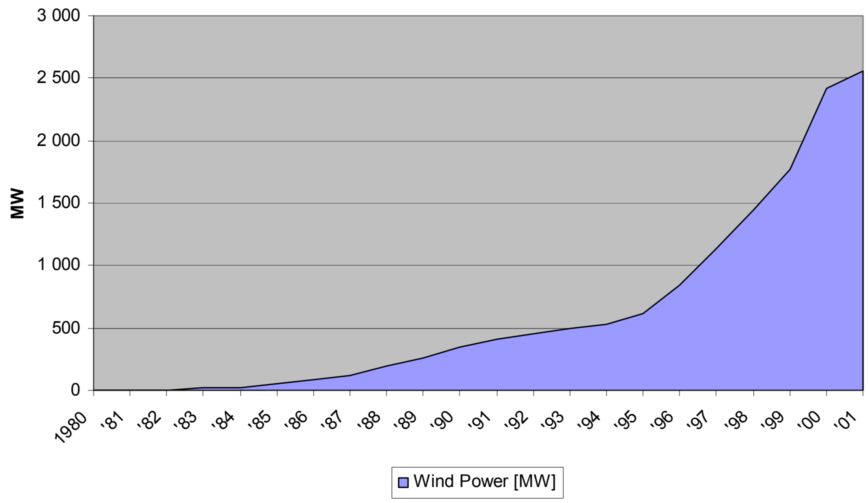
Source: (Energy in Denmark: Development, Policies and Results)

This energy policy (Energy 2000) became the first policy to establish the goal of sustainable development in the energy sector (Inforce 2006). The reduction of the emissions was planned to be done through the environmental friendly fuels, thus integrating the environmental issues into the energy policies.

This increase in the renewable energy consumption can be attributed to the fact that in 1995 a "Green Tax Package" was introduced for trade and industry. This was an effort to make energy consumption more efficient in this sector. These taxes came with an agreement scheme for those that were energy intensive, and were also recycled in the form of subsidies for energy saving and reductions in the taxation of labour. This made companies use more and more renewable energies in order to obtain economic advantages (Energy in Denmark: Development, Policies and Results).

In the same year (1995), new legislation was introduced, entitled "The Development Programme for Renewable Energy" (DPRE) consisting of two programmes: "Promotion of solar cell systems" and "Promote expansion of household wind turbines".

Figure 5.15 Wind Capacity



Source: (Danish Energy Agency 2008a)

Both initiatives used subsidies to encourage the development of the technologies using demonstration projects and small-scale installations. This made the development of the technologies much more economically viable (Energy in Denmark: Development, Policies and Results).

Another major plan that was inspired by the the1990s' situation was introduced in 1996 entitled "Energy 21". This policy contained also the previous targets, but new goals were defined. Its main purpose was to promote energy savings, the expansion of the combined heat and power systems (CHP), and the increase of renewable energy usage. The policy introduced new initiatives with respect to renewable energy, to try to facilitate the achievement of these targets. The three schemes that were used in order to reach the aim of the policy show that wind power energy managed to gain acceptance and accuracy during the years. The names of these schemes are as follows: "Land based view order", "Offshore wind order" and the "Renewable Energy Island Project". Offshore wind power was outlined to reach 1.500 MW capacities by 2005, which corresponds to a total production of 3.2 TWh annually. The first offshore turbine was installed in 1991, and by 2006 the installed capacity of the offshore wind turbines reached 423 MW powers, which was far from meeting the goal. This was equal to 4% of all installed turbines and 13% of the total wind power in Denmark at the time (Danish Wind Industry Association 2008c).

The government's opinion of this achievement was very positive. They stated that this policy instrument has been successful (Energy in Denmark: Development, Policies and Results). There is definitely no doubt of the success and increase in the wind power installed capacity. However, some might raise the question: was the target realistic set? Or it was something that Denmark could easily cope with? Another legislative instrument to aid renewable energy was the stopping construction of the coal-fired power plants, which increased the interest of the electricity sector in renewable energies.

The “Renewable Energy Island Project” selected Samsø Island as a place of realization in 1997; the whole project was subsidized in order to demonstrate economic/technical/organizational conversion of an entire community to 100% renewable energy supply by 2008 (Energy in Denmark: Development, Policies and Results).This plan was been achieved successfully and on time, which represented a colossal amount of work for the small community of Samsø Island (Energiakademiet 2007).

Overall, these were the Danish national energy policy plans and projects regarding wind power energy; the latter policy plans were internationally determined and applied by the Danish government with few adjustments. The fist such international policy plan was established in 1997, as the *Kyoto Protocol*, which represented an international step towards combating global warming. In the same year, the EU directive on the liberalization of the electricity market was implemented, and later another EU directive on the promotion of electricity from renewable energy sources in the internal electricity market was adopted. Therefore, Danish energy policy was shaped by these legislative measures in following years (Energy in Denmark: Development, Policies and Results). The Danish targets within the Kyoto agreement were the reduction of greenhouse gas emissions (GHG) by an average of 21% in comparison to the 1990 levels in the years 2008-2012. (CO_2 is the dominant GHG) Also, in the year 2000 it was found that CO_2 levels had fallen 11% compared to the 1988 level and, if the current path was continued, then targets would be met (Energy in Denmark: Development, Policies and Results). Unfortunately, according to the data available on the Danish Energy Authority website, this target could not be met; there was a half percent decrease by 2005 compared to the 2000 level, but later the CO_2 emissions increased instead of decreasing.

In 1998, the shares of renewable energies had not grown sufficiently to meet the targets because of the slow development in other sectors, such as biomass.

Therefore, in order to achieve the targets, the government increased energy tax rates. But at the time, the country could not focus only on meeting these targets because it was under pressure from the EU directives to liberalize the electricity market and establish the green certificate system (Energy in Denmark: Development, Policies and Results).

As a response to the EU directives, the Electricity Reform followed in 1999, which aimed to set up an internal green market. All Danish political parties agreed on this reform, and the government set out an obligation for the consumers, that 20% of their energy consumption had to come from renewable energy sources by 2003 (Energy in Denmark: Development, Policies and Results). This target was met eventually, but was postponed until 2005.

Consumer demand could represent a stable base for future energy consumption, building a secure market for renewable energy. This new energy act introduced a shift from the feed-in model to a special market for green certificates and to a combination with consumer quotas for green electricity (Carlson, Madsen 2007).

> Green Certificates are awarded to generation companies per MWh produced and then these can be sold on the green market. The certificate will exist only in electronic form in the green certificate register with information concerning the time of issue origin technology etc. The establishment of this market was expected to increase the share of renewable energy to approximately 27% in 2003 therefore already surpassing the targets set out previously (Energy in Denmark: Development, Policies and Results).

The EU approved the Green Market in 2000, the same year as the EU directive on the Promotion of Electricity from Renewable Energy Sources was published. This recognized that a market based on certification would help to harness renewable energy and increase its share (Energy in Denmark: Development, Policies and Results). According to the reform, certificates were to be introduced in January 2000. However, at the end of the previous year it became clear that preparations were not anywhere near completion. Therefore, the Energy Minister postponed it to January 2002 ((Danish Wind Industry Association 2008a in Agnolucci 2007). But the same story was repeated, and the final delay of the introduction of the green certificate system ended January 2003. In the meanwhile, the Environment and Energy Minister introduced a “premium-rate” (0.10 DKK/kWh) for the maximum length of 20 years. Beside this, a “scrap premium” (0.17 DKK/kWh) was also introduced, granting an extra rate for new onshore turbines built before 2004, with the clause that the owner had to replace an old and obsolete windmills with the new ones. Finally, in the latest amendment to the electricity supply act (not in force until 2005), the scrap premium was extended until 2009, although at a reduced rate (0.12 DKK/kWh) (Agnolucci 2007).

In 2000 the Danish government introduced "Climate 2012" energy plan, this being the first step towards a comprehensive climate strategy. The progress in 2000 was mainly due to political agreement on the implementation of the Biomass Agreement and also to offshore wind. The offshore wind farm order in this same year established a concrete basis for fixing the settlement prices making it possible for offshore to be as economically feasible as onshore wind. The main purpose of this policy is to form the basis for future decisions on climate change policies in Denmark. In order to do this, there was undertaken a study that predicts a deficit of 4.4% from the target for emissions reduction (Energy in Denmark: Development, Policies and Results).

5.2.3 Organizations

According to the theoretical approach, organizations are the actors of the economy that are governed by institutions and, at the same time, they influence institutions too. This subchapter discusses those important actors that took part both in the development and the obstruction of the Danish wind turbine industry. These actors can be grouped into different categories: individuals or private wind turbine owners, firms and organizations such as NGOs and different kind of associations.

In this respect, the first sub-period of the Danish wind turbine industry is lacking in actors that influenced the development of the industry. Chronologically, the first organization that contributed to the wind turbine development might be considered the Askov High School, where Pour la Cour was teaching and experimenting with wind mills. With the success of wind turbine production, as their numbers increased, the “co-operative wind mills” were formed. Later, private wind farms had the same organizational form as the co-operatives.

A group of families (fifty to several hundred individuals) invested capital in the wind farms, corresponding to their share of the power consumptions.

Therefore, the wind farms are consequently paid in cash on installation. The group of owners is jointly liable for the running costs of the wind farm, but, at the same time, they do have the income, which is considerably greater than the actual running costs. The running costs will normally amount to 14-16% of the income from selling the power). The owners make a contract among them on conditions such as change of ownership of shares, etc. The owners of the wind farm make a joint agreement with the utility company regarding the purchase of electricity. This co-operation between the utility companies and wind turbine owners takes place on a voluntary basis and without any national legislation. A few farms are organized as limited companies (Madsen 1988).

Table 5.2 Data on Danish Wind Farms from 1987

DANISH WINDFARMS Aug.87
Total installed: 16 MW
Number of turbines: 165 units
Keyfigures, operation 1986:
2.3 mill. kWh/MW, 730 kWh/m²

Source: (Madsen 1988)

Starting with the first energy plans, other organizations gained importance in the development of the wind power industry: Danish Academy of Technical Sciences (Akademiet for de tekniske Videnskaber) and Risø National Laboratory. The Academy launched the national wind energy programme in 1976; while in the same year a decision was made by the government to build a test centre for small windmills at the National Risø Laboratory. Two years later it was given the authority to start giving certificates for the windmills tested (Carlman 1988). Only those windmills which had approval from Risø were subsidized. This laboratory initially had an interest in nuclear energy also, but later it became wind power oriented. Today, Risø is the National Laboratory for Sustainable Energy at the Technical University of Denmark - DTU. Risø carries out scientific and technical-scientific research that can provide Danish society with new opportunities for technological development and takes responsibility for the way they are used. Their work is based on the idea that knowledge is the key to the development of an innovative and sustainable society, capable of facing global competition. Risø is engaged in large strategic research and development projects and quality research on an international level. They take initiatives and set targets for research through continuous dialogue with the business sector, the political system and the research community and their research is part of national and international networks. Their research can especially impact energy supply, energy consumption and health-related technology. Risø has large test facilities and interdisciplinary research environments that enable them to solve problems across traditional professional boundaries and competences. Training and education as well as innovative activities are naturally integrated with Risø's research activities. Their research is furthermore the basis of customer-driven activities including advice to the business community, institutions and authorities (Risoe National Laboratory 2008). So, they are like the centre of the knowledge generation network in the area of renewable energies.

In 1978 the Danish Wind Turbine Owner's Association, DV, (Danmarks Vindmølleforening) was formed, which was an association of the Danish Wind Turbine Owners. The year after its formation, a general meeting was held where the first chairman of the Association clearly expressed the ideology:

"Knowing that our energy stocks of coal, oil, gas and uranium are limited, we are surprised that since the first energy crisis in 1973 nothing really effective has been done to initiate relevant research and to sort out legislation related to renewable energy ... It puzzles me that the state energetically talks about and plans energy only related to coal, oil, gas and uranium. Only in passing remarks is the energy from the wind and sun mentioned, well knowing that the first mentioned energy sources are limited, whereas the wind and sun are inexhaustible. It also surprises me that the energy planners, when talking about coal, oil, gas and uranium, minimize the irreparable pollution connected to the use of these materials. I am thinking of the dangers in connection with carbon dioxide, sulphur, lead, and radiation. Is disaster necessary to open our eyes to the fact that these substances firstly are a health hazard, and that secondly their availability is very limited?" (Tranaes 1997).

This speech represented the essence of the goals they wanted to achieve. But before that, the turbine owners had to establish mutual interest in relation with the electricity boards, authorities and manufacturers and secondly, to do some serious research about the possibilities of wind power erection. Wind turbine owners had experienced difficulties with the authorities and electricity distribution companies, who tried to resist or showed a lack of interest towards the erection of wind turbines. At the same time, wind turbine owners had to establish relationships with the very few manufacturers of the time, in order to maintain the quality, service and warranty improvements and, after a while, the proper insurance contracts (Tranaes 1997). The way the Association kept in touch with the public and authorities (MPs working with energy issues and to the Ministry of Energy) was through the newspapers, with written contributions to editors on the subject and through publishing their own magazine, entitled *Natural Energy*, which disseminated all kinds of information about wind power. The magazine still has the same name and performs the same tasks (Tranaes 1997).

The next organization that was established was the first wind turbine Guild in 1980 near Århus, it and quickly proved to be a pioneer model for future development. Tranaes says that there is a historical explanation for the establishment of the Guilds. People's willingness to form a team is so strong, that it is enough to have 3 or 4 people with the same interests. The ideology behind this is related to the great Danish poet, author, historian, vicar, MP and social critic, NFS Grundtvig. According to his conception, "the point was to arouse their national consciousness and feeling of identity and through that to increase their confidence so that they were able to change their own conditions of life". It seems that this idea worked over the years, in terms of the fantastic evolution within the agricultural (and later, other) industries (Tranaes 1997).

A commercial revolution in the history of Denmark was the establishment of co-operatives in 1866, but only twelve years later did these became known worldwide. In time (1970s) many cooperative undertakings disappeared or were amalgamated into larger units and placed in provincial towns. Therefore, people from villages felt the lack of community spirit that has been formed through the cooperatives, "they missed something meaningful like being together with a common purpose. Here wind power filled the vacuum". In striving for renewable energy, and for a better environment, people needed to have community spirit, otherwise problems were too big (for economic and social reasons) to be solved by individuals (Tranaes 1997).

The cooperatives soon became partnerships in order to obtain the advantages of tax deductions of the loans that were taken out on the wind turbines. However, these guilds were comprised of grass roots activists, who worked hard to obtain the permission from the Danish Wind Power Station to erect turbines (Tranaes 1997).

Wind power stayed in the hands of three important organizations: the Wind Turbine Owners Association, the Parliament and the Public Authorities. The majority of the Danish Parliament supported the development of wind power; otherwise it could not have been done. Besides the environmental concern that they showed, other incentives were recognized that caused them to pursue to such actions: for instance, the potential for job creation and export possibilities. On the other hand, Public Authorities weren't as generous as the Parliament. For instance, the Woodland and Nature Administration of the Ministry of the Environment were only looking for their interest and threw obstacles in the way of wind power development. The same attitude Customs and Tax Administrations had, having severe rules to make it more difficult or even impossible the adjustment to wind turbines. County Councils and Borough Councils had the decisive word in the wind power planning process, but they determined politically whether the majority would support wind turbines or not. Finally, the highest authority to which citizens could appeal, the Nature Conservation Board safeguarded only animals' lives, and did not care about the wind power development (Tranaes 1997). Under such circumstances it was hard for Denmark to develop its wind power industry, but it succeeded in one way or another, never gave up, even though development was delayed.

The most decisive organization was developed because of the need to solve a problem related to the insurance of the wind turbines. Now it is possible to insure the wind turbines that have been purchased not only against damage and consequential losses, but also against the risk that the manufacturer goes bankrupt. It took a lot of time and effort (both physical and financial) on the part of the Danish Wind Turbine Owner's Association (which was called the Danish Wind Power Station before) to arrive at this point, where insurance can covers all kind of risks related to wind power. It was a continuous learning process for manufacturers, owners and insurance organizations, because wind power was a new and unknown phenomenon at the time. The best solution for the Danish Wind Turbine Owner's Association seemed to be the establishment of their own insurance organization. Although they had barriers to overcome, in 1991 “Denmark Wind Turbine Insurance” was established. According to Tranaes (1997) this move represented another important step in the development of wind turbines. So the solution to the problem created a new organization, which spun off from the DV. Some points of DV's activity have been discussed in relation to the insurance of the wind turbines. However, there are other areas where DV is present. Its main purpose is to take care of the wind turbine owners' mutual interests regarding authorities, political decision-makers, utilities and wind turbine manufacturers. It also creates possibilities for its members to come together with representatives of the above mentioned parties, in order to debate and share knowledge on present issues (Carlson, Madsen 2007, Danmarks Vindmølleforening 2003 in).

Throughout the years, the economically independent organizations, NGOs played a major role in the development of the wind turbine industry. The link they had with the Parliament was strong because the NGOs spent a lot of time spreading both their opinions and facts to the public and to politicians, writing open letters and participating in public discussions. A few NGOs were also members of public committees and, through them, their viewpoints were expressed (Carlson, Madsen 2007).

Some of the NGOs that were and are still involved in the development of renewable energies are: Anti Nuclear Movement (Organisation til Oplysning om atomkraft, OOA); Organization for Renewable Energy (Organisationen for vervarende energi, OVE); The Energy- and Environmental Office (Energi- og Miljkontoret, SEK); The Nordic Renewable Energy Center for People (Nordisk Folkecenter for Vervarende Energi, FC) and last but not least, the Danish Wind Turbine Owner's Association (Danmarks' Vindmolleforegning, DV), which has been already presented.

The OOA's main goal was to stop the construction of nuclear power plants in Denmark, and to shut down the one in Sweden, which was very close to Copenhagen (20km). The ultimate goal was achieved in 2005 and since then the organization stopped its activity as a grassroots organization (OOA 1994).

OVE has been active since 1975, with the purpose obtaining an energy supply based on renewable energy sources. The Copenhagen group of this organization took credit for its achievements during the years. This group was focused on lobbying by cooperating with scientists in publishing the alternative energy plans and suggesting different ways of supporting the expansion of the use of renewable energy. This organization is continuously changing its goals according to the needs. Therefore, besides the objective mentioned before, they were focused on energy savings too. Later, the group's goal changed into a longer-term objective, saying that the energy must be supplied 100% through renewable energy by the year 2030 (OVE 2008).

SEK is the umbrella body for the local energy and environmental associations. In contrast to the other organizations (eg. OVE), SEK has the purpose of representing the common interests of local associations promoting the change to an energy supply based on renewable energy, energy savings and the transition to a sustainable society (Carlson, Madsen 2007).

Danish Wind Industry Association (FDV or DWIA) is another non-profit association whose purpose is to promote wind energy at home and abroad. The association was founded in 1981. DWIA today represents 99.9% of Danish wind turbine manufacturing measured in MW and more than 180 companies with activities in the Danish wind industry (Danish Wind Industry Association 2008b). The association publishes information about wind energy and they are engaged in advocacy too. With its work, the association (along with the DV) has contributed to the development of the wind turbine industry. But the most effective means are that the DV started to use very early and which contributed decisively to better conditions was simply information. Each month *Naturlig Energi* had a list of all turbines with an indication of what they produced, and which technical problems there had been. This definitely had a positive effect on development. The turbine owners themselves then had the opportunity to explain how well or how badly their turbines performed. The manufacturers discovered that their own turbines quickly became either a good or a bad advertisement for their business. The statistics of production helped to remove the turbine sales people, who promised people wonders without the background of a good product placed on a good windy site. In the process of development the statistics also showed the importance of good placing. Future turbine owners were not less important - in the statistics they could find the information necessary to make the decision of which turbine they may want to buy. The public obtained serious information about the potential of wind power. To a high degree, this contributed to exploding many of the myths about how little energy there was to obtain from wind turbines. Also, statistics clearly reflected the developments, which took place in purely technical areas. The statistics continued through the years and now appear monthly from over 2.400 wind turbines. Ignoring the trifles and a few rough patches, the co-operation between the manufacturers and wind turbine owners is definitely one of the good stories about wind power (Tranaes 1997).

Utility companies, as an organization in the development of the wind turbine industry, do not have a positive image throughout the history. Over the years, they have been on the opposite side of the debate. In terms of the fact that they analyzed wind power only from the point of view of its profitability and did not take into consideration the environmental benefits of it. Therefore, the new legislation seemed to them to be a punishment and they were determined to fight for their rights despite the established legislation. They reacted very late to the implementation of new technologies and tried to obstruct the developmental process (Tranaes 1997). To live with the author's words: “power companies are deeply involved in politics... they are energy merchants”. Their duty is to provide the safest possible supply of electricity at the cheapest possible price. This only requires that the political system is aware of this and gives a clear definition of the limits within which the electricity supply can function. In this way the electricity suppliers ought to have instructions to carry through energy saving campaigns, to build wind turbines and arrange for proper connection conditions for wind turbines. It has taken quite some time for this attitude to penetrate the political system (Tranaes 1997).

5.2.4 Industry analysis

In this project, the main purpose is to analyze the Danish wind power industry from a comparative perspective of the main driving forces of competitiveness over a long period of time. Therefore, the focus is on supplier power, consumer power, substitute products and entry/exit barriers, which all contribute to the rivalry of the industry.

5.2.4.1 Supply power

A supplier group is powerful if they are more concentrated than the industry they sell to, or if the customer group is not important for the suppliers; or if the product is an important input to the buyer's business, or they have built up switching costs; or the supplier group poses a threat of forward integration (Porter 1998). All these factors will be related to the Danish wind turbine and wind power industry in the following in order to decide the magnitude of supplier power within this industry.

In the beginning of the 1980s when wind power was supported by the population and the government was also behind its development, the industry grew to a significant level, with 20 different companies producing turbines, and most of these had past experience as producers of farming machinery. The 1980s was the decade where the market for wind power in California exploded. A few years later the market collapsed, because subsidies in California had been removed. This was tough on Danish businesses and several companies went bankrupt. In the 1990s many of the companies were up and running again thanks to the Danish market. More than 3000 wind turbines had been built due to joint ownership with approximately 20-40 owners each. Through this method there were between 100.000 and 150.000 wind turbine owners in Denmark, and they were members of wind turbine guilds (Hvelplund 2005 in Carlson, Madsen 2007). Today a lot of the guilds do not exist any longer, because many of the smaller wind turbines have been taken down and replaced with larger and more expensive wind turbines (Carlson, Madsen 2007).

Due to this fact, by the end of this first period and even today, there are two large companies producing wind turbines in Denmark: Vestas Wind Systems and Siemens Wind Power, who are also some of the largest producers worldwide (Carlson, Madsen 2007). Therefore, the supply side of the industry has become very **concentrated** from the initial state in 1980.

Another factor that determines the supplier power is product differentiation and switching costs that are applied when switching from one product to another. In this respect, the two global companies from Denmark build very similar wind turbines, because of strong standard requirements. Therefore, the clients do not have this incentive to choose one over the other. The decisive factor for customers can be the price or other market elements that they consider to be important. Switching costs are also low due to the similarities between the two wind turbines. Since the wind turbine models are so standardized, the input products must be also very similar, if not the same. Therefore, it does not make any difference in the supply power. However, the last important factor represents the threat of forward integration, which means that the suppliers set up subsidiaries that distribute products to customers or use the products themselves. Both companies (Siemens and Vestas) have development, manufacturing, sales, marketing and maintenance of wind power systems that use wind energy to produce electricity, among their core activities. Their suppliers are from all over the world and are in many different industries. Therefore, they have already integrated forward.

Overall, taking into consideration that these two companies supply the final products and services for the wind turbine industry in Denmark, they have a lot of power in their hands.

The above forces that determine supplier power are the same for the next periods too, so it will not be repeated. The focus will now be on the **installed wind power capacity, the export of wind turbines and the wind power share in the electricity production/consumption.**

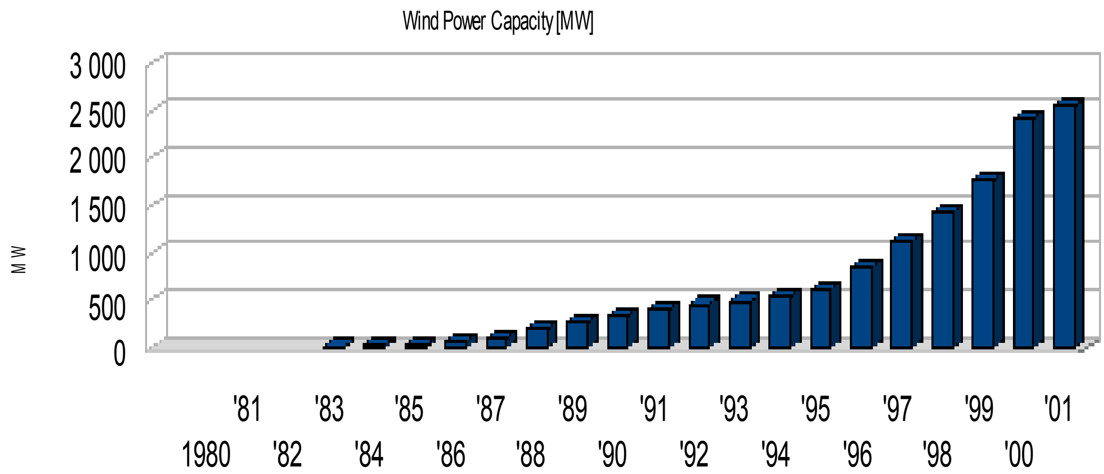
Different legislation (that came into force in 1995) shifted the industry structure from the well-known joint ownership wind turbines to individual wind turbine ownership. This was because many of the areas dedicated for wind turbines were part farm land, and, according to the current legislation, ownership of an entire wind turbine was only possible if you owned the land and lived in a building on it. Many farmers saw this as an opportunity to have their own wind turbines built. These ownership limitations have since then been abolished (Danish Wind Turbine Owners' Association 2002 in Carlson, Madsen 2007).

By the end of the nineties, when new policies were introduced in connection with the liberalization of the European energy markets, electricity consumption Denmark reached a high level and it developed very quickly until 2001. At the time, wind power covered around 14% of Danish electricity consumption, and had increased to almost 19% in 2004 (Meyer 2005 in Carlson, Madsen 2007).

Fig. 5.16 shows the total wind power capacity up to 2001 and that there was a definite increase over the years. In some periods (1983-1986; 1992-1995) there was stagnation in the installed wind capacity.

There is no graphical representation about wind turbine exports, but from the literature about the wind turbine history it can be concluded, that more than half of production was exported, mainly to California.

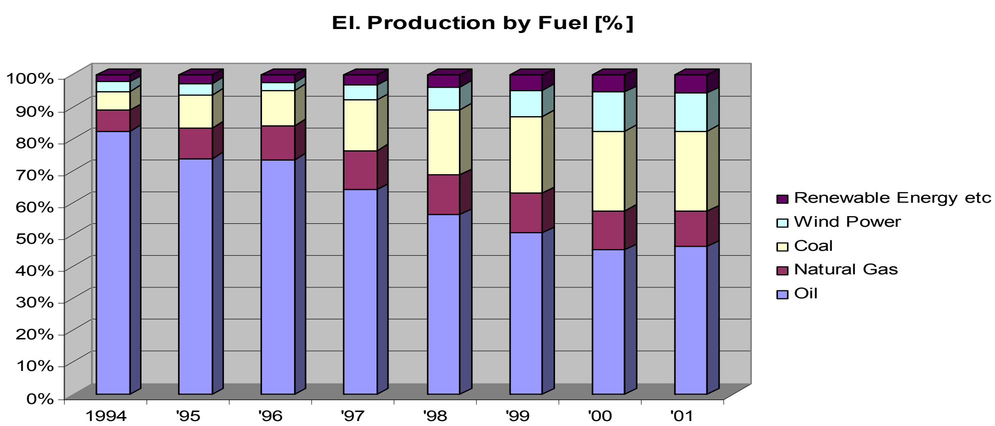
Figure 5.16 Wind power capacity



Data source: (Danish Wind Industry Association 2008a)

The last indicator that will be used as a tool for comparing the different periods is presented in the following figure and it shows the share of wind power in the electricity production. The highest share was reached in 2000, with 12% for wind power, which one year later dropped by almost 1% (for a precise representation, see Figure A in the Appendix).

Figure 5.17 The share of different fuels in the electricity production



Source: (Danish Energy Agency 2008a)

If the growing tendency that has been observed over the years keeps going at the same pace for wind turbine as well other renewable energy sources, it would be possible to meet the 20% share of the renewable energy in electricity production by 2003.

So, it can be concluded that wind turbine supply makes a concentrated share of the industry, but in terms of installed wind power capacity, although there has been continuous development, it needs to be improved further and the capacity increased.

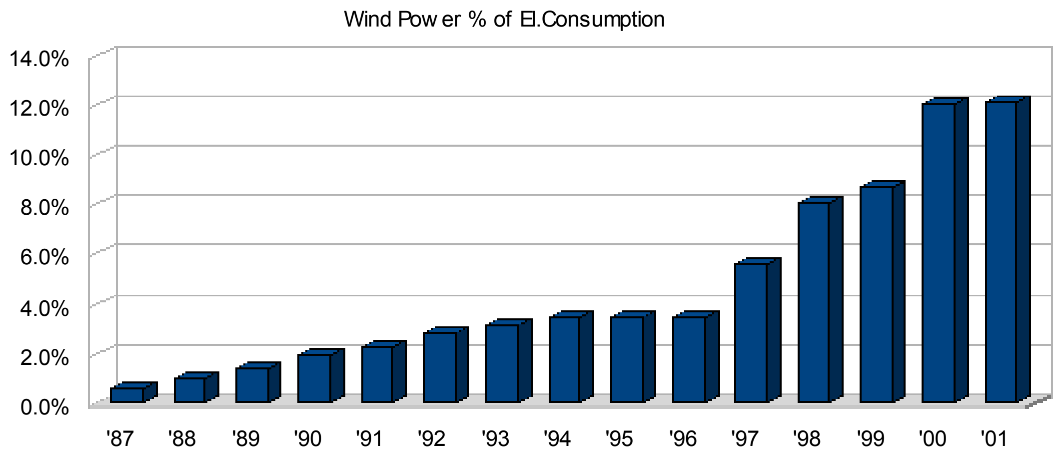
5.2.4.2 Consumer power

As it seems from daily business life, buyers represent the most important element of the market. Satisfying buyer needs is indeed a prerequisite for the viability of an industry and the firms within it. Buyers must be willing to pay a price for a product that exceeds its cost of production, or an industry will not survive in the long run. Satisfying buyer needs may be a prerequisite for industry profitability, but in itself it is not sufficient. The crucial question in determining profitability is whether firms can capture the value they create for buyers, or whether this value is competed away to others (Porter 1998). This part of the analysis will assess the buyer power within the wind turbine and wind power energy industry.

In the beginning of the 1970s, demand was present in the form of a curious hobby of a few educated people, who started experimenting with windmills. Later, when the first oil crisis began in 1973, the demand for wind power and other renewable energies started to increase. The second oil crisis in 1979 has increased this tendency toward wind power development. Since then, there has been a growing tendency in the demand, which came, on one hand, from the population's willingness to produce clean energy through wind power and to reduce their oil dependency; and on the other hand there were incentives from the state that generated demand. Demand for wind energy was provoked by negative incentives, such as taxes on energy, which first were introduced in Denmark in 1977, when a tax of 2 øre was added to the price per kWh. Later on, the taxes increased on a regular basis, and the price of oil tripled. These negative incentives generated the desire for “free energy”. Beneficial incentives were introduced in 1979 by the Danish state. The first subsidies, covered 30% of the expense of buying a wind turbine (in Carlson, Madsen 2007), and then another law boosted the demand towards erecting wind turbines and installing other renewable energies. Until 2001 it was possible to get these subsidies, but, with the new government they were phased out over the next year. Today, subsidies are limited to some supplements for the payment for the electricity to the producer (Energitjenesten 2007 in Carlson, Madsen 2007).

In the meanwhile, the state introduced more and more taxes on energy, on emissions of toxic gases and on environmentally unfriendly actions. For instance, taxes on CO_2 were introduced in 1992 for private households and the corporate world. Besides this, the taxes on energy were changed so that CO_2 subsidies would be given for the production of environmentally friendly electricity – mostly wind power. Of course this was very pleasing to the wind turbine industry. (Energitjenesten 2007 in Carlson, Madsen 2007).

Figure 5.18 The share of wind power in the total electricity consumption



Data source: (Danish Energy Agency 2008a)

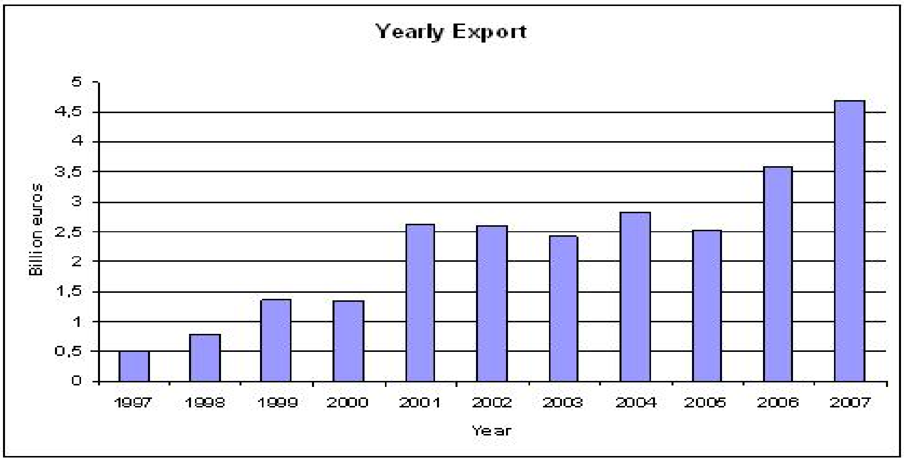
The 1999Electricity Reform's goal was to set up an internal green market. Part of the agreement was the obligation of consumers to ensure that the goal would be met, thus forming a stable demand for renewable energy and stimulating its growth. The goal was to meet the 20% share of electricity consumption by all renewable energies in use by 2003. According to the above figure, wind power achieved a 12% share by 2001.

So, the wind power demand was influenced by the incentives defined through different governmental programmes and energy plans. The important thing is that demand has been created in the end.

In order to draw conclusions on wind turbine demand we need to assess some factors that define buyer power. Buyer volume defines the concentration of demand, which is also influenced by the information that buyers receive. A buyer group is powerful if they are concentrated, or they purchase large volumes of products relative to the sales of the dealer. In this case, the dealer has no protection from the buyers. Also, when a buyer has greater information about market prices, demand, costs of the suppliers and about the products in general, this usually yields the buyer greater bargaining leverage than when information is poor (Porter 1998).

Danish demand is represented by the utility companies, and retrospectively thinking, the wind turbine owners represented a demand before they bought the turbines, although now they are suppliers of the wind energy, but there is also an external demand which is hard to identify since the industry has achieved global dimensions. Data on export could give some insight into the external demand. The external demand was significantly higher in the second sub-period; half of the Californian installed capacity was supplied by Danish manufacturers (Gipe 1991). The newest report on Danish wind turbines export contains data on the next part of the analyzed period. The following figure shows the yearly exports for a 10 year period.

Figure 5.19 Danish wind industries yearly export



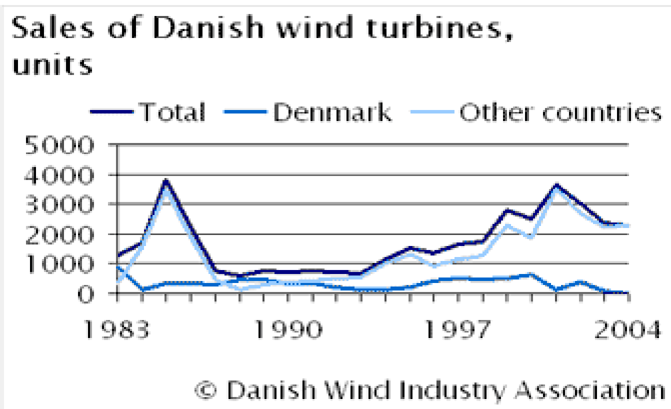
Source: (Danish Wind Industry Association 2007)

Until 2001, the Danish wind turbine manufacturers managed to increase their global market share to 50%. Germany and the US were the major consumer markets for Danish manufacturers, but Spain, Italy and Japan represented an impressive share in the purchase of turbines (Danish Wind Industry Association 2002).

DV had a membership of 2.150 wind turbines in 1996. The turbine guilds had 54.844 members (Tranaes 1997). According to newer data, the current number of members is about 6.000 (2006), which consists of single wind turbine owners and co-operatives, as well as people simply interested in wind energy. The membership of the co-operatives means that Danish Wind Turbine Owners' Association actually represents about 60.000 members (Danish Wind Turbine Owners' Association 2008). The share of membership calculated per population is around 1.2%. It is hard to determine if this number is high or low. However, the strength they have carried through the years seemed to be more decisive for the industry. Together, as a group with same goals, they managed to create strong buyer power in the Danish wind turbine industry.

In terms of wind turbine sales units, the following graph shows the development for a twenty year period. The number of wind turbines produced reached the second largest number in the history of the Danish industry, 2.814 machines. (In 1985, 3.812 machines were sold, but these machines were small, with a total generating power of only one tenth of the modern machines). 17% of the turbines were sold on the Danish market in 1999 (DWIA 2000). As the figure shows, sales in Denmark have always been very low compared to other countries (eg. Germany, US); between 1997 and 2000 a little bit of an increase can be seen (in 2000 566 MW), but in 2001 it dropped to 77 MW (See Figure 5.20)[15].

Figure 5.20 Sales of Danish wind turbines



Source: (Danish Wind Industry Association 2009c)

Sales to other countries have increased much faster since 1992, ensuring the development and sustenance of the industry. The growth in 1999 was partly caused by

[15] Nordex no longer manufactures wind turbines in Denmark and is no longer included in the statistics. This explains the decline in 2003.

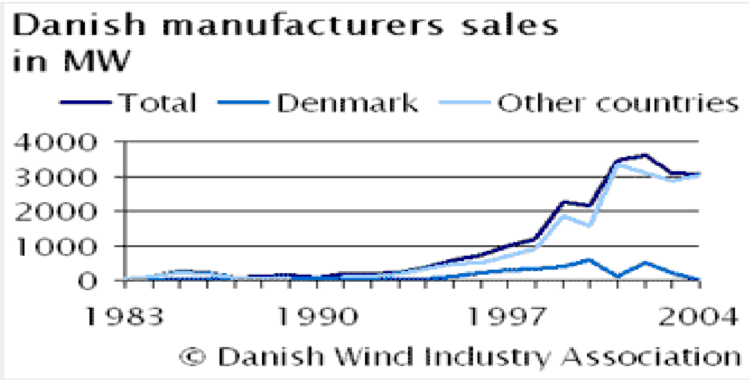
a boom in the US market due to the temporary lapse of the federal production tax credit (PTC) for renewable energies, which caused a buying spree before its end (DWIA 2000).

The development in wind power energy technology means that the average capacity of wind turbines rises every year. This development means that the sold capacity is divided by fewer wind turbines and therefore the sales in MW remained the same in 2004 even though the sales of units declined. The sales in megawatts of rated power are a much better measure of production than the number of wind turbines produced, since wind turbine sizes grew very quickly during this period. The wind turbines generators' sizes in megawatts are measures of the maximum power production capacity of wind turbines (energy production per unit of time) (Danish Wind Industry Association 2009c).

The Danish wind turbine industry (including foreign subsidiaries) sold 2.241 MW in 1999 compared to 1.216 MW the year before.http://www.aut.ac.ir/departments/elec/downloads/Wind/en/news/stat1999.htm - 1 Manufacturing increased six-fold over the course of five years, corresponding to an annual growth rate of 44% per year. The Danish Wind Turbine Manufacturers Association expected a growth in industrial activity of some 10% in the year 2000, and slightly stronger growth in 2001. However, the Danish market crashed completely, and not a single turbine was contracted in 2000 for delivery in Denmark in either 2000 or 2001 (DWIA 2000). This was due to the fact that there were no EU-approved payment regulations for electricity from new wind turbines in Denmark. EU Commission approval might have been given by 1 January 2001 at the earliest, but there were neither any regulations for - nor any usable analysis of - the future (green certificate) payments system for wind energy in Denmark. Under these circumstances no financing was available for investing in wind energy in Denmark. In connection with this it was immaterial that the Government had recently revised its ownership rules for wind turbines and removed the discrimination against owners outside the local municipalities, since there were only buyers for shares in wind turbines which were contracted in 1999 (DWIA 2000).

In the following figure there is a representation of the Danish sales in megawatt capacities. Comparing the two figures, the technological development in the size of turbines can be easily observed.

Figure 5.21 Danish manufacturers' sales [MW]



Source: (Danish Wind Industry Association 2009b)

Danish manufacturers had a world market share of approximately 40% in 2004. The sale in 2004 brings the total wind turbine capacity in Denmark to approximately 3.100 MW.

Other factors, such as price sensitivity, play an important role in defining buyer's power. Since investments in wind turbines represent a major part of the buyer's costs or purchases, this industry is very price sensitive. At the beginning of the analyzed period, the turbines were very inefficient. Therefore, the manufacturing costs were high, and this fact resulted in multiple resignations from the majority of people. Over time the technology was improved, and therefore turbines became cheaper, but still they needed serious investment. The price sensitivity influences the buyer's power quite strongly. In terms of wind power, the oil crises and the increase in prices of the substitute alternative energies influenced the buyer's power as well. People were more and more willing to adopt wind power energy, which was producing free energy in the case of individual wind turbines, or the ones connected to the grid produced electricity at reasonable price. Therefore many people were supportive of wind turbine developments.

The last factor that has relevance within this discussion is the threat of backward integration. Buyer power increases with the increase of the likelihood of their backward integration, which means that buyers decide to set up production units to supply themselves with the components or items needed. This is not that obvious in the case of buyers compared to suppliers. Buyers have an organization behind their interest, which keeps a strong relationship with the wind turbine manufacturers in order to insure buyers from major risks when investing in wind turbines. The organization has also the power to influence governmental decisions in the favour of wind turbine owners. Therefore, strong buyer power can be assumed in the Danish wind turbine and wind power energy industry.

An observation could be made related to the competitiveness of the industry. In 2001, government subsidies stopped and this resulted in a fall in the installed wind capacity in Denmark. However, the industry could survive this drop, because as the export figure shows, in 2001 the exports almost doubled their share.

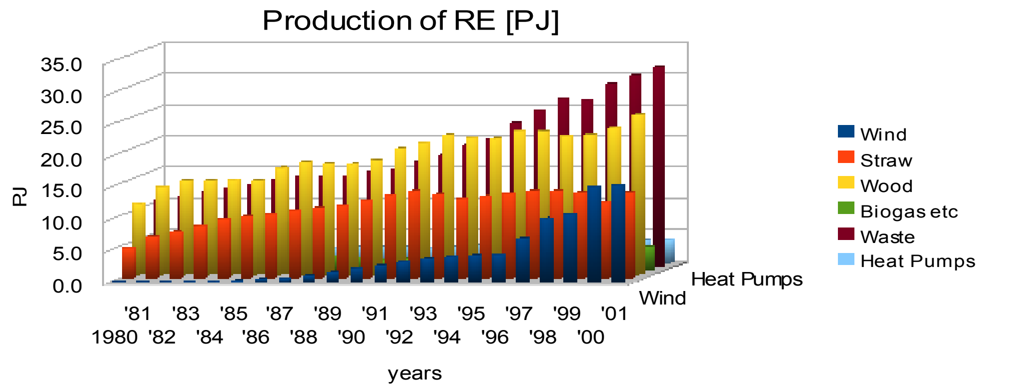
The Danish Wind Turbine Manufacturers Association had foreseen that the Danish market would be taken over by developers and institutional investors in the future. This was due to new extremely complex financing models for wind turbines with futures contracts, financial options and performance bonds. These forms of advanced financial engineering would be necessary in order to make the new green market for electricity from renewable energies operational. This would be the most complex support scheme for renewable energies in the world. The industry believed that there would be large transaction costs and a lack of transparency for small investors, so that the economies of scale for international investors would gradually erode local ownership of wind turbines in Denmark (DWIA 2000). This would represent a “social failure” in the wind turbine industry. Social cohesion would be reduced by the different types of ownership of different cultures; therefore, the strength of demand formed during the years could disappear totally. The Danish wind turbine industry would lose the unique characteristic that had been formed and “polished” through such a long history.

5.2.4.3 Substitutes

The threat of substitutes determines the extent to which another product can meet the same buyer’s needs, and thus places a ceiling on the amount a buyer is willing to pay for an industry's product (Porter 1998).

Substitutes in this case are the common non-renewable energy sources, such as: oil and natural gas (and coal in the beginning of the analyzed period); the other types of renewable sources: solar, waste, biomass (straw, wood, biogas), and heat pumps. The following figure presents the production of these renewable energies that threatens the wind power industry. As can be seen from the figure below, the waste power dominates the renewable energy production, followed by different types of biomass (wood and straw) and only then by wind power.

Figure 5.22 Production of different renewable energy types

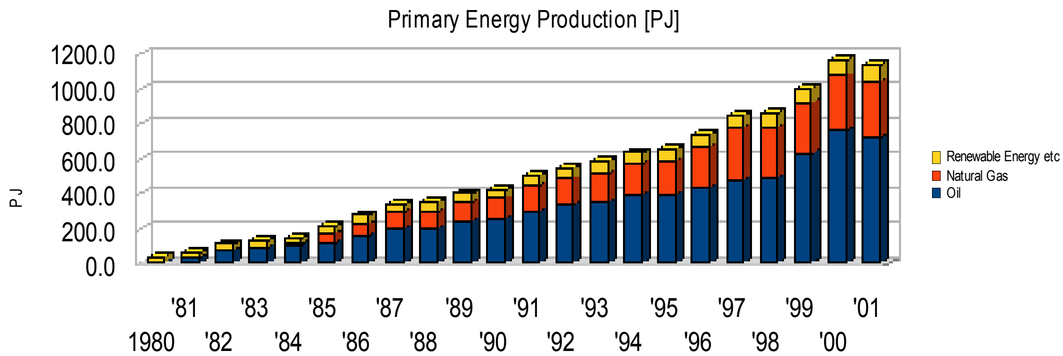


Data source: (Danish Energy Agency 2008a)

The factors influencing substitutes are the following: price elasticity, switching costs, buyer inclination to substitutes and price performance. We have talked about all these factors in previous parts of this project, so there is no need to repeat them.

As the following figure shows, the oil dominates the primary energy sources together with natural gas, and only a small share is taken up by renewable energies.

Figure 5.23 Primary energy production by fuel types



Data source: (Danish Energy Agency 2008a)

Unfortunately, in terms of prices, the production of non-renewable primary energy sources is cheaper than that of renewable energies, and therefore it is an important decisive factor when choosing between the two, especially on big scale. Consumption of energy is increasing year by year due to the increase in population, the increase of the technical products that function with energy, and, last but not least, changes in the lifestyle demands more and more energy consumption (for instance the individualistic lifestyle, divorced couples). The reserves are not big enough in the long-term to supply all of the consumption. So the question is not about substituting oil and gas with renewable energies, but to develop the most efficient renewable energies according to the geographical positioning of countries and the historical roots of the energy sources.

As a conclusion, in Denmark, although there is a strong wind power culture and a long-lasting wind turbine history, this type of renewable energy needs to compete with the waste and biomass energy sources. It will be able to overcome the advantage that the previous energy types have achieved only through technological innovations that will make wind turbines more efficient and therefore more accessible.

5.2.4.4 Entry / Exit barriers

The last factors that influence the competitiveness of an industry the short and medium term are the barriers that firms within or outside the industry have to overcome both at exit- and entry phases. The first factor that represents a major barrier is the government. Through laws and regulations, the government can influence the development of the wind power industry in both directions: to enhance development or to obstruct it. Fortunately, in Denmark during the analyzed period there was a continuous debate on wind turbines with quite strong parties that could fight against opposition. (The debate was mostly between the utility companies and DV). In the following, there will be a representation of the various criteria that were brought against wind turbines.

The first criteria pertain to consumption, ownership and residency. In the late 1970s when the development started, it was possible to erect turbines as big as you wanted to or were able to. The only limitation was that all members of the guild should live within the same electricity supply area - all members had to live within a distance of no more than 3km from the turbine. This was called “the criterion of residence“. The idea was - according to the theory - that if anyone in the local area suffered any inconvenience, they should also be the ones having the advantages. But this criterion created a disadvantage for the people living in cities (Tranaes 1997).

In the middle of the 1980s the rule was adapted so that guild members should be living within the same borough in an area of maximum 10 km away (there are from 3-4 to 15-20 boroughs in an area of electricity supply). At the same time a consumption criterion was introduced. Every guild member could only have shares in the wind turbine production corresponding to his own consumption + 35%; however, always with a minimum of 6.000 kWh. This was introduced after pressure from the power utilities, which wanted to prevent individual, often well-off people, from buying big wind turbines and becoming private electricity producers. The power station people wanted central management of the electricity production and were against the public support of the wind turbines. DV could accept the principle representing individual persons and guilds, who want to make their own electricity, free from pollution.

In principle DV could accept the criterion of residence as well as the criterion of consumption; they just found these criteria too narrow. Therefore, they have started to work politically in order to have them modified. This was partly achieved in connection with the new Law for Wind Turbines, which was passed in 1992. Here the criterion of residence was extended so that guild members could live in the same borough or in the neighbouring borough. This was a good thing. It meant that guild members could be collected from 3-5 boroughs. In the Law for Wind Turbines the criterion of consumption was also extended so that you could subscribe for electricity from a turbine corresponding to your own consumption + 50% and always 9.000 kWh, irrespective of consumption (Tranaes 1997). Later on, in 1996 new regulations came into force related to the consumption criteria: every person was allowed to have shares in a wind turbine corresponding to 30.000 kWh, and that there would be some slackening in the criterion of residence. The result was that a person, who worked in a firm or owned a house or real estate in a borough, had the right to take part in a wind turbine project there, even if he lived elsewhere (Tranaes 1997). Later, the rules of ownership changed; saying that the owners could buy a share corresponding to the power consumption of their own household (Madsen 1988).

Although the tendency started to show a clear path towards the wind turbine development, the resistance had not diminished over the years, and a new effective weapon against the wind turbines was introduced: planning presented major problems. The end of 1970s there were major debates in terms of planning and positioning wind turbines (Madsen 1988). The good windy sites were very often in conflict with landscape protection and preservation rules. For instance, when the utility companies were preparing installations of wind farms, they were very often facing considerable opposition, often from groups who generally were identified themselves with the idea of producing electricity from local resources and without pollution. Today the problem is so large that it has directly been a part of the delay in the enlargement of the utilities' wind power programme.

In the planning process in the past, everybody, who might have had anything against wind turbines (nature conservation people, ornithologists, sportsmen like hunters and anglers etc.) was invited, they all pointed out areas where they felt that there should have been no wind turbines. The Woodland and Nature Administration demanded a free zone of 3 km from all coastlines. (Denmark has a 7.000 km coastline, which will have the effect of deducting 21.000 square kilometres from the total area of Denmark of 44.000 square kilometres). In addition to that towns, woodlands, lakes and preservation areas need to be deducted, so, it is obvious for everyone that there will not be many areas left, where you can put up wind turbines (Tranaes 1997).

At present the Danish Countries are establishing an appendix to the existing Regional plans allocating more space for the enlargement of wind farms. This was done by taking into account the overall planning, which has to consider a number of different interests such as: Secure Areas, Areas with an exceptional landscape beauty (RAMSA-Convention), bird sanctuaries, military reservations, agricultural land, raw material interest, telecommunication lines, and areas reserved as open space etc. The only element which is not a part of the Counties Regional Planning is the overall Energy policy aim of obtaining sites for wind power corresponding to 10% of total consumption. Furthermore there has already been a comprehensive examination of the possibilities of sites for wind power in Denmark. This examination (which was carried out by the National Agency of Physical Planning under the Ministry of Environment) concluded that it was possible to pick out sites for 2000 1MW wind turbines in Denmark which would supply 10% of the electrical consumption in the year 2000 (10 % = 4 Twh) (Madsen 1988).

When it comes to site searching for windmills (especially large-scale ones) Denmark faces the problem of standards for the distance between a windmill and a residence. Furthermore, it also faces problems with the visual impact on the landscape. The "residence-free" area is very dependent on the noise levels. The visual impact seems to be of great importance to planning authorities (Carlman 1988).

Other factors that might represent an entry barrier are: the network that needs to be built up in the promotion of wind turbines; differentiation among the products; capital requirements and switching costs. The “network” factor deserves to be emphasized, because Denmark is a very good example of this. In the development of turbines, two major associations (turbine owners and manufacturers) became linked to each other. This represented a very strong base of the evolving network. The two associations were protecting their members’ interests; therefore they took part in the political life as well, involving the government in their network (here, network is meant in a social understanding). As the wind turbine industry merged into the power industry, the utility companies were also connected to the network. After some time financial institutions also got involved in the wind turbine industry, so the network became wider and wider. In such case the distribution channels for energy had been assured, governmental support for wind power was also attributed, discussions with pros and contras were carried out, so this network was very balanced. For new entrants it was easier to enter into the industry than for the established companies to exit the industry, because of the high capital investments that such a wind turbine requires.

In terms of capital requirements, entering into the wind turbine business requires a huge amount of capital for investments, due to the high costs of the turbines, sites, maintenance, etc. The investment does not have a quick return; therefore it has to be subsidized.

The other factor representing an exit barrier is the switching costs. In the production of wind turbines, there are many component suppliers which produce components for various types of technologies; so if they have to exit the industry, there is still the chance of being able to keep producing for a different technology, but of course there are switching costs involved. On the other hand, the knowledge embedded in the wind turbine technology creates a barrier for entrants because of the specificity and complexity of the knowledge. This also makes it hard for the companies to exit from the industry.

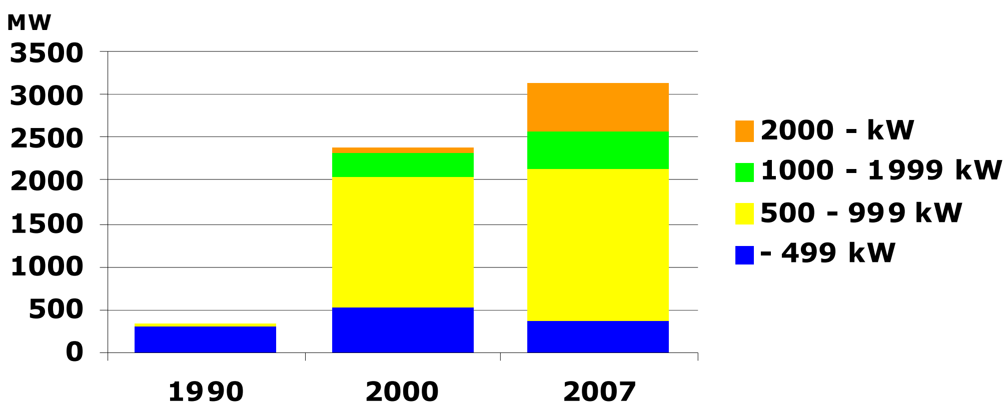
Overall, it can be said, that the Danish and the Californian government has very much influenced the wind power energy industry with their decisions on subsidies, taxes and planning legislation, but also the network had contradictory effects upon the industry. Therefore, I assume that the Danish wind power energy industry developed in a relatively competitive way during the analyzed period.

5.3 Second Period (2001-2007)

5.3.1 Technological system

Manufacturers continue to reach for the stars as machines grow ever larger. Megawatt class turbines dominated much of the world market in 2002 for the first time, pushing average installed capacity per turbine above the 1 MW mark. Britain, USA, and Spain saw average sizes approach 900 kW per turbine while Denmark, Germany, and Sweden fully passed into MW class territory. The average size of each turbine installed in Denmark and Germany approached 1.4 MW in 2002 (Gipe 2003). A more conclusive presentation of the wind turbine capacities is given in the following graphic, where it can be seen that the 500-1000 kW size turbine dominated this period. The figure also reveals that some of the smaller turbines (<500 kW) have been replaced by the larger ones at the end of this period.

Figure 5.24 Installed capacity of wind turbine by size in Denmark



Source: (Danish Energy Agency 2007)

The offshore market may demand even larger machines. Several manufacturers installed multi-megawatt prototype turbines in 2002, for instance: GE Wind installed a 100 meter diameter, 3.6 MW-turbine in Spain; Vestas erected its V90 3-MW turbine in Denmark, while Enercon raised its monstrous 4.5 MW-turbine with a 112-meter rotor in Germany. NEG-Micon completed its NM92, a 2.75-MW turbine on the isle of Orkney. Nordex has been operating its N90, 2.3-MW turbine and Bonus is marketing its 2.3 MW-model (Gipe 2003). The technology for offshore wind energy faced more challenging circumstances than the onshore wind turbines. Projects are located in harsher conditions, confronting technology developers with more challenging demands (Smit, Junginger & Smits 2007).

Within the technological system, there is the certainty of economic performance, due to the improvement of turbine capacities and cost reductions of new turbines. Concrete evidence was presented about offshore wind turbines in a paper by Smit, Junginger & Smits (2007), and as a parallel trend must have happened with onshore wind turbines too, taking into consideration that these represented the learning base for the offshore technologies, which are more sophisticated. In order to achieve rapidly growth in the industry, actors shared the vision to upscale the technology to multi-megawatt machines (IEA 2006). Although turbine manufacturers were promoting the fastest up-scaling development, this vision spread easily among other actors in the Danish industry: equipment and service suppliers, knowledge institutes were all attacked by the promising future of the offshore wind. Such a development is called “social performance” (Smit, Junginger & Smits 2007). So, during the analyzed period there were technological, economic and social performance observed in the Danish wind turbine industry.

5.3.2 Institutions

An important step was taken by the Danish political actors in this period to put on hold the introduction of the green certificate system in 2002, because the country was not prepared for it at the time. Instead, the new way of thinking in Denmark was to re-power the old onshore wind turbines. After 2002, the Danish government did not back off from supporting the wind sector (since the “scrap premium” and the “premium rate” add up exactly to the maximum price of green certificates), but is simply leading it to a more efficient and technologically advanced state. So, most of the additional generating wind capacity in 2002 was due to re-powering (Danish Wind Industry Association 2002). 300 MW of new capacity was installed after the removal of 100 MW of turbines less than 150 kW. Danes decommissioned about 1.200 turbines under the program. The old but still usable turbines were then destroyed rather than placed on the used turbine market (Gipe 2003).

In 2003 (under the right-wing governance of Denmark), Denmark crafted a new climate strategy, which put stronger emphasis on meeting GHG targets through emission reduction investments outside Denmark. The wind power lobby has since partly succeeded in convincing the government about the importance of the domestic wind power investments as a solution to the climate problem, through “meeting part of Denmark’s reduction commitments within the self-imposed Danish maximum cost limit of 120 DKK/tCO_2” (Buen 2006). During this period, the government decided to end the subsidizing of wind power. R&D funding was cut and the feed-in tariff for wind power and also other renewable energy sources has lowered quicker than would otherwise have probably been the case. This action definitely had a reduced diffusion of wind power on the Danish home market during the analyzed period (Buen 2006).

Another important step in the development of the wind turbine industry was the “Mega-wind partnership” established in autumn 2006 as part of the Danish government’s action plan to promote eco-efficient technology. The overall aim of Mega-wind is to develop a new shared strategy for research and innovation in wind power energy in order to strengthen Denmark’s position as a world leader in this area (Danish Energy Authority 2008).

Also, an important decision by the Government took place in an agreement with the electric utilities about the large scale demonstration projects in terms of which the electricity sector was to build five offshore wind farms with a total wind power of 750 MW by the year 2007 (Danish Energy Agency 1998). This target has still not been met today. Only half of the target capacity is installed today.

5.3.3 Organizations

Apart from the organizations mentioned in the previous section, others were created as a result of new legislation or need.

With the development of the offshore wind industry, organizations that support such technologies were created. The Offshore Wind Energy Europe (OWEE) is a webpage offering an independent information source for professionals working in the field of offshore wind energy. Apart from the expert guides that provide an introduction to subjects in this field, the site also wishes to be an up-to-date and convenient source of the latest information on offshore wind energy. It provides a list of events of interests: news about the latest research activities in the offshore wind energy field; provides databases; up to date information about the existing wind farms and those that are in construction and finally the website is used as a portal for research projects. The website started out as the dissemination website for the Concerted Action on Offshore Wind Energy in Europe (CA-OWEE) project. This project was finished at the end of 2001 and received funding from NOVEM to develop the site further and operate it until the end of 2003. After that, the website operated independently. The main goal is to develop the site further as a portal for research projects. The research projects on this website are not connected to this website, but use it as a platform for their information dissemination (Offshore Windenergy Europe 2008).

Another organization emerged due to the existence of the certificate markets, (called Renewable Energy Certificate System (RECS International), which is a non profit organization, registered in Brussels. Its main goal is a pan-European market for renewable energy facilitated by harmonized certificate systems of renewable energy. The testing period originally was 2000-2002. Since 2003 RECS International is fully operational, changing its status from foundation to association in 2004. RECS International had about 200 members from 24 (European) countries in 2007 (Renewable Energy Certificate System).

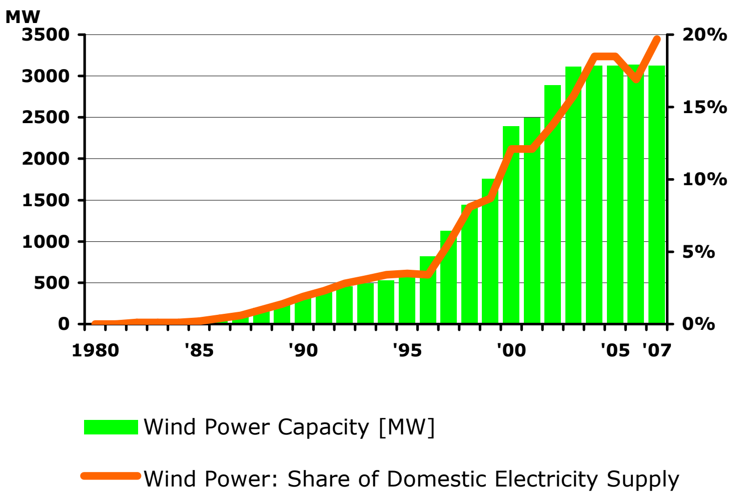
Danish wind turbine manufacturers and subcontractors have achieved international recognition for being innovative, quality-conscious and reliable pioneers within the wind energy sector. To maintain this position, leading Danish companies formed the Danish Wind Energy Group (DWEG). In the spring of 2004 the Danish Wind Energy Group was established as a sector under the Danish Export Association to support and encourage Danish subcontractors within the industry. They provide a solid platform for joint promotion, participation at international fairs, and the exchange of knowledge and establishment of professional networks. The DWEG operates by planning and executing export campaigns, often linked to international trade fairs and exhibitions, and by providing a forum for Danish exporters and foreign buyers. The DWEG is a member of EWEA and the Danish Export Association, giving DWEG access to a considerable network of knowledge (Danish Wind Energy Group).

5.3.4 Industry analysis

5.3.4.1 Supply power

In 1996, 4% of electricity production came from wind power. Already in 1998 this figure had increased to 8%, and plans for expanding the share of wind power energy to 18%, and then to 21% share of electricity consumption by 2003 was agreed upon in the Parliament (Lund 2000). Figure 5.25 shows the wind power capacity and its share in the domestic electricity supply. According to this figure, wind power energy achieved an 18% share of the electricity supply by 2002 and only after 2007 did it reach the 21% target.

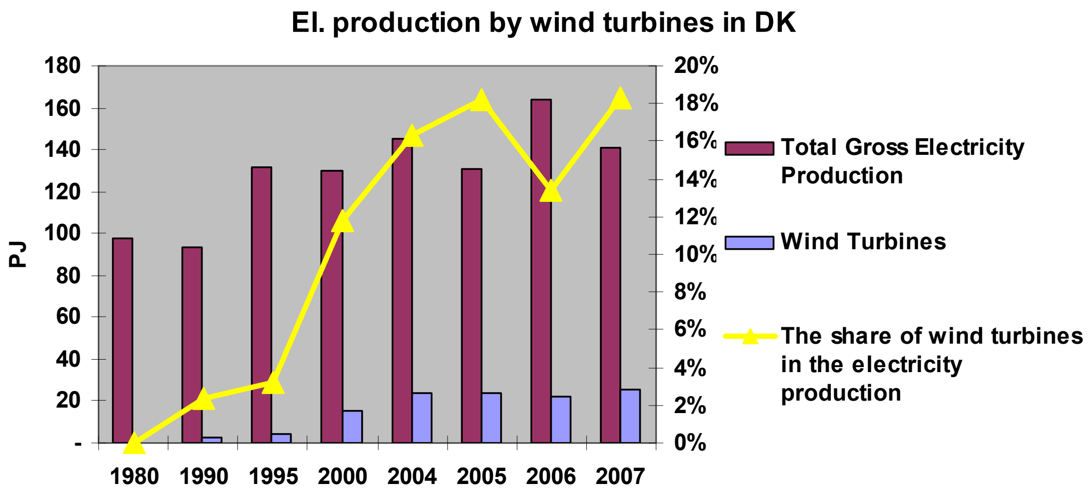
Figure 5.25 Wind Power Capacity and Percentage Share of Electricity Supply



Source: (Danish Energy Agency 2007)

The following figure is also a representation of the share of wind turbines in electricity production. The two figures (Fig. 5.25 and Fig. 5.26) are quite similar, which proves the authenticity of the data source. In Figure 5.25 the share of wind power energy in the electricity production is calculated, relative to the wind power capacity. In the latter figure, it is shown according the produced wind power energy. Therefore, the latter graph is closer to reality than the previous one.

Figure 5.26. The share of wind power energy in the electricity production in Denmark



Data Source: (Danish Energy Agency 2007)

In terms of installed wind power capacity, the growing tendency continued from the previous period. There was an increase of almost 500 MW from 2001 to 2002, but in the following years, there was a clear stagnation in turbine installations, as the figure above shows. 2003 was the starting point of the stagnation period. (For a better understanding see Figure D in the Appendix).

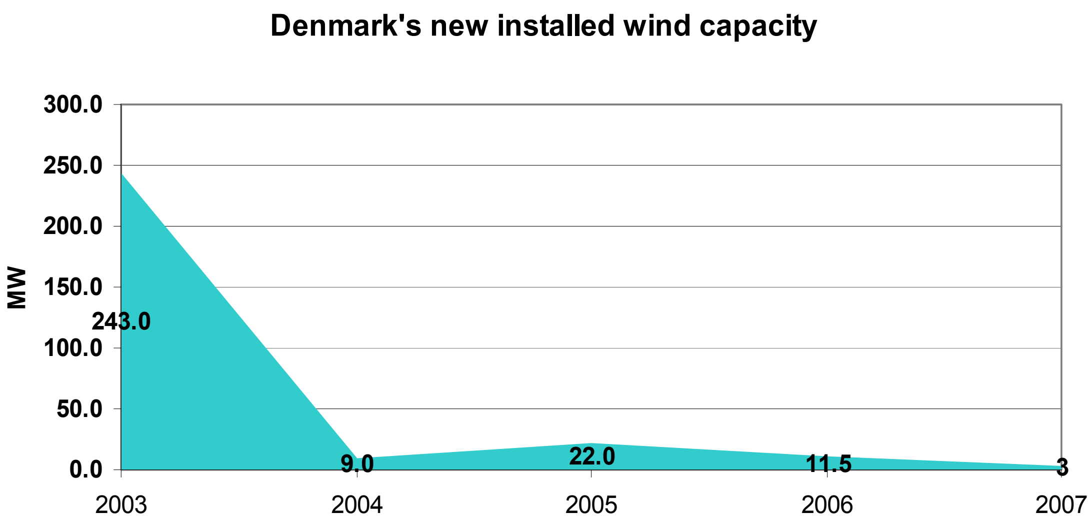
The cumulative installed capacity in Denmark during the analyzed period is expressed in the following graphical representation in percentages, which shows the increase in the installed wind power.

Figure 5.27 Variations in the total installed wind power capacity in Denmark between 2002 and 2007

Primary data source: (EWEA 2007)

It clearly shows that over five years, only 1.5% increase was achieved in wind turbine development. This is a very weak performance of the wind industry compared to the previous periods and also to other countries.[16] It is even more frightening if we take a look at the newly installed capacities year by year. In the following figure the enormous drop after 2003 can be seen. This sudden drop is due to the policies adopted in 2001, when various promoting forms of the wind power energy (subsidies, R&D funding, feed-in tariff) ended with the establishment of the government of that period. The weakest year was 2007, with only 3 MW installed.

Figure 5.28 The new installed wind power capacities in Dk (2003-2007)



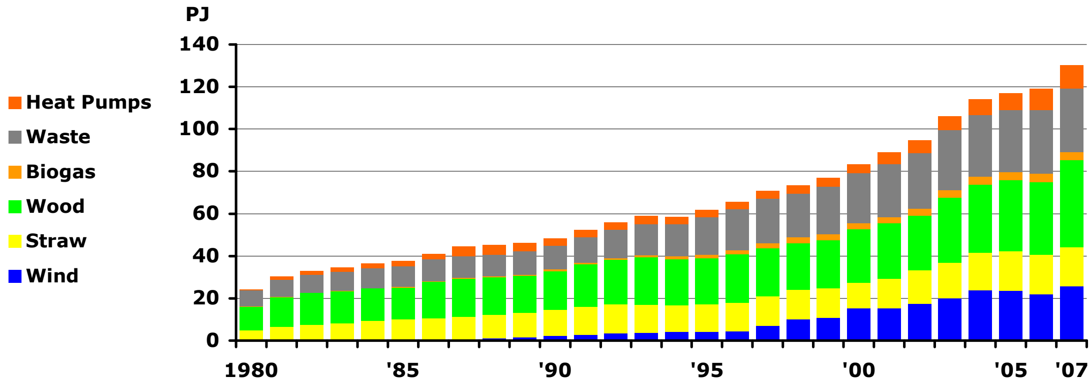
Primary data source: (EWEA 2008)

The production of wind power energy is represented in the following figure, where it can be seen that wind is only the third (after wood and waste) major

[16] The comparison with other countries will be presented at the end of the third period.

renewable source produced in Denmark. Though wood and waste are not as clean energies as wind, is because they have pollutant residuals. According to this figure, wind power was produced in increasing levels until 2004, where it reached stagnation and even dropped in 2006. In 2007 the production increased again and reached the highest level ever.

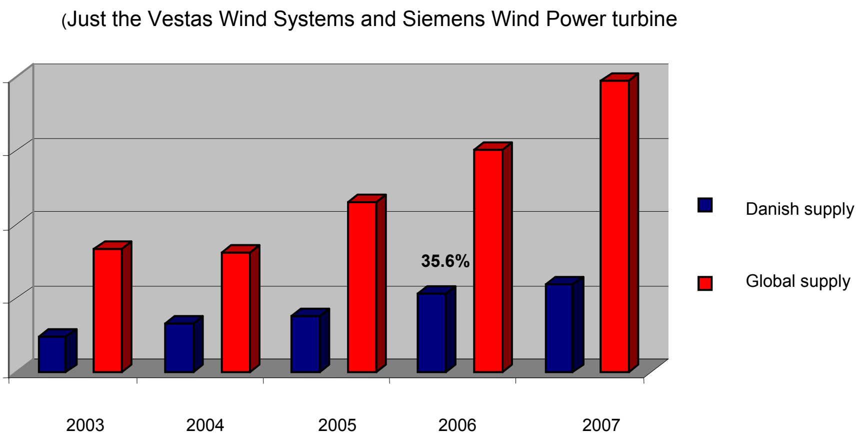
Figure 5.29 Production of renewable energy by energy product



Source: (Danish Energy Agency 2007)

In terms of market share, the following figure shows the Danish supply and global supply too. In Denmark the supplied capacity for the analyzed period was less than in previous years. In 2007 it achieved nearly 30% of market share, compared to the previous periods that overtook the lead with 35% in 2006 and 40% in 2004. The reason of the decrease in the Danish market share is due to strong Chinese development in this industry, as they supplied more than 50% of the turbines in 2007.

Figure 5.30 Global market share of Danish companies



Source: BTM Consult ApS – World Market Update 2003 – 2007

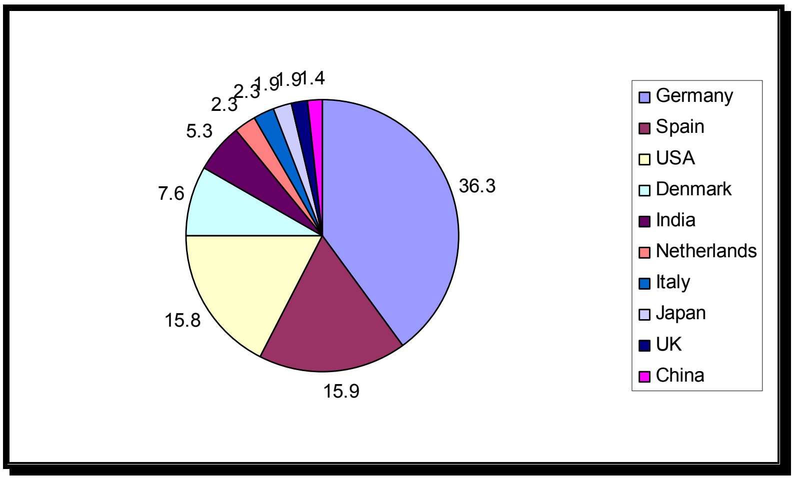
If we compare Denmark with other countries from the market share point of view, it produces a lot of turbines, but most of the produced turbines (70-90%) are exported worldwide. For instance, Vestas had an average export share of 98.6% in 2003 (BTM Consult 2004). The top five European wind energy markets in 2005 were Germany (1.808 MW), Spain (1.764 MW), Portugal (500 MW), Italy (452 MW) and the UK (446 MW). In cumulative installed capacity, two countries had more than 10 GW (Germany had 18.428 MW and Spain 10.027 MW) and seven countries had more than 1 GW (Denmark 3.122 MW, Italy: 1.717 MW, UK: 1.353 MW, Netherlands: 1.219 MW and Portugal: 1.022 MW) (European Wind Energy Association).

Although the price of energy produced by wind turbines has been falling due to the "learning by doing" effect, the potential for further cost reduction is likely to be small in terms of the estimated average wind turbine price per kW over time. Companies presume that offshore wind power will become the "big thing" in the future, contributing to the reduction of the energy price and driving the wind energy to close competition with traditional energy prices (Brandt, U.S., Svendsen, G.T. 2006). In terms of offshore, Denmark became the world's leading country with 300 MW installed capacity in 2002, of which the 160 MW Vestas Horns Rev projects was also the leader on the world market among offshore projects (Gipe 2003). By the end of 2007 the offshore capacity increased to 409 MW, which puts Denmark in second place after the UK, with 27.5% of the total offshore market (Primary data source: EWEA 2008).

5.3.4.2 Consumer power

In the beginning of this period, the Danish domestic demand was so low that it could have driven the whole industry into a near-collapse (Lauber 2002). Fortunately, the US market the industry maintained a constant growth in the period. However, the fall of the US dollar relative to the Euro has boosted GE Wind's US sales to new heights and made it difficult for Danish manufacturers to compete. Like falling dominoes, the collapse of utility industry giants in the US, and the near bankruptcy of many others, has hurt financing, cutting into American Wind Energy Association's (AWEA's) projections for new projects in 2003. At one time, AWEA projected a repeat of the 2001 boom year with new capacity reaching 1.700 MW as developers rushed to beat another year-end, tax-credit deadline. But the roiling US utility industry has led AWEA to cut its projection to somewhat more than 1.000 MW (Gipe 2003). Therefore, the US is placed in third place after Germany and Spain, in terms of buying and installing wind turbines. The following figure is a representation of what the global markets looked like in 2003 and this is a good indication for the installed capacity of wind turbines too. Looking at the global demand in 2003, the main buyer countries were placed in Europe. Since wind based energy is not competitive yet, demand depends on national subsidization schemes (Brandt, U.S., Svendsen, G.T. 2006).

Figure 5.31 The 10 largest markets for buying wind turbines by the end of 2003 (Market share %)



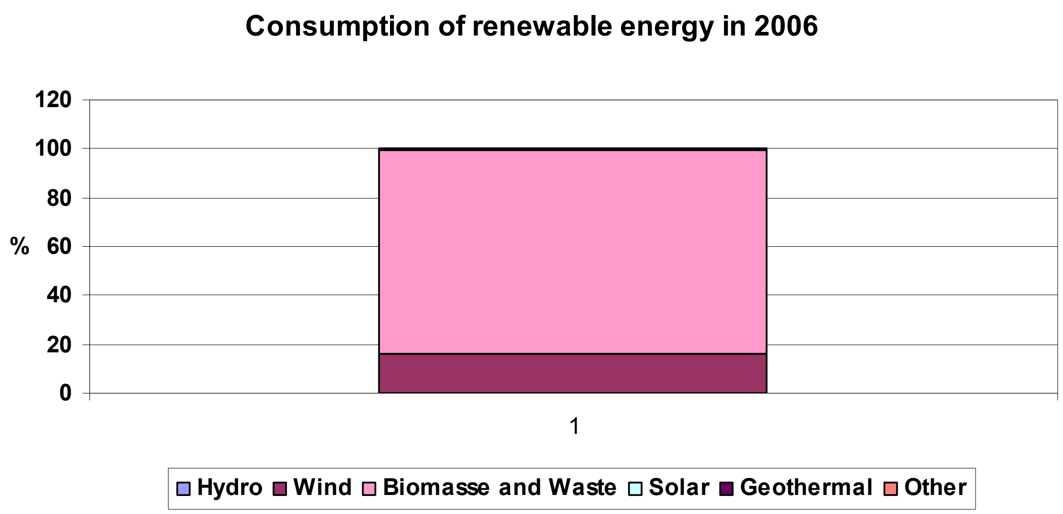
Data source: (BTM Consult 2004)

In terms of exports, Figure 5.19 from the previous period shows that Danish export has been quite variable in the analyzed period. The figure showing the Danish exports limits itself by the fact that it is expressed in money values, which means that in some situations the changes in the export shares can be due to the changes in the exchange rates between currencies. And, as we all know, the financial crisis in the US started in 2006, and as a consequence the $ (US) lost its value compared to the EUR and other currencies. It would be more accurate to know for instance the capacity or the number of wind turbines that were exported.

In terms of domestic sales, we saw a sudden decrease in 2001, which recovered a little bit in the following two years, but it dropped again in 2004 (Figure 5.28). The domestic sales for later periods can be also expressed through the newly installed wind capacity in Denmark (Figure 5.28, Figure D, E and F in Appendix). As has been said earlier in the supplier part of this project, wind power and biomass &

waste constitute the majority share of renewable energy. The figure below does not even show the very small percentages of the other resources, such as: hydro (0.1%), solar (0%) and geothermal (0.4%). According to the figure below, the wind power consumption was 16%, while the biomass and waste reached 83% (Primary data source: Danish Energy Agency).

Figure 5.32 Consumption of renewable energy by energy types in 2006

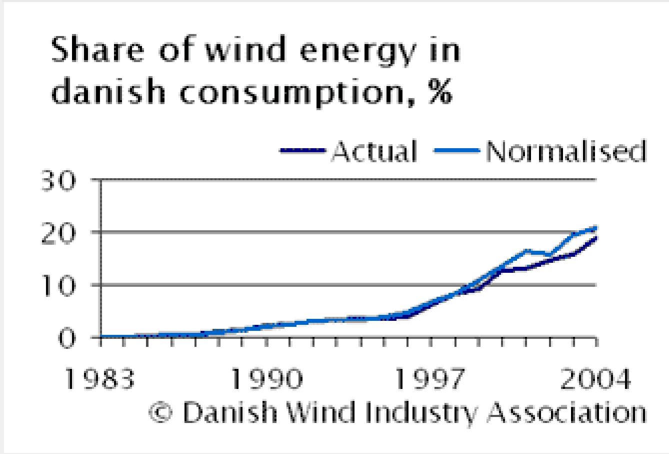


Source: (Danish Energy Agency 2008b)

Figure I. in the Appendix represents the consumption of all kinds of renewable energies (wind, straw, waste, biogas, wood, heat pumps) in Denmark until 2007. After 1995, a tendency started where renewable energies could not cover the consumption, and therefore it was imported. The share of imports increased during the times.

Danish energy plans said that 20% of Danish electricity consumption should come from renewable energies by the end of 2003. Approximately 15 to 16% may be expected to come from wind energy. In 2004 the share of wind power energy in the Danish electricity consumption continued to rise. Wind power equalled 18.8% of Danish consumption, which equals the consumption in 1.4 million Danish households. 2004 was below-average for a normal wind year, where wind power energy would have covered 20.8% of Danish electricity consumption (Danish Wind Industry Association 2009d).

Figure 5.33 Share of wind energy in the Danish consumption



Source: (Danish Wind Industry Association 2009e)

There is no further data for the following years, however, if the installed capacity had not increased over these years, the share of wind power of electricity consumption must have remained constant.

5.3.4.3 Substitutes

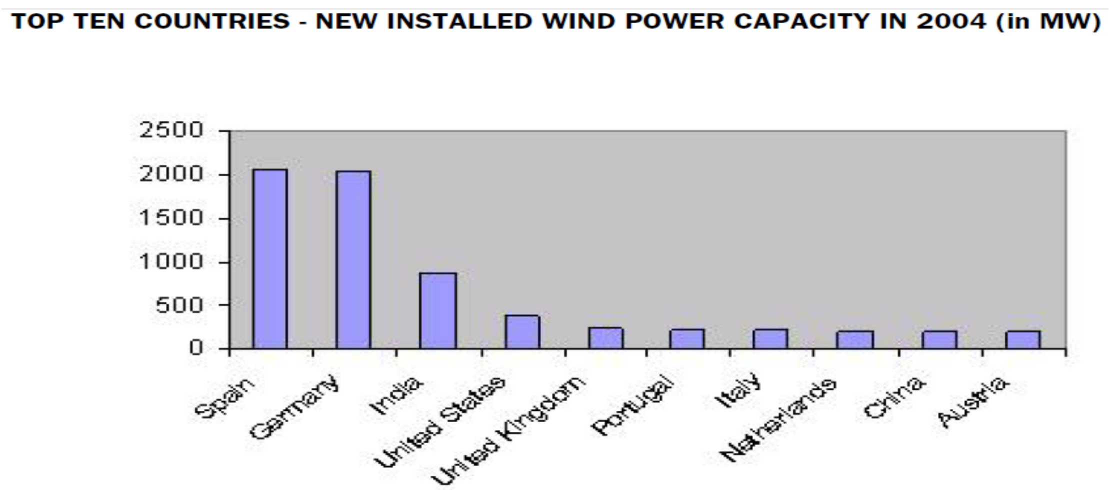
The substitute products in this period are the same as in the previous one, just their share in the production of renewable energy and energy consumption differs. As shown previously, in Figure 5.29, the share of wind energy has increased moderately, with a sudden decrease in 2006. However, the share of wood and waste power is bigger compared to wind power, and their increase has also been very moderate.

5.3.4.4 Entry / Exit barriers

In terms of Danish wind power energy this period is considered the weakest of the entire wind power history of the country. 2001 represents the turning point when the old subsidies ran out; therefore there was no financial encouragement for further investments in installing wind turbines. On the electricity market there was a complete uncertainty caused by the many discussions around the introduction of the complex green certificate system and the abandonment of the so well-functioning feed-in tariff system. The government lost interest in promoting wind power energy in any way; therefore there were no new actors that have entered the market. The whole industry saw not only stagnation, but even a decrease during this period. What saved the two main manufacturers from exiting the market were their well developed external relationships and their accumulated experience through which they managed to increase their exports and thus maintained their production activities.

In a global perspective, Europe continues to account for two-thirds of total worldwide wind development. And Germany - seemingly the perennial pacesetter - continues to outdistance all other markets. Germany again led the world in wind development, accounting for 40% percent of the total market. In 2001 Germans installed an amazing 2.600 MW, more than 60% greater than the year before, itself a record (Gipe 2001). In global dimensions, though more new capacity was added in 2002 than 2001 and total new investment exceeded any previous year, the rate of growth stalled at a mere 6%. Growth in the market was down from the more than 50% increase in 2000 to 2001 and previously in 1998 and 1999. As in past years, much of the fall off in new additions is attributed to the confused US market where dramatic swings from 1600 MW in 2001 to 400 MW in 2002 have become commonplace (Gipe 2003). Nearly 90% of new capacity in 2002 was added in Europe, with the giant German market accounting for more than half the expansion. Spain accounted for one-fourth. The poor 2002 showing for the “potentially mammoth” US market knocked the Americans off their second-place perch, pushing them behind Germany, Spain, and Denmark. The situation was quite similar in 2004 too, when the newly installed wind capacity reached the 2000 MW accomplished by Spain and Germany.

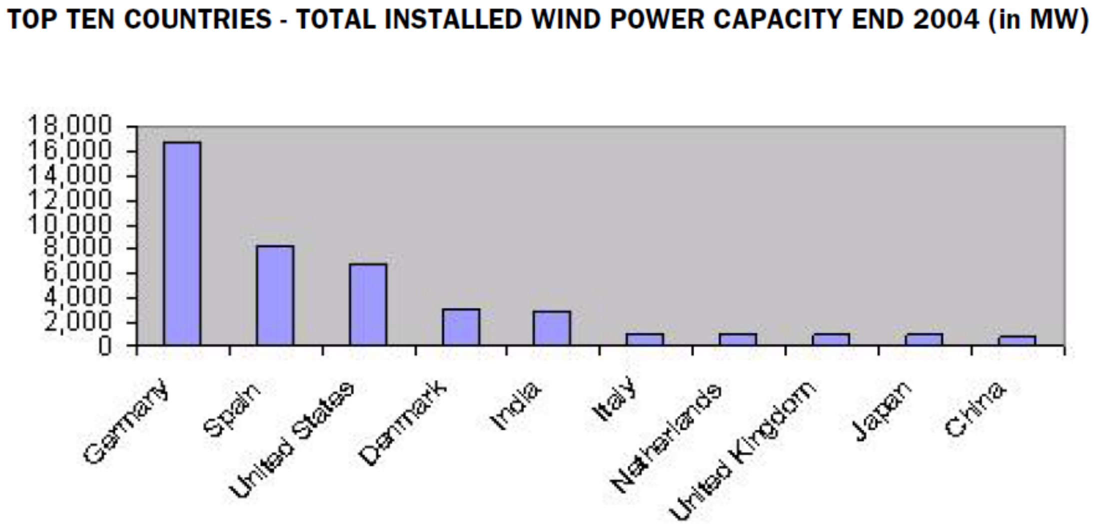
Figure 5.34 New wind capacity installations by the end of 2004



Source: (Global Wind Energy Council 2009)

The total installed wind capacity by the end of 2004 also put Germany in the front with approximately 16.000 MW of installed wind power. According to the figure below, Denmark is in the fourth place after Spain and the US, reaching around 3.500 MW wind power capacity.

Figure 5.35 Total installed wind capacity by the end of 2004



Source: (Global Wind Energy Council 2009)

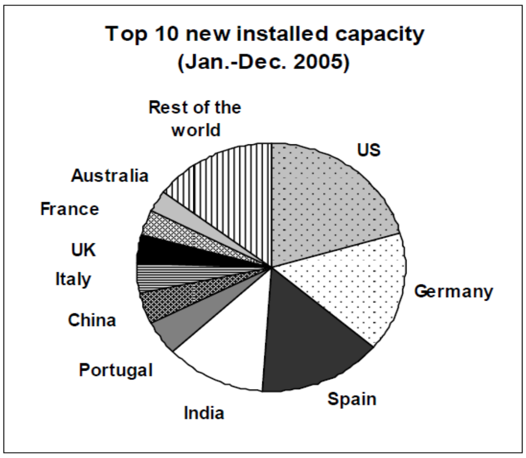
http://www.ewea.org/fileadmin/ewea_documents/documents/gwec/news_release/050304-Global_Wind_Energy_Markets_-_FINAL.pdf

One year later, the US managed to take first place in newly installed capacity, having a share of 21.1% of the total market. Spain was also overtaken by Germany, with a very small lead (Table B in Appendix). In terms of cumulative wind power capacity, Germany is leading the world with over 31% share, followed by Spain with 17%, and the US with 15.5% of total wind power capacity. Unfortunately, Denmark dropped one place behind and India overtook it with almost 2% share difference. (Table A in Appendix).

2005 was considered a record year by the GWEC (Global Wind Energy Council). The new installations represent a 40.5% increase in annual additions to the global market compared to the previous year. The total installed wind power capacity acknowledged an increase of 24% compared to 2004 (GWEC 2005). In this year Europe was still leading the market with 69% of the global total. In 2005, the European wind capacity grew by 18%, providing nearly 3% of the EU electricity consumption in an average wind year. “The European market has already reached the 2010 target set by the European Commission of 40.000 MW five years ahead of time” said Christian Kjaer, the EWEA Policy Director (GWEC 2005).

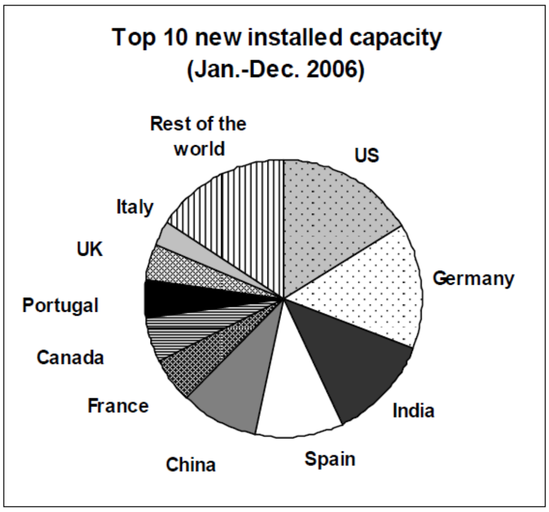
In 2006 the newly installed wind power capacity brought a change to the global share for India, and the ex-leader, Spain: they switched places. The two leaders remained the same as in the previous year. Total installed capacity remained almost the same as in the previous year, just China made an improvement of 1.6% increase in the global market share (GWEC 2006). (Table D in Appendix).

Figure 5.36 Top 10 new installed wind power capacity by the end of 2005



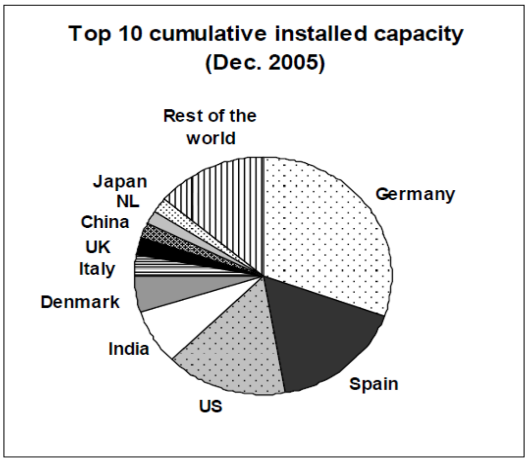
Source: (GWEC 2005)

Figure 5.38 Top 10 new installed wind power capacity by the end of 2006



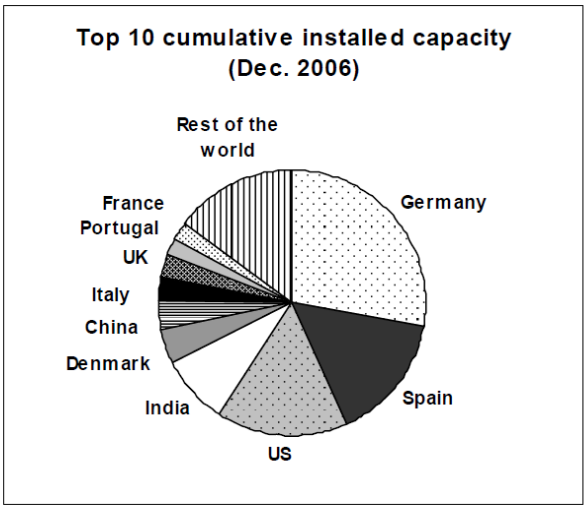
Source: (GWEC 2006)

Figure 5.37 Top 10 cumulative installed wind power capacity by the end of 2005



Source: (GWEC 2005)

Figure 5.39 Top 10 cumulated wind power capacity by the end of 2006



Source: (GWEC 2006)

5.4 Third period from 2007 on

5.4.1 Technological system

In this period, the focal point of the technological system shifted towards offshore wind turbines. They represent a challenge for future development. It is expected that offshore wind energy will become a niche market. Offshore wind turbines also represent the hope for energy cost diminishments to a level where these costs become competitive with the costs generated by traditional energy sources. Since the offshore placements of wind turbines create many challenges for the equipment manufacturers and scientists (taking into consideration the depth of the sea, stronger wind conditions, humidity, salty water, erosion, animal friendly placing and maintenance, etc.) future wind turbines will not only increase their capacity to multi-megawatts, but they will also incorporate major innovations. Therefore there is a need for producers, users, scientists from knowledge institutes and other offshore industry specialists (e.g. offshore oil platforms) to work together and strengthen their relationships within the technological system.

The development and market launch of new efficient and environmentally friendly energy technologies is an extremely important part of the basis for meeting the energy and climate policy challenges at the lowest possible cost and thus is also the basis for ever more ambitious targets. In this light, the government wishes to increase the funding for energy research, development and demonstration to DKK 1million from 2010 onwards. Knowledge and education is crucial in providing the necessary skills development and therefore it is important that there is good cooperation between engineering research circles, the various professional disciplines at universities and private business (Government 2008).

5.4.2 Institutions

The promotion of renewable sources of energy is a crucial aspect of the government's future vision of fossil-fuel free energy supplies. Today, the primary sources of renewable energy are wind and biomass. A great deal of electricity and heating is also produced from waste, which is a valuable resource which would otherwise be lost. Wind power technology plays a crucial role in current renewable energy supplies, and is undergoing constant development. Thus there are many indications that wind power will continue to make a very important contribution to Danish energy supplies, and allowances must be made for this when drawing up plans for the future energy infrastructure (Government 2007).

In recent years, the government has implemented a number of specific initiatives to reform subsidy schemes and promote the increased application of market mechanisms in the renewable energy area, under which public subsidies for renewable energy will be applied considerably more efficiently in the future than is the case today (Government 2007).

In terms of wind power, the “scrapping scheme” has also been set up as planned, but so far has not produced the expected results. Under the scheme, wind turbine owners are guaranteed additional remuneration of 12 øre/kWh for 12.000 hours if they scrap their old wind turbines. The scheme will remain in place until 2009 (Government 2007).

The energy policy for the period 2008-2011 has the aim of further reducing Denmark's dependency on fossil fuels (oil, coal and gas), and contains a range of initiatives aimed at ensuring that Denmark meets its obligations and pledges in relation to the integrated climate and energy proposal put forward by the European Commission in January 2008. By 2011 it is further expected that renewable energy will provide 20% of the country's total energy needs. For Denmark it has been proposed in the EU Climate and energy package that 30% of the final energy consumption should be supplied from renewable sources by 2020, which is equivalent to 27% of gross energy consumption (Government 2008). The energy agreement includes establishing new offshore wind farms generating a further 400 MW of clean electricity, tax-exempting cars using hydrogen as fuel and electric cars up to 2012, and the provision of state funding for research into electric vehicles, solar energy and wave power. The last two energy sources will be subsidized by the government in this 4 year period (Danish Government 2008). In the future, up to 2030, the Government wants to maintain its objective of 1% more renewable energy per year, thus covering 35% of the total energy consumption (Danish Energy Agency 1998). In addition, the government wishes to promote the use of biogas, which could both contribute to reducing consumption of fossil fuels and emissions of the greenhouse gas methane and solve a waste disposal problem for the farming industry. The government will work to promote the use of increasing amounts of waste in central power stations for the highly efficient combined generation of power and heating. Finally, it is promised that the government will seek to establish a good framework for Danish wind capacity, including through the promotion of onshore and offshore demonstration and trial sites and the drawing up of an infrastructure plan for offshore wind turbines. All these proposals are planned to be achieved through the following principles: to use the largest amount of renewable energy possible for the money, to increase tendering and competition as much as possible and last, to increase the transparency and predictability regarding subsidy levels (Government 2007).

5.4.3 Organizations

According to the Energy Policy Statement 2007, two new organizations have been emerged. Since the wind turbine industry developed in such a way, that offshore wind turbines reopened a new market niche in the Danish industry. Therefore, both organizational and institutional developments needed to be introduced. As a result, the government appointed two committees, one to examine the future location of offshore wind turbines and the other to the planning of future onshore wind turbines. The committee dealing with onshore wind turbines has just reported on its work, and work has started on following up on its recommendations. The Offshore Wind Turbine Committee is also expected to complete its task in the near future (Government 2007).

A new event will take officially place in 2009, “The Climate Conference” in Copenhagen. The conference represents an enormous challenge and may be of decisive importance for climate and energy policy development both globally and within Denmark. At this conference it is expected that a **new global agreement** will be signed. The agreement will follow two tracks: the negotiations concerning the obligations of industrialized countries under the Kyoto Protocol and negotiations under the climate convention. For this reason, the government has appointed a broad-based professional climate panel (the second organization in respect to climate issues) with members from a number of organizations, companies and knowledge institutions. “The purpose of this panel is to advise the government on business activities and branding in connection with the climate conference and the exploitation of growth opportunities in the climate area and on the responsibility of business and knowledge institutions with regard for climate challenges" (Government 2008)

A third organization regarding climate issues will be set up by the Danish Energy Authority, called the "Knowledge Centre for Climate Adaptation". The centre will work along a cross disciplinary co-ordination forum for climate adaptation made up of all the relevant government authorities, the National Association of Local Authorities in Denmark and the regional authorities, and a co-ordination unit has already been set up for research into climate adaptation at DMU/Århus University (Government 2008).

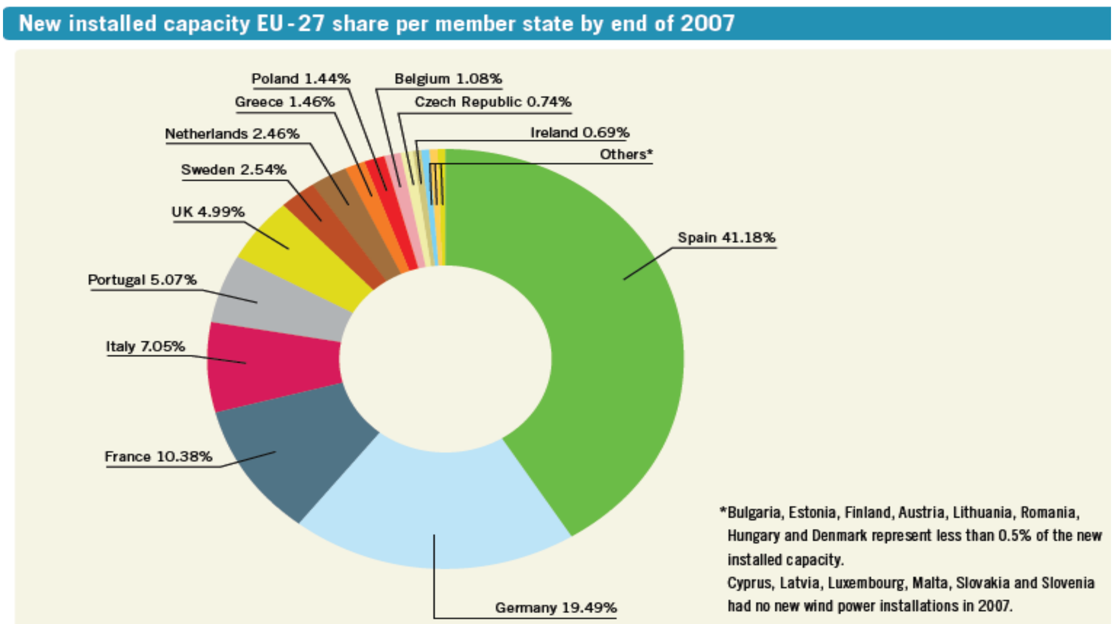
5.4.4 Industry analysis

5.4.4.1 Supply power

In the period that reflects the present and future tendencies, it is recommended to take into consideration an international perspective, as well as international economic and political development.

The year 2007 was very weak for the Danish wind power industry in terms of turbine installations. Only 3 MW were installed. Therefore, Denmark does not appear among the countries in the following figure.

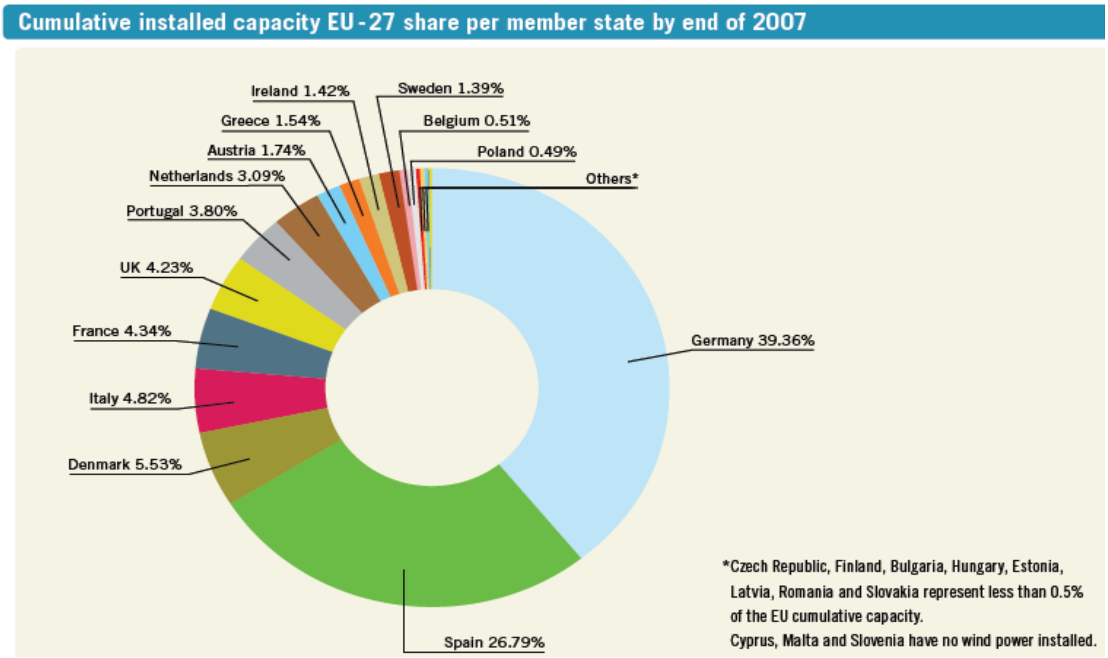
Figure 5.40 Onshore newly installed wind power capacity by the end of 2007



Source: (EWEA 2007a)

According to Figure 5.40, Spain was the strongest country in new installations, followed by Germany and France.

Figure 5.41 Onshore cumulative installed wind power capacity by the end of 2007



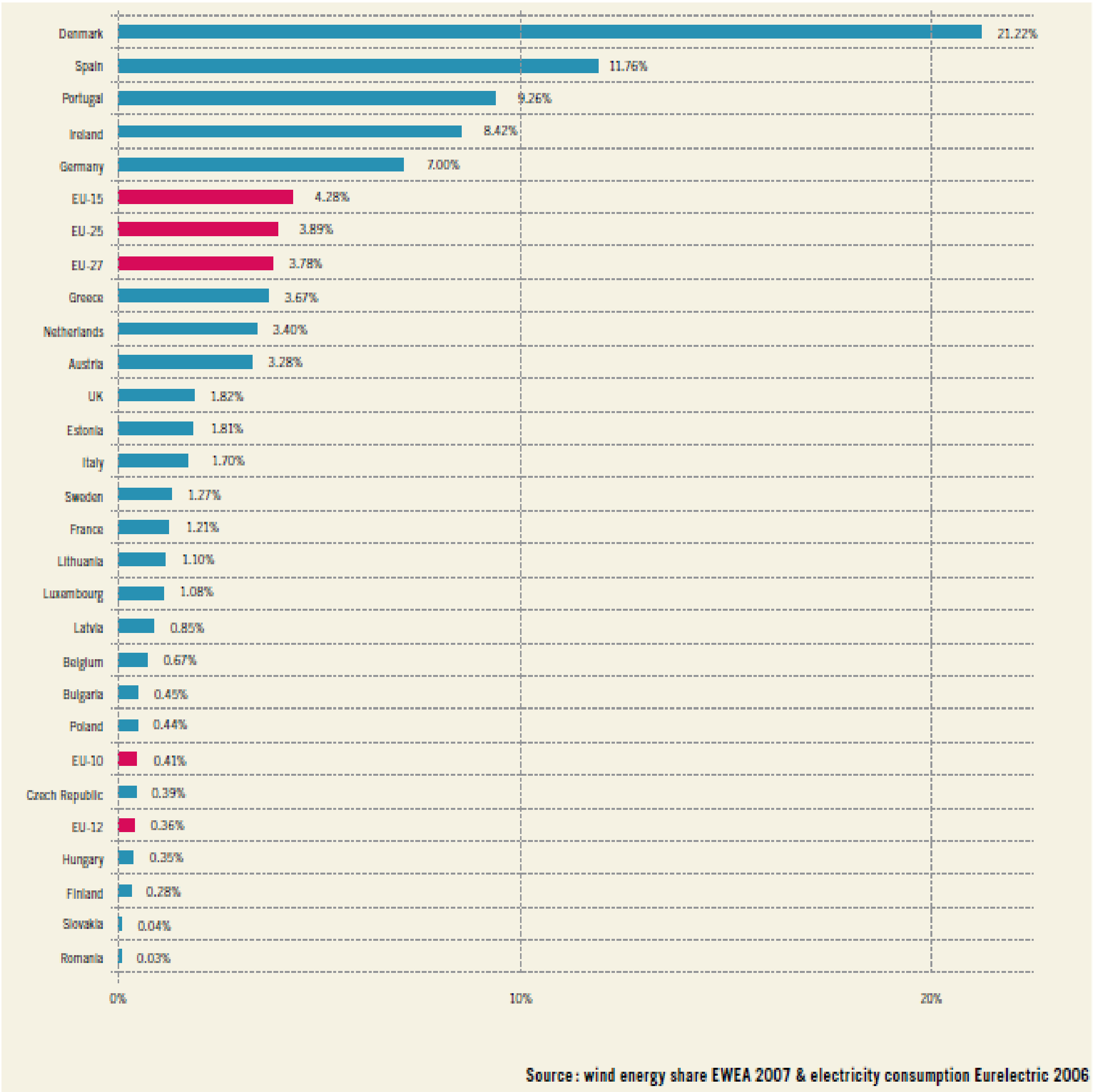
Source: (EWEA 2007a)

In terms of cumulative installed capacity, Denmark is lucky to have the first mover's advantage of installing wind turbines very early in the past. Still, Denmark lost its leading advantage before Germany and Spain, who had almost 40% and 27% respectively of the cumulative installed capacity by the end of 2007, as Figure 5.41 presents.

The wind capacity calculated in accordance with the number of inhabitant (Figure 5.42) shows very good results for Denmark. It takes first place among the European countries, with an impressive advantage ahead of Spain and Germany and the lead is at around four times higher than the EU-25 average.

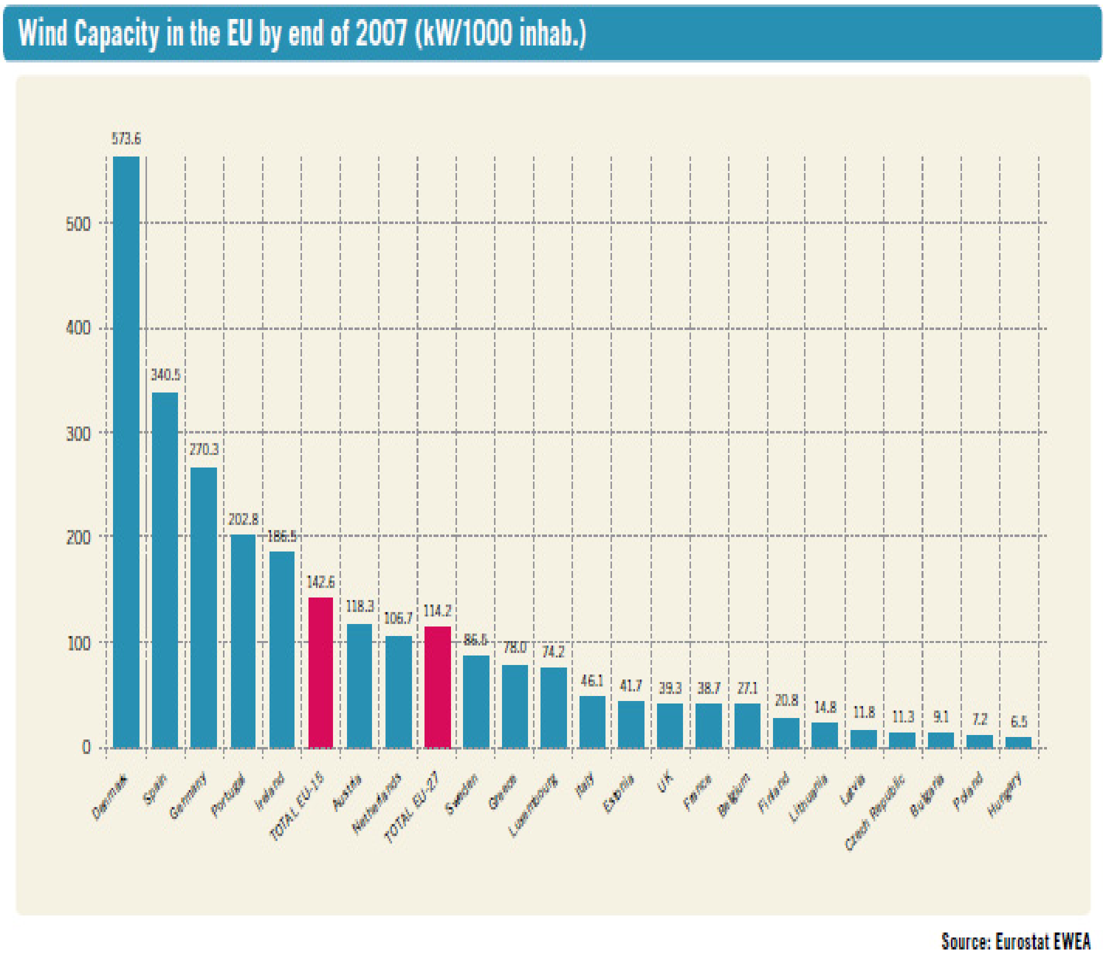
So far there was a presentation of the Danish wind power installed capacity in the third period. The second indicator that is worth discussing in analyzing the supply within the industry, is the wind share in electricity consumption. According to the EWEA Eurostat data source, Denmark has achieved the highest share of wind power in its domestic electricity consumption. By the end of 2007, the wind power energy was over 20% share of electricity consumption.

Figure 5.42 Onshore wind capacity per 1000 inhabitants by the end of 2007



However, today Denmark has the lowest energy consumption per unit GDP of all countries in EU. This has been achieved by implementing over the last 30 years considerable savings in energy consumption in various sectors and by enhancing the efficiency of energy supplies and production, including through the increased use of combined heat and power production (Government 2008).

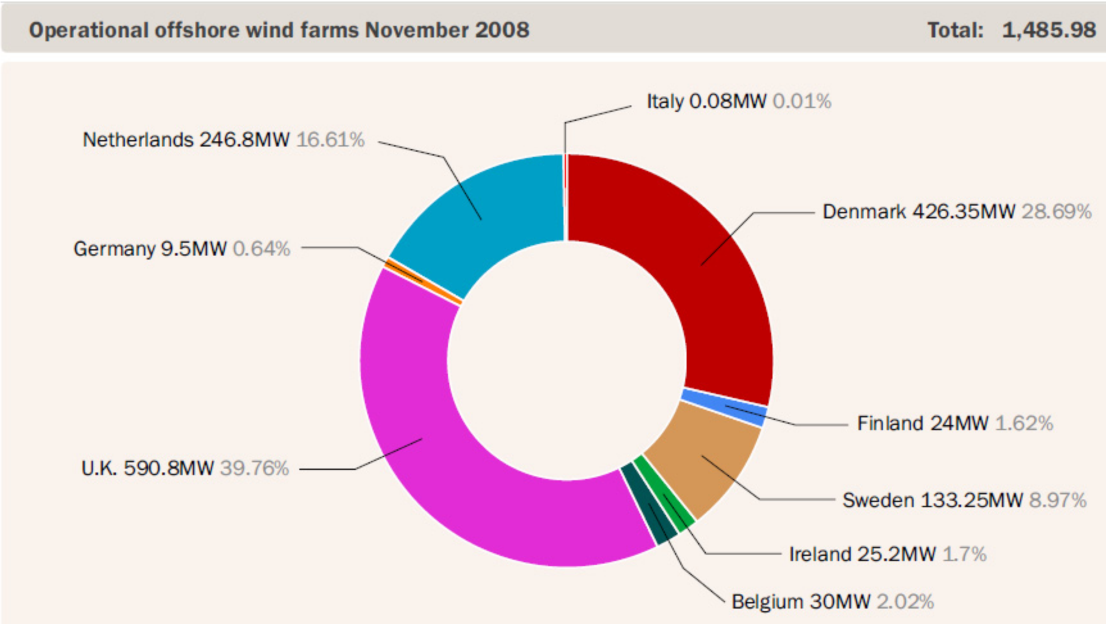
Figure 5.43 Onshore wind share of electricity demand by the end of 2007



Source: (EWEA 2007b)

As discussed earlier, the offshore wind industry comprises a lot of future challenges. It is already considered a separate, niche market within the wind power industry. The continued expansion of offshore wind turbine facilities will make an important contribution in achieving renewable energy targets. The work of offering two offshore wind turbine farms of 200 MW each or possibly one farm of 400 MW started in 2008 with a view to commissioning them in 2012 (Government 2008).

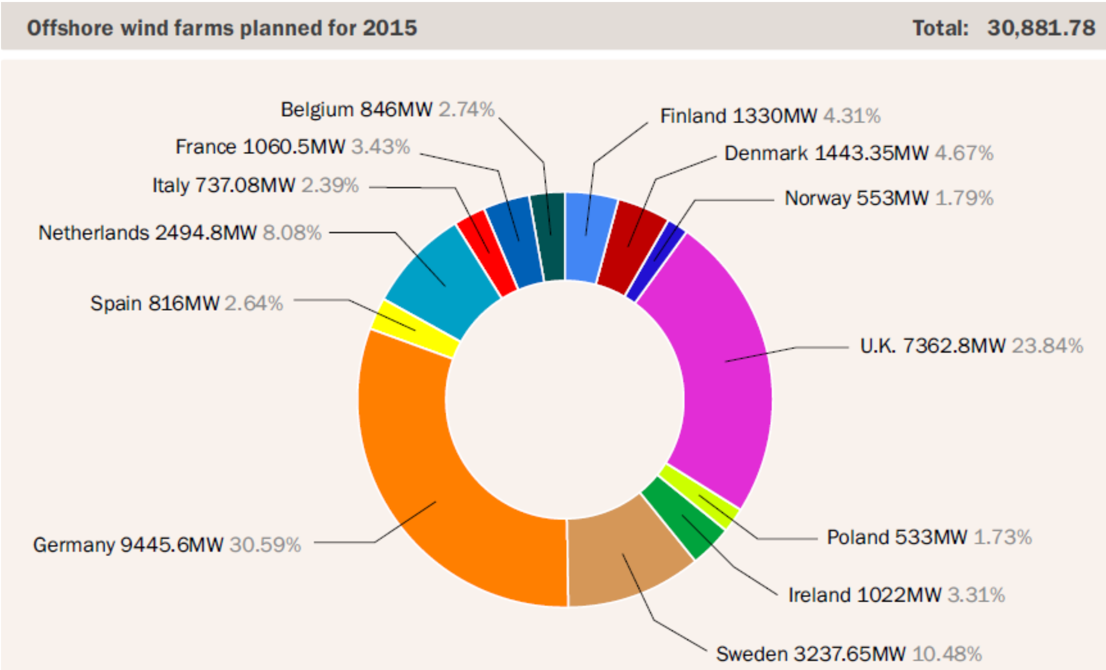
Figure 5.44 Installed offshore wind farms in Europe



Source: (EWEA 2008)

The decrease of the installed onshore capacity in wind power may be due to the fact that Denmark has limitations in placing onshore wind turbines; therefore the government, together with industry, has already planned for offshore wind turbine projects. Of course, the offshore plans had opponents as well, as in the case of onshore turbines at the beginning, saying that offshore farms are harming the environment of the sea, but there had to be an agreement because wind power is needed in Denmark. As a result, by the end of 2007 Denmark had 426.35 MW offshore installed capacities, occupying the second place after the UK. (Figure 5.44, Figure H in Appendix). This capacity looks great in the beginning, but it is not enough for Denmark to maintain its competitiveness in the industry. Looking at the following figure, offshore wind farm projects planned for 2015 increase the wind capacity by approximately 5% Europe-wide compared to the 2008 capacity.

Figure 5.45 Offshore planned wind farms in Europe by 2015

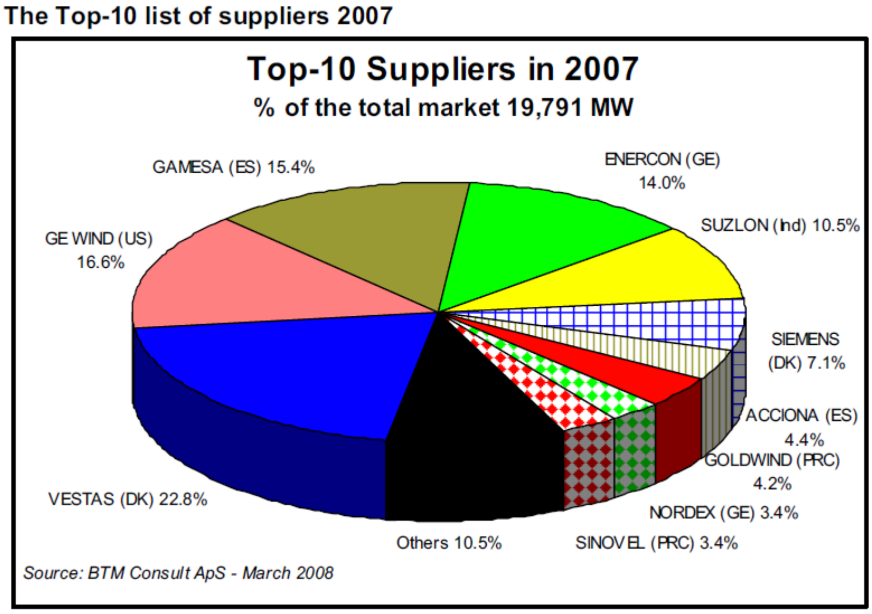


Source: (EWEA 2008)

According to the above figure, Germany seems to be the biggest player in this future projection, with more than 30% of the total European installed offshore wind power capacity, followed by the UK with almost 24%, then Sweden, the Netherlands and finally Denmark with almost 5%. Comparing the two figures (Figure 5.44 and Figure 5.45), each country is planning to install around 1000 MW of offshore turbines.

In terms of the global market share in supplying wind turbines, Denmark still has first place on the global market, but it has to take into consideration its rivals as well, such as Spain, Germany, the US and India (Figure 5.46). In 2007, over 20.000 MW of wind power was installed, which means an increase of 31% compared with the 2006 market, and represents an overall increase in global installed capacity of about 27%. The leaders in these numbers were the US, China and Spain. Overall, US wind power generating capacity grew 45% in 2007. It can be expected that the US will overtake Germany as the leader on wind energy by the end of 2009 (GWEC 2007).

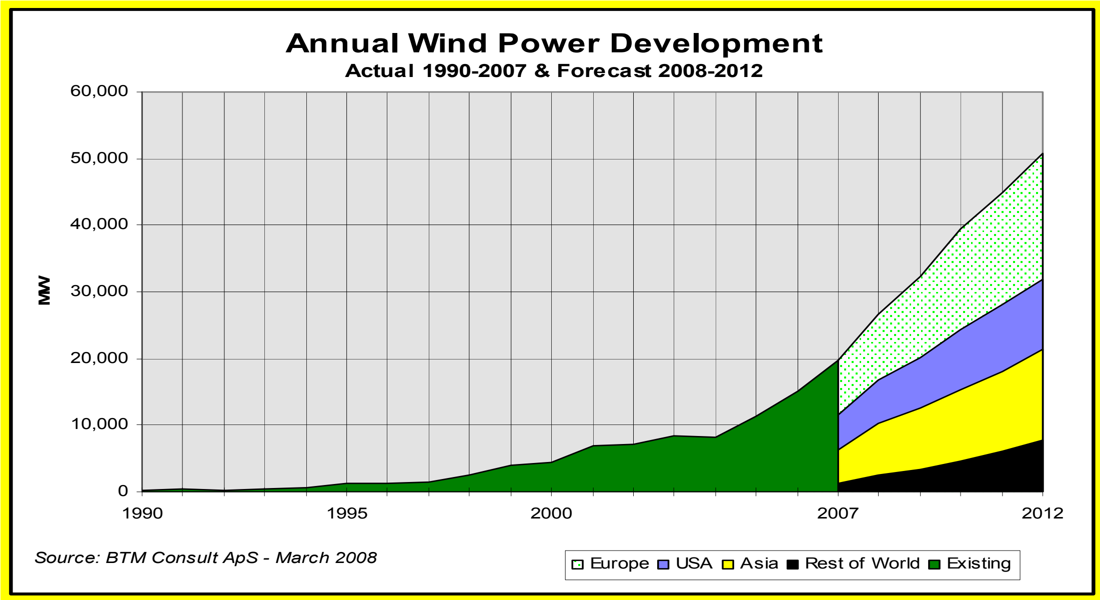
Figure 5.46 The world leading suppliers in wind technology



Source: (Krogsgaard, Madsen 2008)

China has increased its annual installations by an average of 93% per year since 2004. China makes remarkable progress in building up its own wind industry – including the related supply chain for key-components (Krogsgaard, Madsen 2008). According to the expectations presented in the above figure, the Asian wind industry will cover almost the same amount of the market as the European, leaving the US and the rest of the world behind. China made incredible progress during 2007, it showed a growth of 156% over 2006, and it ranked fifth in installed wind energy capacity at the end of 2007. Based on this growth rate, the Chinese Renewable Energy Industry Association forecasts a capacity of around 50.000 MW by 2015 (GWEC 2007). "The growing wind power market in China has also encouraged domestic production of wind turbines, and they now have more than 40 domestic companies involved in manufacturing. In 2007, domestic products accounted for 56% of the annual market, compared to 41% in 2006" said Li Junfeng, Secretary General of the Chinese Renewable Energy Industry Association (GWEC 2007).

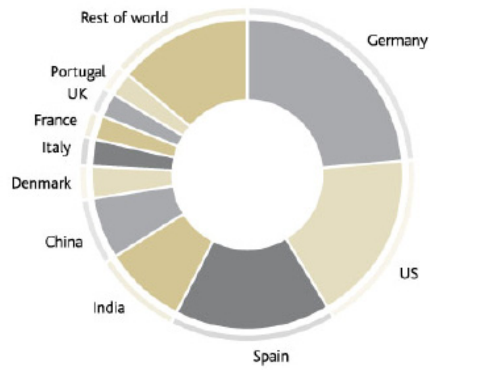
Figure 5.47 Wind power development: past data and future expectations



The future looks bright for the global wind power energy industry. In its revised 5-year forecast until 2012, a significant growth is expected. In the past 5 years the average growth in new installation annually has been 22.3% per year, while until 2012 an annual growth rate of 20.7% per year is expected (Krogsgaard, Madsen 2008).

The big surprise was Spain with more than 3.500 MW of new capacity installed in 2007, earning its second place globally after the US. Total installed wind energy capacity stood at over 15 GW in Spain. While Europe remains the leading market for wind energy, new installations represented just 43% of the global total, down from nearly 75% in 2004. For the first time in decades, more than 50% of the annual wind market was outside Europe, and this trend is likely to continue in the future. The Middle East and North Africa region increased its wind power installations by 42%, reaching 534 MW by the end of 2007 (GWEC 2007).

Figure 5.48 Top 10 total installed wind power capacity by the end of 2007



	MW	%
Germany	22,247	23.6
US	16,818	17.9
Spain	15,145	16.1
India	8,000	8.5
China	6,050	6.4
Denmark	3,125	3.3
Italy	2,726	2.9
France	2,454	2.6
UK	2,389	2.5
Portugal	2,150	2.3
Rest of world	13,008	13.8
Total top 10	**81,104**	**86.2**
Total	**94,112**	**100.0**

Source: (GWEC 2007)

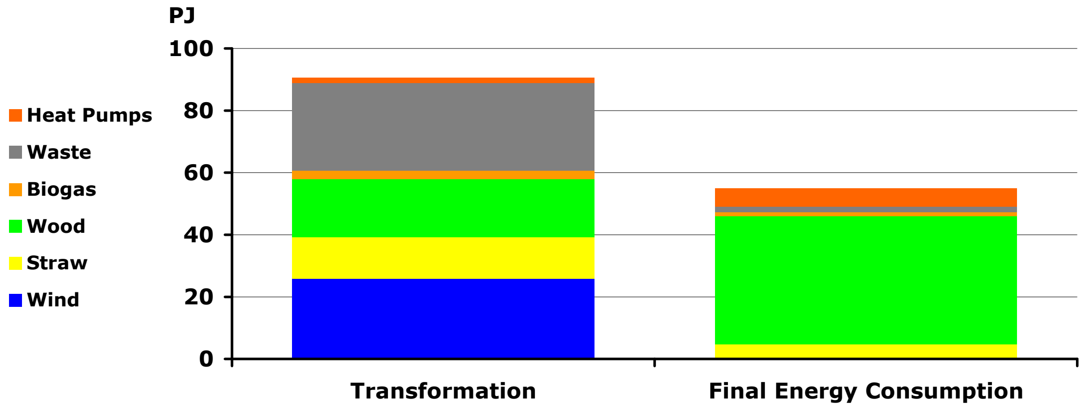
This might be the reason why European manufacturers are relying on North America. Already Vestas has announced a new assembly plant in Portland, Oregon, the Green capital of the country. Danish companies are being forced like never before, to move overseas (Gipe 2001). Status by end of 2007 shows that year 2007 was the year with the highest installation ever. There was 19.791 MW installed worldwide, which resulted in the accumulated installation worldwide making up 94.000 MW (Krogsgaard, Madsen 2008).

5.4.4.2 Consumer power

There is not much data available for the last period of the analysis; however some predictions can be made, which include goals of the future. By 2030, 50% of Danish electricity consumption should come from renewable energies, in particular 4.000 MW of offshore wind power. This means that around 40-50% of wind power energy will be supplying the electricity consumption (DWIA 2000).

The following figure emphasizes that waste and wind are the most commonly used renewable energy types in Denmark. The more than 20 PJ wind power energy that was produced in 2007, has also been used for supplying the electricity consumption.

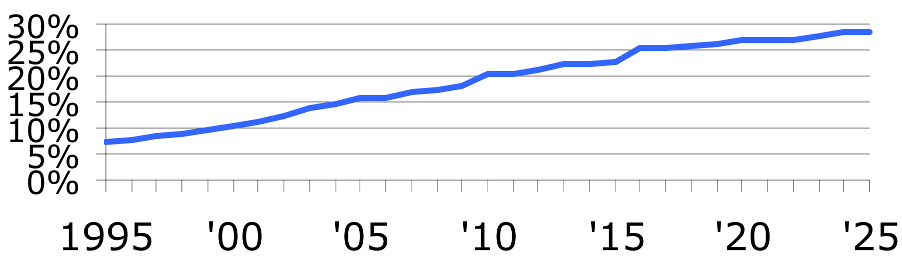
Figure 5.49 Use of renewable energy in 2007



Source: (Danish Energy Agency 2007)

The next figure is also a representation of renewable energy consumption as a share of gross energy consumption, without specifying the different energy types that are provided for use. In the future, we can expect for an increase in the share of renewable energies in gross energy consumption

Figure 5.50 Consumption of renewable energy-share of gross energy consumption.



Source: (Danish Energy Agency 2007)

Having seen both the supply and demand side the installed wind power capacity, and the produced wind turbines, it can be said that Denmark is very strong in producing wind turbines and exporting them to other countries, but in terms of installing them, is lagging far behind.

5.4.4.3 Substitutes

Solar energy is definitely not a threat to the wind power industry. The biomass type energy resources could, however, represent a threat, but they are different energy types compared to wind power. The future energy sources, which are still in experimental and testing phases, could, however, be a threat to wind power in a longer time frame.

As interesting as it seems, the offshore wind energy is taking serious steps in the development of the wind industry, so it might be possible to acknowledge some competition between the onshore and offshore wind energy in the near future. Onshore wind turbines are limited by space on land for erecting the turbines, but they have a "first mover's advantage" and experience in technology, while the offshore wind turbines are only limited by the bounded rationality of the scientists, engineers, etc. who have to overcome the challenges of placing the turbines in water, with challenging environmental conditions.

5.4.4.4 Entry / Exit barriers

Since 2007 there has been a change in the Government and a separate Ministry of Climate and Environment has taken over the guidance in climate and energy issues. As predicted before, the two types of wind turbines (offshore and onshore) have taken new directions. Therefore, the new government has appointed two different committees, one to examine the future location of offshore wind turbines and the other the planning of future onshore wind turbines (Government 2007). In the future it is expected that much change will be seen. It is hard to predict in which ways this will happen because the government has defined some measures that promote not only wind energy, but also biogas, bio fuel, hydrogen powered cars, heat pumps and waste energy. Therefore, the wind turbine industry will have to be very competitive with the other renewable energy types.

In conclusion, it can be said that if Denmark wants a competitive position on the international market in supplying wind turbines, it has to take certain and proactive decisions in terms of future projects. Unfortunately, Denmark has lost its competitiveness towards Germany, the US, Spain and India, etc. in installations.

5.5 Summary of the analysis

The answer to the first question (**How was it possible for Denmark to sustain its global competitiveness in the wind turbine industry during the analyzed period?**) is based on the past events in the Danish wind power energy industry, and there are more or less obvious solutions to this question. The answer to the second research question (**How will the shift in energy policy after 2007 influence the wind power industry?**) relies on future prognosis, which is hard to estimate. However, based on past experiments; solutions to it will be given as well.

Going through the analysis, it became clear that Denmark had a very competitive wind turbine industry until the beginning of the 21st century. It was competitive in **wind turbine manufacturing**, **wind turbine installations** and **exports** as well. However, after 2001, Danish competitiveness can be measured only in **the supply of the wind turbines** to the global market, the **wind power share in the electricity production** and a slight competitiveness in the **cumulative installed capacity** of the wind turbines. In the domestic installed capacity Denmark has lost its leadership to Germany, the UK, Spain and a few others. Denmark was doing well in the first period, but after 2002 the country had its weakest performance, yet. The cumulative installed capacity hardly achieved 1.5% between 2002 and 2007. What were the reasons behind such a development? The following part of the chapter will cover some of these observations.

First a technological base for the development of the wind turbine industry was formed. The major developments were provoked by technological innovations in the *first period* of the analysis. Together with the development of the better performing wind turbines, the infrastructure also reached the stage where the industry began to exist. By the early 1980s it could produce wind turbines by mass production for the US. This represented an important step and incentive for the further development. It was a success for the industry. However, looking over the whole period, development was always caused by a previous "crisis situation", that transformed the individual powers into a much stronger collective power that reacted in order to solve the situation. For instance, there had to be two oil crises to wake people up and start working against the oil dependency. There had to be catastrophic events and extreme climate conditions to start acting against the global warming effect. The initial success might be due to the fact, that projects were **planned** for **longer periods of time** (10 years), the legislation was also very stable, changing the rules in 5 year increments, which made a quite **stable political environment** for the investments. As a result of this, at the beginning there was a very **competitive supplier** side of the industry against **the strong demand** from both domestic and external partners. Therefore many companies saw an opportunity and entered into the industry. As the demand side became weaker, the subsidies ran out and the feed-in tariff system was also changed (2003), the suppliers decreased in number, and only two big companies survived the changes, which created a **concentrated supplier side**. (This description is represents the *second period)*. The reasons behind the decrease in the installed wind turbines could be manifold.

The majority of the professionals in the industry are of the opinion that this weak performance is due to the changes in the government (the Ministry of Energy and the Ministry of Environment were merged) and the loss of focus on the renewable energies, as well as the end of the subsidized period, which had multiple effects all over the industry. Loosing the strength of domestic demand was also among the reasons, which could have been provoked by the so widely defined targets.

The abundance of so many new laws and rules after 1995 increased uncertainty among investors and led to a very complex institutional system, which shadowed the transparency.

Another reason behind the decreasing installed capacities could have been the liberalization of the electricity market. The wind power industry was subsidized from 1981 for the investments made in turbines and power production. At the end of 2002, these subsidies were abandoned, and only the private wind-power producers, who made their investment decisions in the pre-market regime, were offered subsidies for a ten year period. After the electricity reform, the subsidies are paid by the electricity customers through the transmission and distribution price and they were quite stable in 2001-2004. Wind power production increased by 50% during that period; this implies that the customers pay a relatively lower subsidy per kWh of electricity consumed. To counteract the decreasing number of wind turbine installations, the government decided (2005) to pay for the CO_2 permits in cases where the emissions are over a certain limit. In this way the competitiveness of the fossil fuel based technologies decreased against the wind power technology. It is a hope that the loss of pre-reform subsidies will be counterbalanced by a gain from the introduction of a market-based mechanism (Munksgaard, Schioppfe 2006).

The second period contains a success story related to the **wind power share in electricity consumption** in Denmark, which is the highest among the European countries. The target was achieved sooner than expected in 2002, and therefore they have increased it to 21% by 2003 (Krohn 2008).

The *third period* is characterized by an industry grown to global sizes; the two major companies (Siemens and Vestas) take 30% of global market share, which means that they are doing extremely well in the turbine production and export. Their success is the result of a cumulative process of learning throughout the years. They have gained experience by starting the production of turbines from small sizes, such as 30 kW, and increased them step by step as technological developments emerged. Major beneficial effects can be accounted for, from external demand that kept the production continuous, and the networking effect, which shared the knowledge and information among the buyers and producers. Probably the most important proactive influence came from the Risø National Laboratory that carried out tests, experiments and research on turbines and played a controlling role in the industry. In the present day, it has widened its activities towards more research in the field of renewable technologies.

The effect of the organisations on Danish competitiveness has not been mentioned yet, but it is obvious that behind each and every action there is an organisational form that supports the activities. I would like to emphasize the organizations' characteristics and "behaviour" during the analysed periods. The Danish ownership of the turbines represents a unique form of ownership that is not quite as common in other countries, maybe because the wind industry does not have such a long history in those countries. Since the costs of erecting wind turbines were very high, Danes applied a specific organisational form in this respect, the so called "co-operative wind farms", where one wind turbine had many owners. Thus, they could afford to build wind farms in the permitted sites. This could only have been possible due to the social cohesion and the unique combination of formal and informal institutional system that existed in Denmark in that period of time. Due to the large membership of the Wind Turbine Owner's Association, the development of the industry could be (and still is) sustained over longer periods compared to other countries.

The answer to the second question is only deductible from the promises and goals that were set in 2007 by the Danish Ministry of Climate and Energy, certainly taking into consideration the global economical and political conditions too.

The new energy policy challenge and objective refers to climate change; security of supply and economic costs. Denmark has a good foundation upon which to start meeting these challenges. Its energy consumption is low compared with the level of economic activity (the overall target is to reduce the total energy consumption by 2% in 2011 and by 4% in 2020 compared with 2006 consumption); it has a modern energy sector with a large proportion of renewable energy and a well-developed infrastructure. In the short term the energy supplies are more than self-sufficient, in particular as a result of oil and natural gas production in the North Sea (Government 2008).

In order to meet the long term challenges, efforts will have to be increased in coming years. The areas affected by the new policy are: energy savings (under the Danish energy policy agreement for 2008-2011 annual savings in final consumption will increase to 1.5%) and enhancement of energy efficiency, increased use of renewable energy (the overall target is to increase the use of renewable energy to 20% of gross energy consumption in 2011) and technological development. Our research question is closer to the last two areas. The policy states: *"The use of renewable energy and other environmentally friendly types of energy must continue to grow. This is a precondition if we are to move towards the Government's long-term goal of Denmark becoming independent of fossil fuels in the longer term. The increasing shares of renewable energy must be adapted as efficiently as possible to the energy markets, while at the same time ensuring efficient competition and continued high security of supply"* (Government 2008).

The Energy Policy Statement from 2007 is very similar to the one from 2008, stating that the wind power technology plays a crucial role in the current renewable energy supplies and undergoes constant development (Government 2007). According to this statement, the governmental measures are manifold: beside the wind turbine development, they refer to different renewable energy sources, such as: biomass, bio-fuels, waste treatment, hydrogen powered cars and heat pumps. In general, renewable energy subsidies are increasing, among others those supporting the expansion of onshore and offshore wind energy installations, the increased use of biomass in power stations and the continued expansion of biogas facilities. Therefore, the wind industry has to prepare itself for serious competition with other renewable energies.

For this reason, the "Mega-wind partnership" project in 2006 was adopted, which develops new shared strategy for research and innovation in wind power to promote eco-efficient technology. The Danish government in its 2008 policy statement supports (through continued increased investment) research, development and demonstration of cost effective technologies, which "reduce energy consumption and enhance the efficiency of energy production technologies, which can increase the use of renewable and environmentally friendly energy sources in a cost effective manner" (Government 2008).

From a global point of view, the Danish experience and knowledge accumulated over the years will serve other markets, because each new market benefits from the experience of older markets. It is taking less and less time for new markets to reach a 2.000 MW threshold. Newer markets begin with better technology and much larger turbines than older markets. It took Denmark 16 years to reach 2.000 MW; Germany, 7 years; and Spain, only 5 years. As Texas demonstrates, markets today can top 2.000 MW in three years or less (Gipe 2001). This is a necessary misconduct of the industry, which threatens Denmark's competitiveness in the future. To explain the "necessary misconduct" term: the gains made through technological progress are necessary for industrial development, but also have a malicious effect on Danish industry, because the newly born wind turbine industries in other countries can easily overtake the knowledge that has been accumulated during the years in Denmark, through purchased products, through the international affiliates that the Danish companies have, and through the migration and exchange of employees. So, due to the fast growing knowledge and technology diffusion, Denmark will have to face strong competition posed by countries which don't have such a long experimental history in their background. This feels like unfair competition from the Danish point of view.

6 LEARNING IN THE DANISH WIND POWER ENERGY SYSTEM

This chapter includes some general reflection on the notion of "learning", emphasizing it with examples from the Danish wind power energy industry. From the general presentation of learning, the topic narrows to the notion of "policy learning". It also gives a general solution to the third research question.

The role of this chapter is to transpose the findings of the historical analysis into some theoretical approaches, which have the notion of "learning" at the centre.

The Danish wind turbine industry went through a learning process, which is based on knowledge creation and destruction. In order to reach the present state, individuals and organisations needed to renew their competencies (Gregersen, Johnson 2000). The speed of the competence renewal depends on the economic dynamics in general. Thus individuals, firms and even countries have to face major challenges in finding their abilities in this regard, which are crucial for their competitiveness. Learning is very closely related to innovation, therefore innovation is regarded as the "results of learning" (Gregersen, Johnson 2000). Learning as a result is the outcome of the creation, distribution and use of knowledge in a system characterised by dynamism and interaction between its elements. When the knowledge transforms into a valuable result (innovation), it also sustains the competitiveness of that system. Thus, the system's competitiveness can be influenced by the learning process. This process could be seen happening during the analysis of the Danish wind turbine industry and it answers the first part of the third research question.

The Danish wind turbine sector was affected by the way in which the institutional supporting system was built up. First there was the willingness and curiosity of some academics of the time to experiment with wind turbines, then a need was created for independent energy creation, which was an external driving force. Later, the government got involved in supporting the wind turbine experiments, a market was created with proponents and opponents; and, thus step by step a specialized sector/industry was formed. *"Infrastructures, production structures, institutional set-ups, consumer demand structures, and government policies ...are interdependent and they evolve in interaction with each other"* (Gregersen, Johnson 2000). Learning in the wind turbine industry is characterised by a cumulative and also unplanned process. Some results were achieved accidentally, so it cannot be said that the industry developed according to a strongly planned strategy. For instance, the wind turbine manufacturing firms originally were producing agricultural machines, but due to the changing economic environment, they saw an opportunity to produce wind turbines and they switched to it. The unplanned learning usually occurs through different ways: learning by searching, learning by doing, learning by using and learning by interacting. These four types of learning have been tested by a number of researchers in order to see which method most influenced the emerging wind turbine industry in Denmark[17] (Kamp, Smits & Andriesse 2004).

Looking at all of these from the perspective of learning methods in Denmark, first the beneficial effect of learning by interacting and learning by using must be noticed. The subsidies for investments were created at an early stage (1979), which created a relatively large user group (Kamp, Smits & Andriesse 2004). This strong demand at the beginning gave a boost to the industry and provided the opportunity to produce many turbines, and these turbines were improved (learning by using) step-by step by the increase in the production number. This effect was combined with the fact that users and producers organised themselves to associations, and there was continuous communication between the two groups. Knowledge about wind turbine manufacturing was cumulated over time by the actors involved (users, producers and, later, researchers). "The researchers operated on the same cognitive level as the producers and shared the same frame of meaning regarding wind energy" instead of in the Dutch case, where researchers were ahead the producers of the turbines from the very beginning of the emergence of the industry (Kamp, Smits & Andriesse 2004). So, turbine design became a more R&D based and formalised process from the initial

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[17] The research was conducted parallel for Denmark and the Netherlands.

trial-and-error stage, with the emergence of the Risø research centre, which kept a close relationship with the producers and offered them the knowledge they needed at that particular moment. Therefore, learning by searching gradually came into the picture. This order of learning proved to be beneficial to the Danish wind industry innovation system. By achieving good results through this order of learning, it emphasizes the failure of the Dutch wind power industry[18], where learning happened in a different way. “This co-evolution of knowledge demand and knowledge supply from down-to earth hands-on knowledge to more formal R&D-based knowledge in Denmark is in large contrast with the Netherlands, where a gap remained between the science-based knowledge supply and the more practical knowledge demand” (Kamp, Smits & Andriesse 2004).

In order to form a quite complete picture about the wind turbine industry in Denmark, it was necessary to analyse it using the innovation system approach, specifically the sectoral systems of innovation combined with Porter’s competitive advantage theory. This concept offered the possibility of acknowledging not only the innovation policy, but also energy and environmental policies too, and other factors that have an impact on innovation performance. For instance, the informal institutions such as norms of co-operation, habits of trust, collective and non-monetary incentives, may influence innovations in the same way as formal institutions like patent rights, taxation and subsidies do (Gregersen, Johnson 2000).

The main findings of the analysis regarding the first research question (**How was possible for Denmark to sustain its global wind power energy competitiveness during the last three decades?**) refer to the fact that Denmark gained a competitive advantage through the years due to the knowledge that resulted and accumulated from the many trials met during the experimentation period with turbines. This knowledge was shared among the interested actors and it was improved by the feed-back received from a very sophisticated demand group. Other factors such as trust and common willingness of people interested in wind turbine production also contributed to the learning success. There was an informal institutional set up that drove the manufacturers of wind turbines to global competitiveness. Social cohesion,

[18] However, it cannot be stated that only a certain order of learning methods is contributing to the emergence of the industry. It would be a more accurate such statement if there had been other countries involved in this comparative analysis.

which is specific to Danish society, played an important role in the developmental process. Unfortunately, the social cohesion effect seems to have started to disappear as a result of continuously emerging globalisation. Therefore, another factor must substitute it, which is the governmental intervention. It is becoming more important in sustaining industry growth. Thus, “policy learning”[19] achieves more importance, which represents a new approach to economic development, contributing to the formation of the learning economy.

Policy learning in the wind turbine industry covers more policy areas, from energy saving and consumption policies; to energy efficiency policies; climate policies; and to policies regarding constructions and buildings. These policies are both of short and long term and their goal is to improve the performance of the whole economy. Therefore, they are part of the economic policy. The short term policies refer to employment, price levels, balance of payments, etc. while the long term policies aim are to achieve economic growth without harming the society or the environment (Gregersen, Johnson 2000).

According to the above-mentioned academics, policy learning is a kind of policy making that differs from the rational policy designing method.

Rational policy making has a framework which is applied when making policies. First there has to be a well defined goal in the centre of the policy making process, then well defined instruments must exist, being used as a tool for the policy making; information that will be processed by the instruments must be available, and the way in which these instruments work should be also defined. Since policies are designed for future events, there must be a model describing the “structure, functioning and change of the economy” (Gregersen, Johnson 2000). Another element of the framework are: organisations, (such as ministries and government departments), where a group of adequately educated and experienced civil servants have the ability to prepare, implement, control and follow up policy decisions (Gregersen, Johnson 2000). Using a simple expression, the rational policy making process needs institutional capability (Gregersen, Johnson 2000). But policy making

[19] The notion of “policy learning” is taken from my professors, academic researchers: Birgitte Gregersen and Björn Johnson.

cannot be based just on cold rational calculations, choices or decisions driven by explicit knowledge, it must also contain tacit knowledge.

Policy learning compared to rational policy making is a more complex process that is embedded in the learning economy. Another difference between the policy making and policy learning is that the learning process takes up a longer period, an undefined timescale during which the elements of the institutional capability are continuously changing and they develop in interaction with each other (Gregersen, Johnson 2000). Therefore, the results (different norms, rules and laws) are also changing. This learning process can be influenced by different combinations of the elements in the institutional capability framework with the forecasted results, which is called "direct policy learning". However, sometimes learning can be accidental, unplanned (Gregersen, Johnson 2000), a positive externality of the learning process, called "indirect policy making". The direct and indirect way of policy design has been discussed by other authors too, taking innovation policies as an example.

Innovation policies present the learning pattern of how to do new things in new ways (Edquist et al. 1998). These patterns are different in each innovation system and each context. Therefore, there is no such a thing "best practice" that can be applied to any kind of innovation system (Lundvall, Borrás 2005). In this respect, learning has two important elements discussed by the author. "First, there are policies designed at the process of learning itself. In reality, innovation policies support many different types of learning processes, however, the interactive learning should be targeted more directly" (Edquist et al. 1998) this was the case in the late '90s. Second, the innovation policy design should be considered as a process of learning. Thus, the institutions and organizations, theories and data bases related to the innovation policy would be developed gradually through the feed-back from the performance of innovation policy (Edquist et al. 1998). The feed-back mechanisms are in a way the drivers of the changes within the elements of the IS approach, and this process actually becomes policy learning. Since learning takes place in interaction with people and organizations, "social power" including "trust, power and loyalty contributes to the outcome of the learning processes". Therefore innovation policy needs to take the broader social framework into account, even if the objective is one of an economic type (Lundvall, Borrás 2005).

In relation to innovation policy, policy learning can take different forms. According to the authors (Gregersen, Johnson 2000) the following forms may be relevant:

Table 6.1 Different forms of policy learning

"Forming visions about the learning economy as an environment for learning, innovation and sustainable growth and clarifying the value premises of innovation policy.

Development of new concepts, data and theories of innovation and systems of innovation.

Institution building that supports the production and reproduction of social and human capital and locating and diffusing international, regional and local "good practices" in this field.

Stimulating regional and local experiments in policy areas in need of reform and developing new methods to evaluate the outcomes of such experiments that take into account learning effects.

Gradually trying, testing, evaluating and establishing new practices and routines in the conduct of policies stimulating learning and innovation.

Analysing and comparing systemic features and critically important indicators in a form for benchmarking across regions, organisations and nations.

Developing new forms of democratic participation in the design and implementation of innovation strategies including forms of ongoing dialogues between employees, unions, researchers and governments."

Source: (Gregersen, Johnson 2000)

In the following, some examples of the policy learning forms from the history of the Danish wind turbine industry will be given. It is certain that policy learning within the industry has happened in both ways: through direct and indirect methods.

At the beginning of the industry formation, the notions of "learning economy", "innovations" and "innovation policy" were very distant from the academics of the time. The vision that spurred the development of the turbines was the willingness and curiosity of some people to make energy out of wind. But the initial turbines of the time did not prove to be economically feasible and the visions were dropped for a while. A change in the economy (the oil crisis) that turned the view back to independent energy generation methods was needed. Later, other concerns (like climate change and emission targets) contributed to the promotion of the wind turbine development. If we carefully follow the appearance of the new policies, we can remark upon a gradual broadening in their area of action. Wind power was included in the energy system along with conventional energies, and also environmental concerns, which were of the nature of energy savings and malefic gas emissions. As the requirements increased, the technology had to develop accordingly, contributing to the formation of new data, new concepts and new products. The dynamics of the learning economy has “pushed” the wind turbine industry into a system, which later was called an innovation system, and wind power policy became a part of industrial policy (Gregersen, Johnson 2000).

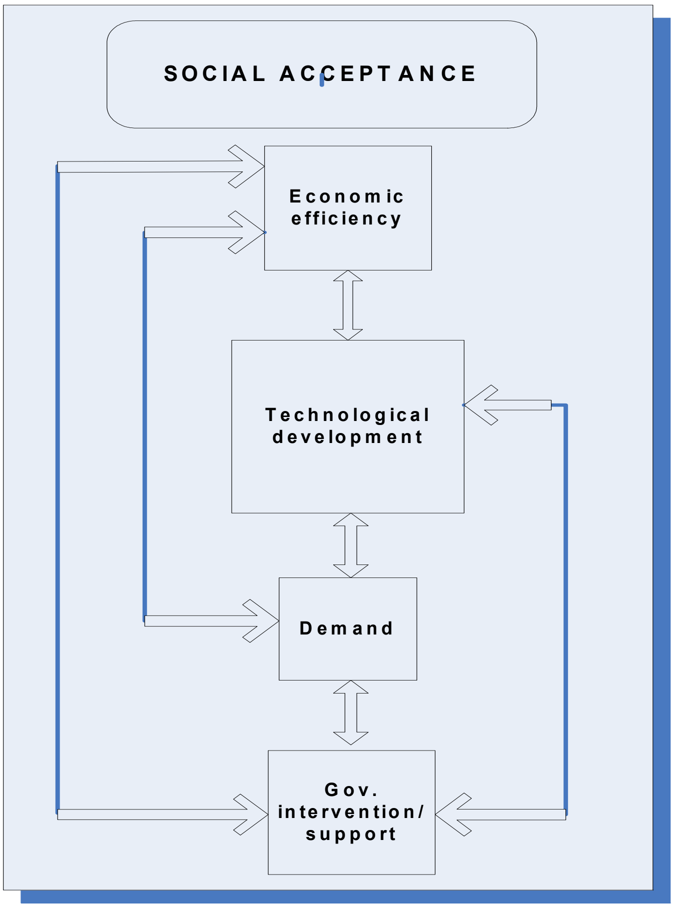
The best example for the institution building type of policy learning is the “Risø” Research Laboratory, which plays many major roles in relation to wind power: it certifies the safety and performance of wind turbines; it acts as an intermediary in knowledge sharing between the manufacturers, and the owners, researchers and the government. It is also a place where human and social capital is formed.

The Danish wind power industry does not lack experimentation with different policy measures and methods of evaluating the outcomes of these measures. To mention some examples: the electricity reform, which came from pressure from European forces to liberalize the electricity system, influenced the development of wind power industry. A later, but very debatable reform was the introduction of green certificate system in Denmark, which took up quite a long experimentation period and it still does not provide any proof of its beneficial effect.

At the beginning of the analysis there was almost no such thing as comparison of the Danish wind turbine industry with other nation’s wind industry, because Denmark was a first mover in this field, and other countries, even if they tried to develop turbines, failed and abandoned their plans. Later, on the other hand, different statistics based on specific indicators were collected and issued by the turbine manufacturers’ organization, by Risø research center, by governmental organizations (EU statistic office) and by businesses (BTM Consult, etc.). These were issued in different periodicals, where the data and information was shared with everybody interested in it. Today, the most frequently used indicators globally are the wind turbine market share, newly installed wind capacity, and the cumulative installed wind capacity, according to which the countries are ranked worldwide.

The specificity of the Danish wind turbine industry relies in a way on the last policy learning type, according to which new innovation strategies have been designed and introduced in a democratic manner. All the parties (government, public opinion, researchers, and manufacturers) had the chance and right to influence the decisions in one way or another (Eg. The anti-nuclear movement; insurance issues; price settings, etc.).

Figure 6.1 Factors contributing to the sustain of a competitive advantage and the collaboration links among them



Further, the chapter focuses on the conditions which make learning to happen in a changing environment. Using the multi-level theoretical framework, the historical analysis provided to be a good overview of the wind turbine industry, reflecting on technological, economical, political and social conditions that have continuously changed over the three periods. If we had to define a general framework that contributes to the competitiveness of the industry under a changing environment, it should contain a mix of the four areas mentioned before and the framework could be visualized according to Figure 6.1 on the right.

Starting from the very beginning, wind turbine producers focused on improving the capacity of wind mills so that they become more efficient economically. So the costs of the energy produced would be competitive with energy produced from the fossil fuels. This aim was achieved with relatively good rates, when people decided to invest in such turbines, because it was worth it. Therefore, the first condition is the **economic efficiency**.

Next, due to the high domestic and international demand of the wind turbines ("demand-pull" effect) and the collaboration with the Risø research centre, the turbines were technologically improved step-by-step as they were rising on the learning curve. The technological development gave an extra boost to economic efficiency, where the costs of producing turbines were reduced. Also, the cost of energy production has fallen, due to the continuously increasing wind turbine capacities that have been achieved. So, as a second condition **technology must co-evolve together with economic efficiency**. There has to be a **"demand-pull"** factor that sustains mass production. In other words, a breakthrough technology that proves economically unfeasible won't be accepted.

The third condition is related to the political aspects. During the analysis on the Danish wind turbine industry (but also that of other countries), the **connectedness** and **proactive approach** of the government proved to be fruitful for the development of the industry. The demand that was created by the Danish and Californian governments through subsidies was the main driving force behind the economical and technological achievements, as Figure 6.1 shows. However, government force alone is not enough for such improvements. It is necessary that there is a co-evolution and strong linkages of the above conditions.

The last condition is related to a factor that has not been analyzed by many academics and researchers; it is a condition that is embedded in the country's institutional set-up, its culture and the inhabitants' behaviour. This is the **social aspect** of the wind turbine industry. Although some social costs have been noted by many analysts, such as environmental costs of the planning process concerning the landscape, amenity and the preservation of biodiversity, more research is required to understand the societal issues related to wind power. Social costs were reduced by the introduction of feed-in tariffs, which carried social acceptance by allowing large numbers of small investors to enter the wind market[20] (Szarka 2006). However, the

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[20] If someone has a share in wind energy production and receives rent from it, that person accepts easier the negative impacts of turbines (noise, view, etc.).

causality between social acceptance and feed-in tariffs is not very clear. There are doubts around the fact that the "green" thinking values of investors have led to a widespread social acceptance of wind expansion, or it was the "rent-seeking behaviour" that promoted acceptance (Szarka 2006). According to this author it could have been both factors mutually reinforcing each other. This trend was convenient since it had the resulted in the expansion of the wind turbine industry. However, in the future the social acceptance will have to be revived somehow, because with the introduction of megawatt wind turbines and offshore turbines, small investors will gradually exit the industry because of the enormous investment costs that are required for such mega-projects. This scale of investment can only be undertaken by large companies and consortia. Thus, there is a desperate need to find other ways of enhancing community participation to build social acceptance. Society needs to be involved in decision-making processes and to be brought into active engagement in renewable projects (Szarka 2006). A number of ways are expressed by this author, but some of these are only in experimental phase so far. These ways are gathered in the following table.

Table 6.2 New ways of building social acceptance in the future

1. "Empowerment through decision-making: where the community votes on whether or not to proceed with a wind farm project.

2. Local community benefits: where a share of profits from wind farms are recycled in local projects via a community trust.

3. Local taxation: in France, wind farms, like other firms, pay a local business tax, known as the "taxe professionelle" revenue form, which can be considerable for a cash-strapped small commune and can be recycled to finance community schemes.

4. Incentives to local energy consumption: making 'green' energy available more readily and/or more cheaply to locals.

5. Economic regeneration: where profits from wind farms are used to stimulate local job creation in sectors other than electricity generation.

6. Environmental regeneration: where profits from wind farms are used to improve the ecological quality of surrounding land (e.g. in cases where it is degraded and low in biodiversity and/or amenity)".

Source: (Szarka 2006)

Overall, there is a need for more research on the social and environmental impact of wind. By explaining the importance of the social factor in sustaining the Danish wind turbine industry's competitiveness, the second part of the research question has been answered.

As a conclusion to policy learning, the learning process is hard to acknowledge because it happens either in an indirect/unplanned way, or it happens much time later than the policy was introduced, and during this period other changes, which hinder the possibility of following the direct impacts of the policy and its results might evolve. However, a new paradigm is required within renewable energies policy, within environmental policy: an approach in which social and economic interests are taken into consideration with equal weight. In terms of policy design and implementation, parties other than government need to be allowed in, such as businesses, non-governmental organizations and citizens (Szarka 2006).

As a final conclusion to this chapter and a solution to the research question: **"Under which conditions (social, economical, technological and political) can a country sustain/maintain its competitive advantage in a continuously changing environment?"** it could be said that in order to sustain a country's competitiveness in a changing environment, a "learning platform" must exist where economic efficiency, technological development/innovations, strong demand; governmental support and social acceptance. These factors must co-evolve and enforce each other as is shown in Figure 6.1, having a common goal. The co-evolution and enforcement need to be coordinated through the process of policy learning.

7 CONCLUSIONS

The purpose of this chapter is to summarize the objectives and the results of the report. It also brings into the focus the lessons that could and have been learnt during the development of the wind turbine industry.

Innovation as a process is embedded in a system characterised through the interaction and interdependence of the elements and the relationship between them as they contribute to the innovation (Edquist et al. 1998). Within the innovation system, one can identify the institutional system that each nation develops during its history for governing the markets of labour, land, capital and goods. "This national institutional structure shapes the dynamics of the political economy and sets boundaries within which government policies and corporate strategies are chosen" (Zysman 1994). The terms "innovations" and "policies" are related to the characteristics of the innovation process, which is the seed of this report. The innovation process is built up by complex feedback mechanisms that form the interactive relations between science, technology, learning, production, institutions, organizations, policy and demand (Edquist et al. 1998). This is a major advantage that the innovation systems approach offers. It also provides "sign-posts" that become important features of innovation processes. When analysing innovation systems or processes, these sign-posts represent the basis of comparison. Thus, they facilitate the analysis by suggesting where to look for the problems and possible solutions in innovation policy making (Edquist et al. 1998). Therefore, the innovation systems approach was a very useful tool for the present report. The reasonfor presenting the different kinds of innovation systems that were derived from the general discussion of systems of innovation approach and other static approaches was to lay down a base, which constituted the framework for the analysis of the Danish wind power energy system.

The objective of this project was to find out the causes of the sudden drop in the wind power energy industry after 2001. There has been a common acknowledgement that the changes in the Danish Government were the reason behind the retardation of the industry. However, the aim was to see if there were other factors involved in this or not. Therefore the research questions posed were:

1. **How was it possible for Denmark to sustain its global wind power energy competitiveness during the last three decades?**
2. **How will the shift in energy policy after 2007 influence the wind power industry**?
3. **Under which conditions (social, economic, technological and political) can a country like Denmark maintain its competitive advantage in a continuously-changing environment?**

In order to answer these questions, a combined theoretical approach, which contained the following approaches: innovation system (with emphasis on the sectoral systems of innovation), technological systems and Porter's industry analysis approach has been used.

Denmark's global leadership in manufacturing wind turbines dates back to the 80s, when half of the produced turbines were shifted to the US, which constituted the biggest external buyer power for the Danish industry. Denmark could also acknowledge a global leadership in domestic wind turbine installations (especially the installed turbines/1000 inhabitants) until the end of 2001. Since then, with the change in the Government, the industry has shifted its focal point towards producing turbines, but mostly for export. The reasons behind such a sudden turn in the wind power energy industry from 2001 are manifold. The Government's lack of interest had the most influential impact of wind power energy. Then, the subsidies for erecting turbines ran out at the beginning of the 90s and the feed-in tariff system also ended in 2003. Beside these facts, there are some other reasons that have contributed to the lack of wind installations. It was noted during the historical analysis that the goals set in the rules became wider and wider. So, focus was turned from renewable energy and was directed towards environmental issues. The liberalization of the electricity market caused very contradictory effects which created uncertainty on the market, especially for the investors. On one hand the reforms had ambitious objectives to increase renewable energy (especially wind power) rate; on the other hand it weakened the economic conditions for privately owned wind turbines. This led to contradiction and conflicts on the energy market (Lund 2000).

The reasons behind the global leadership in the turbine manufacturing and domestic installations until 2001 are also manifold. Here too, the supportive power of the Government had the most beneficial effect. To this fact contributed that the wind turbine industry was decentralized at the beginning, with turbines all over the country and having many owners. However they were organized into two associations (wind turbine owners and wind turbine manufacturers), which made an impressive improvement for the industry through their collaborative activity with each other and also with other organizations. If we follow their activity, these two associations had a major impact on the rules and laws that came into force as a result of their activities, which were preferable for the wind turbine industry. The analysis of the industry has shown that in the first period there was a very strong demand (domestic and external), created by governments (eg. Danish and Californian), which made the industry very competitive. However, as the global market looks at the moment, Denmark will have to compete with other countries such as China, in manufacturing wind turbines and with Germany, UK and Spain in the erection of wind turbines.

The success of the Danish wind power energy industry is due to long and meticulous planning, periods of trial and error with small scale wind turbines and a quite stable political environment. The Danish achievements could have only be realized in Denmark and not elsewhere. In the pattern of the success some of the informal institutions of Danish society are “hidden”. Such informal institutions are: collective will towards one goal, environmental friendly attitude, trust and persistence. Social cohesion, which existed in Denmark for long time, started to fade out with the emergence of the globalizing economy. This has to be protected in the future if Denmark wants to preserve its unique path towards the success. This requires that wind turbine ownership and the revenues from it should be spread out in the hands of the people and not be centralized for the big players who have the power to invest in wind turbines. In case this tendency happens to be promoted (it already started after 2003 with the two 160MW utility owned turbine constructions), the public will lose their interest in the wind turbine erection and this could provoke disasters for the industry.

All in all, the industry showed a cumulative increase during the first period, the diffusion of wind has been a non-linearly monotonous process (International Energy Agency 2007 in Agnolucci 2007).

Overall, it could be concluded, that there is no concrete sign or calculation to determine which factor caused the collapse or the development of the Danish wind industry, although one factor was constantly present in the reasoning, and that is **“uncertainty”.** Therefore, it is recommended that uncertainty should be avoided as much as possible for the sake of the industry’s future.

The answer to the second question is based on the promises and the goals that were set in 2007/2008 by the new Ministry of Climate and Energy. The new energy policy contains a wide set of targets: climate change, security of supply and economic costs. The long term targets refer to energy savings, the increase of shares of renewable energy in energy consumption, and reducing the GHG emissions. The precondition for these targets is to increase the production and use of all kinds of renewable energies and also to **find a link between the different types**. For instance, the electric car and the wind power energy[21]. If there is a link between them, maybe it will be easier in the future to switch between types/substitutes according to need. Therefore it wouldn’t be necessary to export the overload very cheaply or in other cases import expensive energy.

Denmark’s long term goal to be self sufficient by using renewable energies sets an impressive challenge for the wind energy sector, because wind power has a long history. Therefore, it is considered not necessary for it to be subsidized the way the new renewable energies (such as hydrogen, wave, etc.) are. It will take an effort to compete with these energies. So there is much potential for the wind energy sector in the future, but wind professionals must act quickly in order to win the competition on efficiency issues over the other renewable type of energies, which are and will be subsidized.

Competition can emerge not only from outside the wind power energy industry, but also inside it. The development of offshore wind turbines could reach to the stage where it would be more efficient than onshore ones, and in the long term it may even become a substitute for it.

Finally, the answer to the last research question is like a generalization of all the “sign posts” set during the analysis. It concludes that the principles which can be

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[21] The extra wind power energy produced can be used for charging the electric cars.

learned throughout the project, in order to maintain Danish competitiveness are: economic efficiency, technological development, strong demand, governmental support and social acceptance, guided by the policies in such a way that they can co-exist and co-evolve towards a carefully defined goal.

The Danish wind turbine success is also a story about how to balance the contrasting considerations of wind power and nature protection. Public planning and policy instruments to promote wind power and protect nature in a situation where a conflict exists between the two issues have been analyzed. The problem is solvable if technology development, the social organization related to the use of the technology, and proper planning are brought together to work in a spirit of local involvement (Christensen, Lund 1998 in Lund 2000).

Some authors say that, compared to other countries' wind energy programmes (eg. Sweden), the success of the Danish programmes were the result of having stable organisation with continuity and clearly stated goals (Carlman 1988).

With such results it can be said that the ways in which the theoretical framework was used to analyze the wind power energy industry has been a success. It allowed me to pursue the comparison between the different time periods and to mark those “sign-posts” which were important during the development of the industry. Through the method used, it was possible to show the relation between a policy and its impact on the industry and, in the same time, the industry’s market positioning and its competitive level was revealed. Light was also shed on other factors such as the frequency of the policies/governmental decisions and the breadth of their goals. I feel that the SISs approach best suited the analysis; due to its constituent elements: it was possible to set up the framework according to which the analysis was carried out. Porter’s approach contributed to a more complete understanding (from micro- to macro-level) of the wind turbine industry’s state in different periods.

On the other hand, it was a challenge to incorporate Porter’s framework into the SISs approach. There was a lot of restructuring of the analysis until it got to the present stage. However, the work should not stop here; the combined theoretical framework needs a little bit of polish and refining in order to avoid overlapping. It would also be interesting to see what such a framework that is a reflection of the present framework would result. To be precise, it would be a good idea to design a framework for the innovation systems embedded in Porter's approach. The idea of combining different approaches and theories could be used in future works in many different combinations. (Just the used theories should be compatible with each other). Thus, maybe research could reach a point, where it would be possible to measure innovations through the evaluations of the systems and not through individual elements, such as patents. This could be a method that goes from the outside towards the inside.

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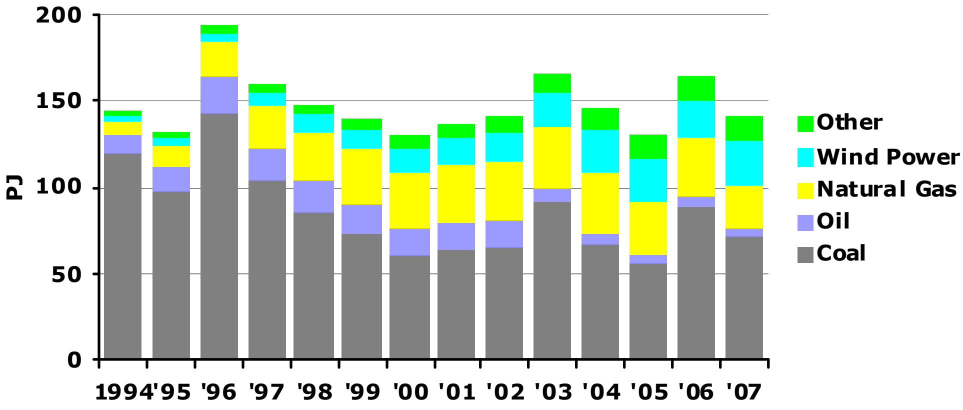
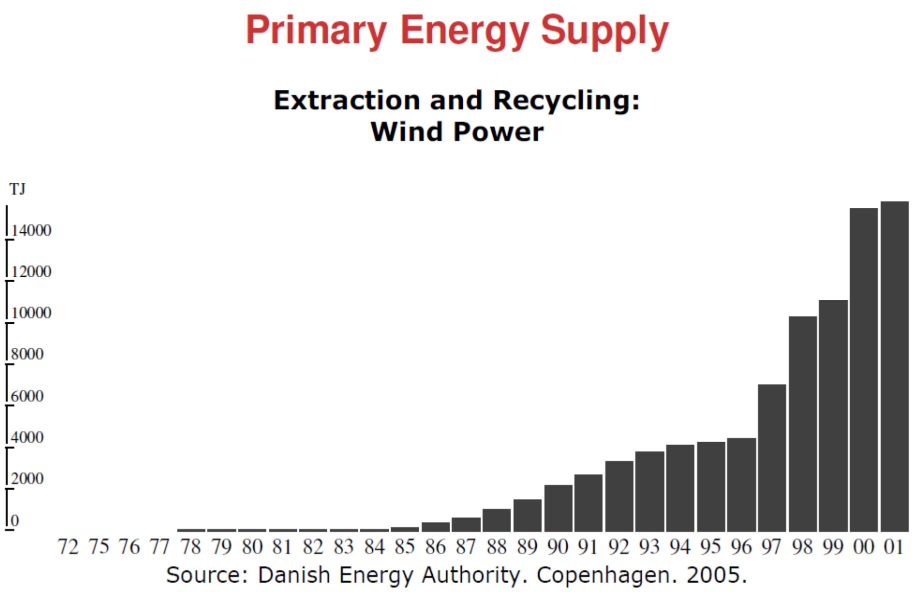
APPENDIX

Figure A. Electricity production by fuel



Source: (Danish Energy Agency 2007)

Figure B. Wind power energy supply. The share of wind power in the electricity production



Source: Primary data obtained from (Danish Energy Agency 2008a)**.**

Figure C. The share of wind power energy in the electricity production in Denmark

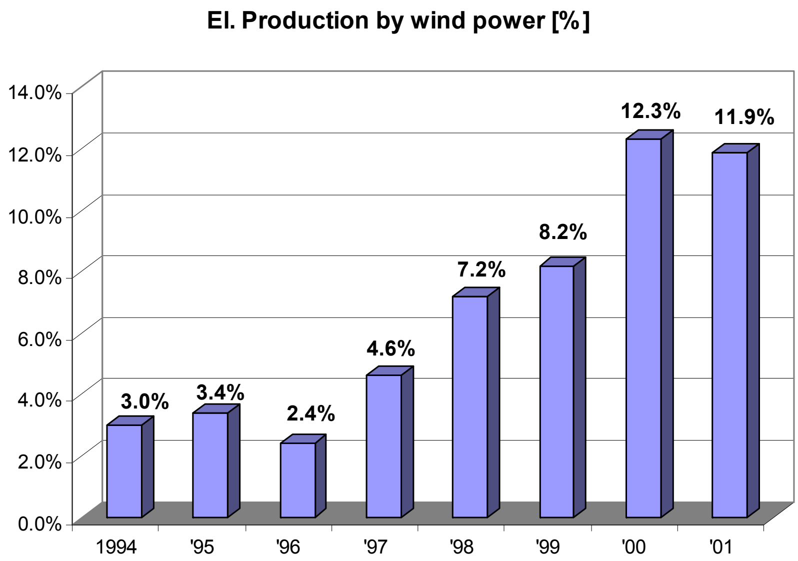
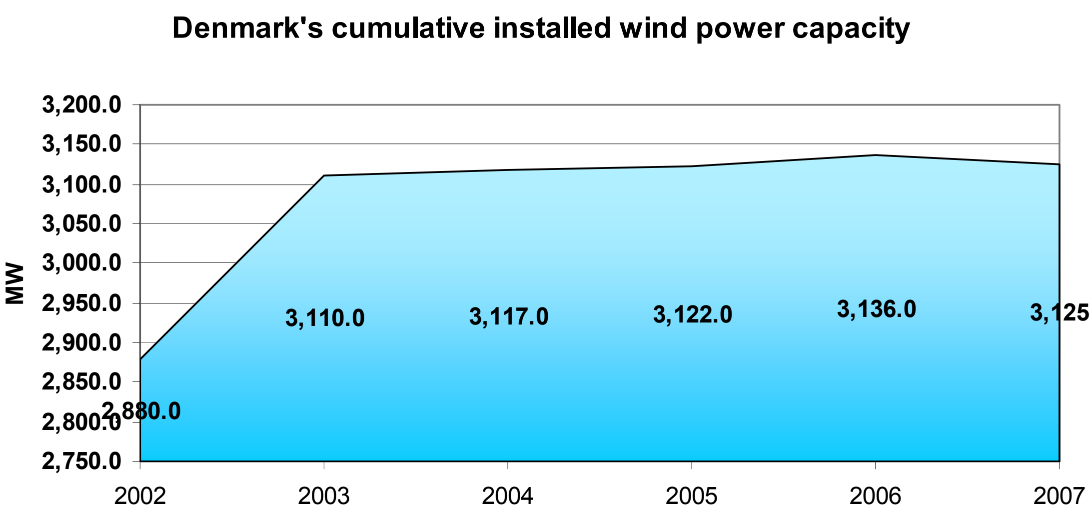
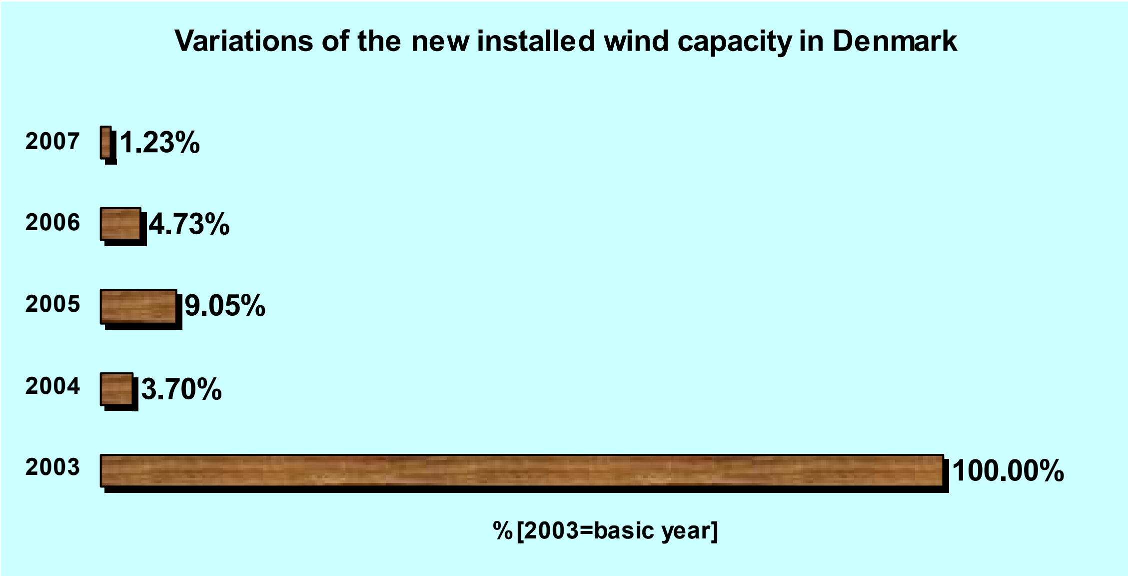


Figure D. The total installed wind power capacity in Denmark between 2002 and 2007



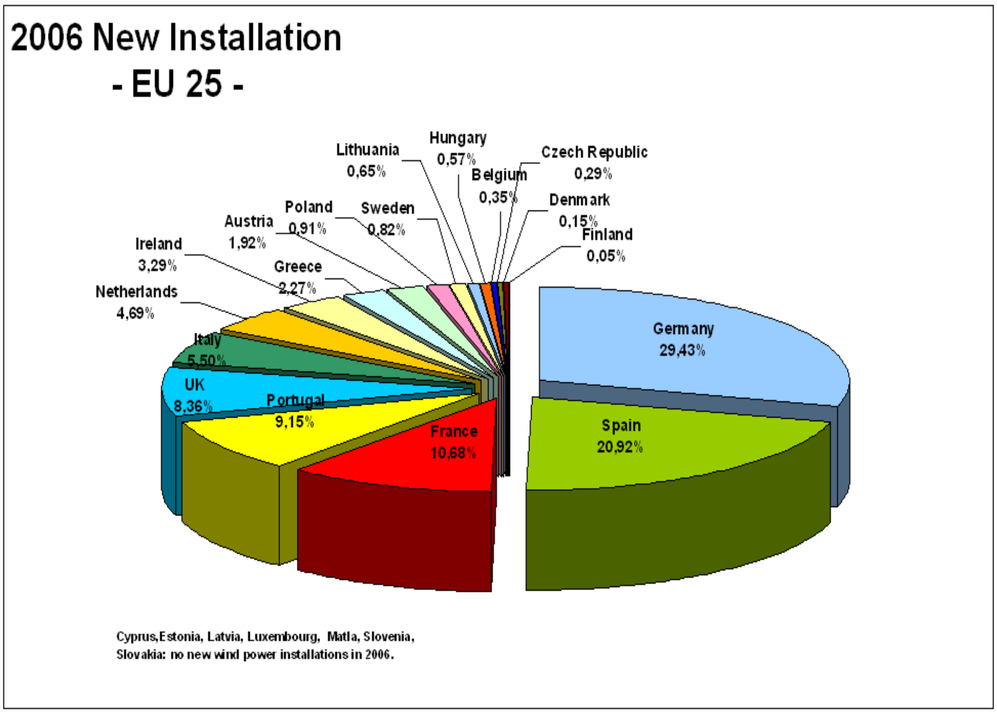
Primary data source: EWEA 2002-2007.

Figure E.



Primary data source: EWEA 2002-2007

Figure F. New installations of wind turbines in 2006



Source: (European Wind Energy Asiciation 2008)http://www.ewea.org/fileadmin/ewea_documents/documents/publications/statistics/2006_new_installation_eu25.gif

Table A. Top 10 cumulative installed wind power capacity by the end of 2005

Total capacity	MW	%
Germany	18,428	31.2
Spain	10,027	17.0
US	9,149	15.5
India	4,430	7.5
Denmark	3,122	5.3
Italy	1,717	2.9
UK	1,353	2.3
China	1,260	2.1
NL	1,219	2.1
Japan	1,078	1.8
Top 10 – Total	**51,936**	**85.8**
Rest of the world	**7,368**	**14.2**
World total	**59,322**	**100**

Source: (GWEC 2005)

Table B. Top 10 new installed wind power capacity by the end of 2005

New capacity	MW	%
US	2,431	21.1
Germany	1,808	15.7
Spain	1,764	15.3
India	1,430	12.4
Portugal	500	4.3
China	498	4.3
Italy	452	3.9
UK	446	3.9
France	367	3.2
Australia	328	2.8
Total top 10	**1,507**	**13.1**
Rest of the world	**10,024**	**86.9**
World total	**11,531**	**100**

Source: (GWEC 2005)

Table C. Top 10 cumulated wind power capacity by the end of 2006

Total capacity	MW	Market share
Germany	20,622	27.8%
Spain	11,615	15.6%
US	11,603	15.6%
India	6,270	8.4%
Denmark	3,136	4.2%
China	2,604	3.5%
Italy	2,123	2.9%
UK	1,963	2.6%
Portugal	1,716	2.3%
France	1,567	2.1%
Top 10 - Total	**63,217**	**85.2%**
Rest of the World	**11,004**	**14.8%**
World total	**74,221**	

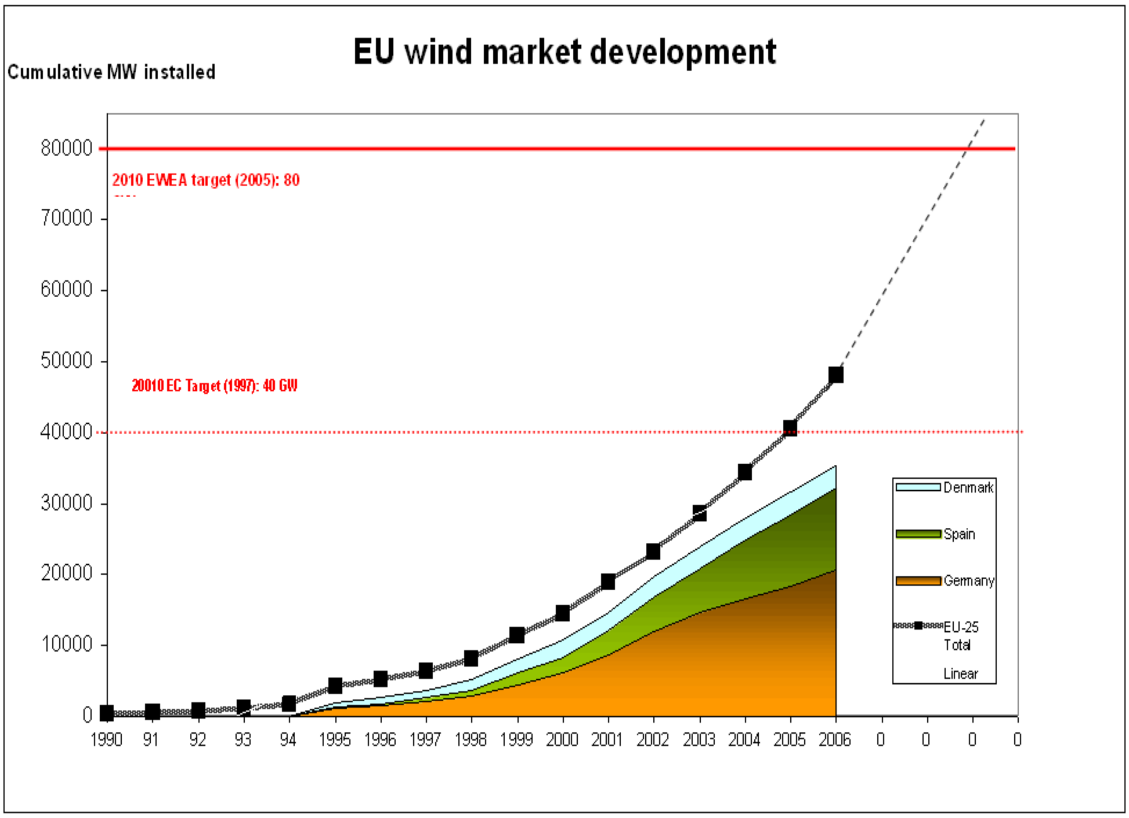
Source: (GWEC 2006)

Table D. Top 10 new installed wind power capacity by the end of 2006

New capacity	MW	Market share
US	2,454	16.1%
Germany	2,233	14.7%
India	1,840	12.1%
Spain	1,587	10.4%
China	1,347	8.9%
France	810	5.3%
Canada	776	5.1%
Portugal	694	4.6%
UK	634	4.2%
Italy	417	2.7%
Top 10 – Total	**12,792**	**84.2%**
Rest of the world	**2,405**	**15.8%**
World total	**15,197**	

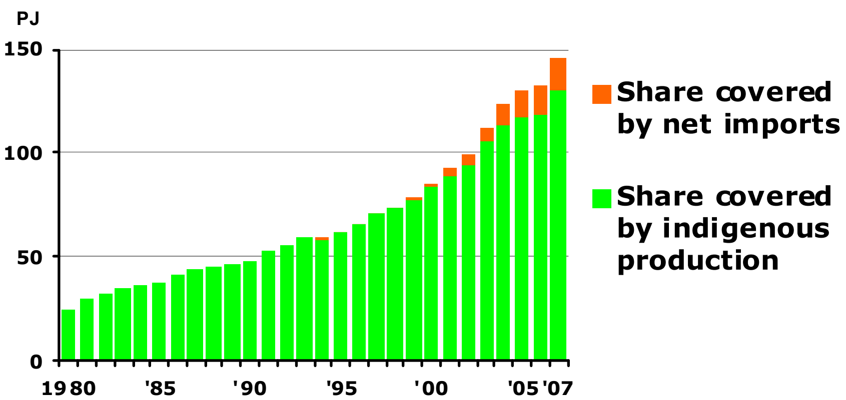
Source: (GWEC 2006)

Figure G. Cumulative installations of wind power in EU



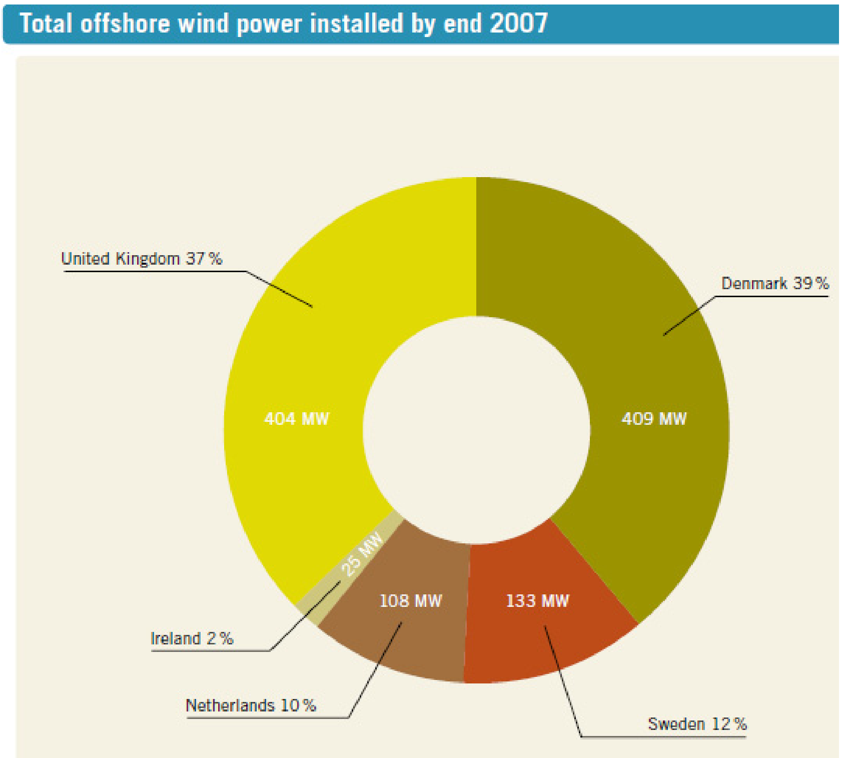
Source: (European Wind Energy Association 2008)

Figure I. Consumption of renewable energy



Source: (Danish Energy Agency 2007)

Figure H. Offshore wind power installed in Europe by 2007



Source: (European Wind Energy Association 2009)