Driving Innovation in the Wind Energy Sector



The Role of EU and National Support Policies

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1. Introduction

Despite the economic crisis, the year 2009 brought new records for wind energy utilization around the world. With a share of 47.9%, almost every second wind turbine installed worldwide can still be found in Europe. The Danish, German and Spanish wind turbine manufacturing industries were still dominating in many wind markets around the world and are anticipated to continue their leading role in the coming years. Yet, new international competitors are expected to come up in Asia and in America (World Wind Energy Association, 2010). In order to stay competitive, Europe´s leadership in research and industry must continue to go along with strong technology and innovation development.

A large number of policy instruments have been developed throughout Europe to support the development of wind energy technology. However, the success of the different policy instruments varies significantly throughout the member states. Whereas some policies promote the technology push in the innovation process, like R&D subsidies, other instruments create market conditions such as feed-in tariffs. The latter ones can also be considered as having an effect on the innovation dynamics by either facilitating or hampering the development of technologies. Since it is of utmost importance to create a stable environment for the development of new technologies, Europe might lose its strong position when it lays back on its success and is not on track with new developments.

1.1. Research Objective and Central Research Question

This study aims to provide an empirical illustration in what ways EU and national support policies impact the innovation dynamics in the wind energy industry by having a look at two of the three leading European countries, namely Denmark and Germany. Since both countries are the front runners in the source, it will be investigated which policies have been used to support innovative technologies, how the actors perceive those policies and which lessons other EU member states can draw from the success stories of the two countries.

Building upon the aforementioned introduction, this study intends to address the impact of EU and national support policies on the innovation dynamics in the wind energy sector. The following main research question has been developed:

"In what ways is innovation in the wind energy sector influenced by EU and national support policies and what are their effects on the innovation dynamics?"

Current literature that focuses on support policies for the wind energy sector examines mostly the effects of those policy instruments on the electricity market. Also in this case, the effectiveness of the instruments varies greatly. This is due to different market conditions or maturity of the applied technologies. However, this study will focus on the process of innovation including different actors and how they perceive the support mechanisms.

1.2 Sub-questions

From this, the following sub-questions have been developed:

1. How is the innovation concept suggested? What are the EU and national support policies for wind energy technology?
2. Which policies support innovation in the wind energy sector and how are they perceived?
3. In what ways can EU and national support schemes be improved in order to facilitate future innovation in the wind energy sector?

1.3 Structure of the Thesis

Chapter 2 of the thesis introduces the concept of innovation by illustrating different approaches to it. An innovation chain will be applied in order to see how policy instruments come about and what role they play for the innovation dynamics. The goal is to answer the first and second sub-question. In chapter 3, an overview will be given on the wind energy industries and political frameworks of the European Union, Germany and Denmark. This serves to learn about the support mechanisms and the national and European perspective on wind technology innovation. Since several actors participate in this innovation process, a triple helix model of university, government and industry is used throughout the thesis to understand the perception of those policies.

Chapter 4 elaborates on the methods used to collect data. In Chapter 5, the results will be analyzed in the light of the innovation concepts and the innovation chain in order to see which support policies work most efficiently by looking at how the actors perceive them. This serves to answer the third sub-question. Chapter 6 sums up the conclusions. In chapter 7, the developed recommendations will give suggestions of how to improve the use of those instruments to keep a strong competitive role in the wind energy sector which is related to the fourth sub-question.

1.4. Relevance of the Research

A stable innovation environment in the wind energy sector not only serves to meet the renewable energy targets stated by European and national authorities, it also ensures investments thereby fostering future projects. Furthermore, it creates desirable conditions to develop a pool of skilled workers that generate a strong knowledge base which is essential for innovation. Next to the societal benefit, the aspect of a clean environment through the use of wind technology is a crucial aspect to combat the negative climate effects we might face in our future. Finally, a strong and innovative wind energy sector can help to reduce the dependence on energy imports.

2. Theoretical Framework

The theoretical part will start with a description of the innovation concept by providing various definitions from different perspectives. In this thesis, innovation is considered as being a process in the first instance. An innovation chain will be applied which is the guiding principle of the theoretical and analytical parts. It will also be considered which actors participate in the innovation chain to understand their roles in implementing and applying the support policies. This is done by having a look at the actors of government, university and industry. Lastly, several support policies will be outlined in order to give the reader an understanding of those instruments and to comprehend their application in Chapter 3.

2.1 The Concept of Innovation

Since the concept of innovation is used in a variety of ways, the thesis tries to narrow down the definition and will concentrate on the process and the governance of innovation in the outlining of the concept.

Having its origins in the Latin *innovare,* the term means to "renew, to make new, or to alter". The term is applied in different scientific disciplines, ranging from economics to social sciences. Like the European Union, that wants to become more innovate by developing competitive advantages through knowledge-based economies, also national governments set priorities in terms of innovation and competition. Furthermore, firms endeavor to become more competitive by including innovative business strategies and universities work in research clusters and excellence centers.

Beginning with Joseph Schumpeter, who wrote about the modern origins of this concept, innovation embraces the introduction of the five so-called "new combinations": *a new good or a new quality of goods, the introduction of a new method of production, the opening of a new market, the conquest of a new source of supply of raw materials or half-manufactured goods, as well as the carrying out of a new organization of an industry"* (Schumpeter in: Backhaus, 2003). Therefore, entrepreneurship is an essential element in driving innovation and fulfilling its function in introducing new combinations of productive means. The idea of *creative destruction*, developed by Schumpeter, plays a key role in this matter. In order to stay competitive, old products and processes have to be replaced be new ones, creating a continuous manner of development, innovation and optimization.

First seen as something related solely to an isolated act (Arentsen, van Rossum & Steenge, 2010 forthcoming), the perspective on innovation was broadened to include joint activities in networks with public-private partnerships. Henry Chesbrough developed the concept of *open innovation*. In his book *"Open innovation: The New Imperative for Creating and Profiting from Technology"* (2003), he states that companies move from the so-called *closed innovation* perspective to a more open way of innovating. The innovation process is hereby no longer only part of an isolated act, but new products can also be created outside the firm boundaries.

The *System of Innovation* approach (Edquist, 2001) stresses the role of governments in contributing to the enhancement of innovation by encouraging the work of knowledge centers and universities. The goal is to facilitate the collaboration of companies with the scientific branch. A strong nation´s knowledge infrastructure plays a major indication for the level of competitiveness and innovation.

2.1.1 Market Failure

But governments not only intervene in the innovation process in order to form collaboration efforts, they also play a crucial part in correcting market failures. Basically, market failures occur when "a market fails to allocate resources efficiently" (Mankiw, 2007). Those failures take place in several different situations, namely where: Knowledge is not perfect, goods are differentiated, factors are not completely mobile, monopolies or oligopolies exist, services or goods could not be supplied in sufficient quantity by the market (merit goods/public goods), existence of external costs and benefits and inequality.

Knowledge has a quasi public good aspect (Tassey, 2005). On the hand, it is considered to have a great contribution to the scientific world by providing sustainable acquaintances. On the other hand, knowledge can be produced at a low cost level and can be disseminated easily. Here, one speaks of non excludability of public goods. Persons that are paying for the benefits of a good or service cannot prevent anyone else form also benefiting from it, which is the so-called free rider problem (Mankiw, 2007). A companies spending on the creation of new knowledge and thus innovation, runs the risk that the expenditures are embraced by competitors. It is important to stress here that spillover of knowledge to companies that did not contribute to the research process is typically higher in the early phases of research (Basic R&D) than in later stages (Applied R&D). As a result, companies have little motivation to spend money on this sort of knowledge creation in basic R&D (Salmenkaita & Salo, 2002). Furthermore, there can also happen market risks in the later stages of the innovation process, such as in the demonstration phase. The process can be slower than anticipated or there can arise unforeseen developments by competing technologies. Martin and Scott (2000) have developed an overview of innovation modes, sources of industry specific innovation failures and policy responses (Table 1).

Table 1: Innovation modes, sources of sectoral innovation failure, and policy responses (Martin and Scott, 2000)

Main mode of innovation	Sources of sectoral innovation failure	Policy instrument
Development of inputs for using industries	Financial market transactions costs facing SMEs; risk associated with standards for new technology; limited appropriability of generic technologies	Support for venture capital markets; bridging institutions to facilitate standards adoption
Application of inputs developed in supplying industries	Small firm size, large external benefits; limited appropriability	Low-tech bridging institutions (extension services) to facilitate technology transfer
Development of complex systems	High cost, risk, limited appropriability (particularly for infrastructure technology)	R&D cooperation, subsidies; bridging institutions to facilitate development of infra-structure technology
Applications of high-science-content technology	Knowledge base originates outside commercial sector; creators may not recognize potential applications or effectively communicate new developments to potential users	High-tech bridging institutions to facilitate diffusion of advances in big research

For this reason, governments have a rationale to correct for market failures. The Systems of Innovation Approach (Chaminade & Edquist, 2010) stresses that companies innovate in collaboration rather than in isolation. Hence, it is concluded that policy makers should intervene where problems arise *between* the organizations (actors) and institutions (rules of the game). Government intervention in market failures becomes necessary in cases where uncertainties and risks are high and private investors are not willing to step in. Furthermore, innovation policies have to be selective, which means that they have to be focused on objectives (why to intervene) and instruments (how to intervene) (Chaminade & Edquist, 2010).

2.1.2 Competitive Advantage

Michael Porters Diamond Model of national advantage states that four variables have an impact on the ability of a company to utilize the country´s resources in order to gain a competitive advantage. The *Demand condition* states that where domestic demand pressure is high, companies will strive to produce high-quality, innovative products. The *Factor Condition* comprises the level and composition of factors of production, such as capital, infrastructure or educational level. Where there are *Related and supporting industries,* companies are able to form sorts of clusters with suppliers and so forth. These networks serve as key for competitive success. Lastly, a *Firm´s strategy, structure and rivalry* also play a crucial role. The extent of domestic competition, the existence of barriers to market entry and a firm´s management style and organization has an influence on the level of competitiveness. Finally, Porter claimed that competitiveness could be affected by government and chance. For example, competitiveness may be influenced by government policies such as incentives or subsidies or through random events such as the location and timing of research breakthroughs. Porter´s Diamond is illustrated in the figure on the next page.

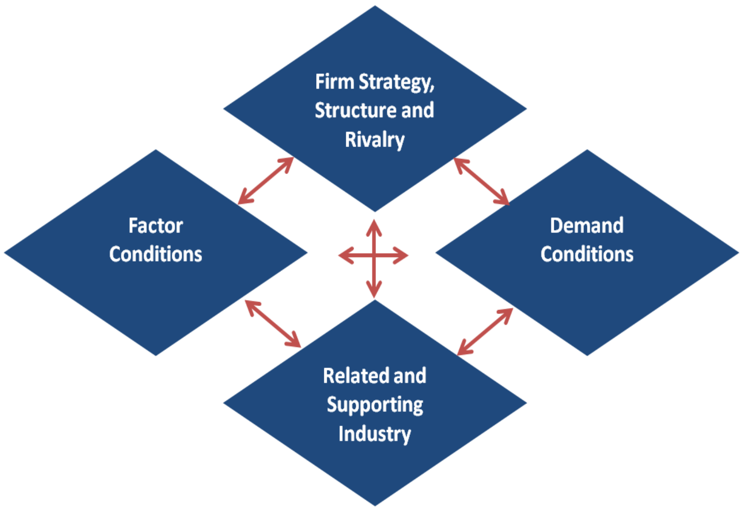

Figure 1: Diamond Model of National Advantage (Adapted from Porter, 1985).

2.2 Technology push and Market pull

Innovation refers both to the *process* and the *output* of arriving at a technologically feasible solution to a problem or a customer's need (Narayanan, 2001). The process of innovation refers to the way by which individuals or organizations arrive at a technical solution. The output refers to a product or a service; and is the end product of the process of innovation. Since this study will put the focus on the process, a detailed description will be provided in the following.

Narayanan (2001) distinguishes between two types of the innovation process: (1) *market pull* and (2) *technology push* (see also Innovation Chain 2.3). Hereby, market pull is the advancement of technology which is primarily oriented towards a certain market need and secondarily towards increased technical performance. On the other hand, technology push is the advancement of technology which is primarily oriented towards increased technical performance and afterwards towards a certain market need.
Considering market pull innovations, the idea to innovate results from a customer's need which is followed by technical solutions to meet that need. Technology push innovations are driven by a new technological advancement which encourages a firm´s search for an application.

Research by *Hirl* and *Palinkas* (2009) indicated that the EU has developed this two polarized view on technology innovation for renewable energy technologies and how to support them. *Technology push* puts emphasis on the creation of low greenhouse gas technologies, particularly through publicly-funded R&D programmes. This has a short-term investment view on technological innovation. Here, support is coming from the national and supranational level. One example is the so-called Framework Programmes that allocate the European R&D budget. *Market pull* means that technological change must come from the business sector and is the result of economic incentives.

However, it is also acknowledged that private investors (mainly from the national level) might prefer to work with technologies that are already familiar to them, rather than rely on innovations which can imply technical risks (Hirl & Palinkas, 2009).
When the need for innovative developments is directed by the market pull, it often considers *incremental* innovations. Those comprise innovations that represent only minor improvements or changes to the existing product or technologies. This is the case because the established markets that launch a need to innovate, base their observations on known technologies.

Contrarily, when the need to innovate comes from the technology Push, one can speak of innovations that are *radical.* These innovations mean revolutionary changes from existing products or technologies and require new organizational knowledge.

2.3 The Innovation Chain

In his article *Technology Innovation and Climate Change Policy: An overview of issues and options,* Grubb (2004) develops an innovation chain that is applicable to the wind energy sector. He states that technology push and market pull are two factors that cannot be seen separate from each other when one is talking about a complex phenomenon such as innovation. For the renewable energy sector, Grubb states that innovations are needed, but not necessarily technological breakthroughs. In the innovation process there are at least six stages to energy technology development in a market economy (Grubb, 2004):

- *Basic research and development;*
- *Technology-specific research, development and demonstration;*
- *Market demonstration* of technologies to show to potential purchasers and users that the technology works in real-world applications, and to test and demonstrate its performance, viability and potential market access;
- *Commercialization* which means either adoption of the technology by established firms, or the establishment of firms based around the technology;
- *Market accumulation* in which the use of the technology expands in scale, often through accumulation of niche or protected markets;
- *Diffusion* on a large scale.

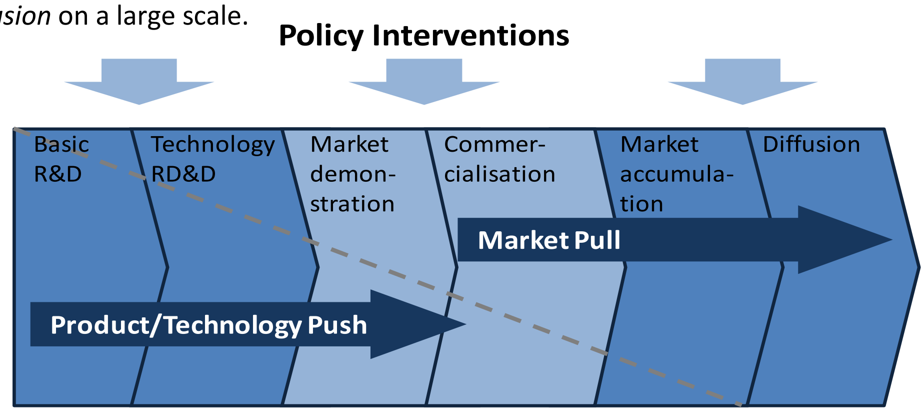

Figure 2: Innovation Chain (adapted from Grubb, 2004).

Between the stages, there is constant feedback. Each stage of the chain is supposed to include technology improvement and the reduction of costs, but the driving forces that enhance the innovation dynamics and the potential barriers change from stage to stage. Technology push elements dominate the early stages of the innovation chain, while market pull elements appear in later stages. Along the innovation chain, the government is playing a key role in introducing support policies in order to drive the innovation process. Those support policies vary in the different stages and are explained in more detail in Chapter 2.5.

2.4 Triple Helix Approach

For the innovation dynamics in the wind energy sector, it is not only necessary to consider the different policy instruments but also which actors take part in the innovation process in order to be able to analyze their perception of the support mechanisms.

The triple helix approach, developed by Etzkowitz (2008) takes into account that the relationship between university-industry-government plays a key role in innovation dynamics. Innovation which means in its general idea the development of products cannot longer be seen as belonging solely to the industry. With knowledge producing institutions and governments becoming more and more essential in driving innovation, there is an expansion of influence on the innovation process.

Etzkowitz (2008) distinguishes between two opposing triple helix models. In the statist model, the government is the assertive actor which is controlling the academia and industry. In the laissez-faire model, the actors are operating separate from each other with only reticent influence. Considering the wind energy sector as an example, the laissez-faire model concentrates on the productive force of the industry which is the main actor in economic and social development. Academia provides basic research and trained person. It supplies the industry with knowledge, whereby it is assumed that the industry should also work on its own capacity to produce knowledge and to collaborate with other firms. Where the market is not able to provide for economic impetus, the government takes up its limited role to act in market failures. Here, the state could provide funds to the universities because the market is not able to do this. Hence, in this model the actors keep their own institutional boundaries with the industry being the primary actor in economic activity.

2.5 Support Policies for the Wind Energy Sector

Policy instruments to support innovation in the wind energy sector differ greatly. Enzensberger et al. (2002) have made a clear distinction between the various mechanisms. Their article puts a focus on the wind energy industry and the graphical presentation of the typology of instruments will be used as an overview in this thesis and can be found in Appendix A. To narrow down the wide number of support policies, the thesis will extract some of them and make a difference between RD&D related measures, investment focused measures and production based measures. These are instruments taken from the supply-push and the demand-pull incentives in Enzensberger´s model. Following from this, one can derive the below mentioned table of support policies.

Table 2: Categorization of main support policies.

	Financial measures	Non-financial measures
RD&D	-Fixed government RD&D subsidies -Grants for demonstration, developemnt, test facilities etc.	-Monitoring procedures -Simplification of authorisation procedure for testing facilities
Investment focused	-Fixed government investment subsidies -Tendering system on the investment subsidy/grant	- Flexible agreements between producers and governments
Production focused	-(Fixed) Feed-in tariff -Premium systems -Tendering systems for long term contracts -TGC system	- Quota obligation on production

Support of RD&D:

National and European programmes support basic research, as well as development and demonstration projects in order to stimulate market accumulation and technologies that are far from commercial uptake. The nature of the support can be of short, medium and long term investment facilitating the relationship between university and industry. RD&D support is necessary not only for developing basic knowledge about the innovation dynamics in the wind energy sector. But it also attracts a wide pool of skilled workers that take their knowledge into a country, thereby fostering the ability to develop the best wind energy technologies. Demonstration projects can be supported by investments and monitoring procedures. RD&D policies help to keep this knowledge in the country by establishing excellence centers for research thus avoiding brain drain.

Feed-in tariffs:

This policy instrument puts an obligation on electric utilities to purchase electricity produced by wind energy in their service area. This tariff is regulated by federal or provincial authorities and is guaranteed for a certain time period, usually 15 years. A fixed *premium* can also be given in addition to the electricity price. The difference between fixed feed-in tariffs and premiums is the following:

for fixed feed-in tariffs the total feed-in price is fixed, for premium systems, the amount to be added to the electricity price is fixed. For a renewable plant owner, the total price received per kWh in the premium scheme (electricity price plus premium), is less predictable than under a feed-in tariff, since this depends on a volatile electricity price (Enzensberger et al., 2002).

Tender or bidding systems:

A defined amount of capacity (desired level of electricity, growth rate over time and level of long-term price security) is launched by governments. Competition between bidders depends on criteria that are designed beforehand. Projects can compete in terms of their costs and sometimes in terms of technical quality or environmental concerns. Contracts are given to the most cost-effective projects and the winners receive a guaranteed tariff for a specific period of time. The tender systems not only work for contracts, but also for investment grants (Enzensberger et al., 2002).

Tradable Green Certificate (TGC)-based quotas:

A certain quota of electricity generated by wind energy is set by the government. The producers are obligated to fulfill this certain percentage. At a settled date, they have to submit the required number of certificates to demonstrate compliance. Because some producers achieve higher percentages, the surplus of kWh produced is sold on a stock market in the form of TGCs (Enzensberger et al., 2002).

The arguments in favor or against the outlined support policies will be outlined in Chapter 5.

Summarizing, Chapter 2 tried to give an insight into the concept of innovation. Starting with the ideas developed by Schumpeter, innovation was described as being characterized by entrepreneurship which is the driving force behind the creation of productive means. Whereas innovation was seen as a rather isolated act belonging to the industry, the later perception of this concept includes joint activities with other branches. The working together of industry, government and university states the *open way* of innovation developed by Chesbrough. The key idea is that new products can also be created outside firms boundaries. Related to this, the Systems of Innovation Approach underlines the role of governments in enhancing the joint activities between industry and scientific branch. A countries goal in furthering its level of competiveness and innovation is stressed by Michael Porters Model of Competitive Advantage. Hereby, four variables (Demand Condition, Factor Condition, Firm´s strategy, structure and rivalry, Related and supporting industry) underline a firm's ability to develop a competitive advantage. However, innovation means also the possibility of potential market failures. The public good aspect of knowledge can lead to underinvestment of the private sector. Demonstration projects might fail due to slower process than anticipated or unforeseen competitive technologies. The government can correct for these market failures by providing subsides, bridging institutions, or support for demonstration projects. Having laid the foundations for the concept, chapter 2 continued to stress the understanding of innovation as a process. This process can be divided into a Technology Push and a Market Pull. With the help of the innovation chain, which is the guiding principle for the research, an understanding for the overall innovation process and the influence of support policies on this process was developed. Lastly, Chapter 2 introduced an outline of specific support policies connected to the wind energy sector. Those can be related back to the several stages of the innovation chain and the technology push and market pull mechanisms. The analytical part of thesis will point back to the concepts outlined in chapter 2 and served as bases for the data collection.

Chapter 3 Overview of the Wind Energy Sectors

In this chapter, a description of the overall wind energy sectors in Europe, Germany and Denmark will be given. This includes some facts about the wind energy markets and the legal frameworks in which the different policy instruments are applied and working. This serves to get the reader acquainted with support schemes in these countries and to develop a structured overview of the wind energy sectors.

3.1 European Wind Energy Sector

Europe is acknowledged to be the worldwide leader in wind energy technology. By the end of 2007, 60% of the world´s wind energy capacity was installed in Europe and European companies had a market share of 66% by the same time (EWEA Factsheet, 2010).

Figure 3: Wind power installed in Europe by end of 2008. (EWEA Annual Report, 2008).

Wind power in Europe showed stable growth rates in 2008, accomplishing 64,949MW in total installed capacity which is an increase of 15% compared to the previous year. In 2007, the Member States of the EU adopted a binding target of 20% of energy which should be generated from renewable energy sources. In 2009, the European Commission published the *National Renewable Energy Plan (NREAP)* template which puts a binding framework on the member states of how they want to meet the national targets. In order to achieve these goals, Member States must first ensure that the wind technology is sufficient enough to meet these goals and being consecutively able to establish well-functioning wind power plants. For the wind technology to function successfully and to be constantly innovative, the Member States have developed different support mechanisms. Currently, 27 different national support mechanisms are operating (EWEA - The Economics of Wind Energy, 2010) and are outlined in more detail in Appendix B.

The variation in support mechanisms can be explained by different national priorities for electricity markets. Furthermore, the markets themselves have distinct characteristics compared to each other. Putting the focus solely on innovation in the wind energy sector, the European Commission (EC) presents on its website for Technology and Innovation, the *Strategic Energy Technology Plan (SET-Plan)* in which it prioritizes the development and deployment of low carbon technologies; wind energy being one of them (European Commission, 2010a). In order to implement the SET-Plan, the EC has established *Technology Roadmap,* indicating the different needs of the various technologies. The Technology Roadmap for the wind energy sector can be found in Appendix C (European Commission, 2009a), including a time frame and the strategic objectives which are to be accomplished. In order to be able to do this, not only the various support policies have to function well, but there also needs to be a distinctive amount of investments into research, optimized technologies, grid integration and resource assessment and spatial planning. The indicative costs to achieve the priorities amount to €6Mio and reflect the combination of public and private investments. This sum comprises costs for research, technological development, demonstration and early market take-up (European Commission, 2009b).

3.2 German Wind Energy Sector

By the end of 2009, 21.164 wind turbines were installed in Germany with a total capacity of 25.777MW. Also in 2009, 7% of Germany´s net electricity consumption was generated by wind energy. The sector employs close to 100.000 people (German Wind Energy Association BWE, 2010). After the oil crises in the 1970´s, the government started to promote wind energy as one renewable energy source in order to reduce the dependence on fossil fuels. Germany focused on five policy instruments for the promotion of wind energy (Runci, 2005):

I. Direct investment in R&D
II. Direct subsidies
III. Government-sponsored loans
IV. Tax allowances
V. Subsidies for operational costs/Feed-in tariffs

However, the major government instrument that led to a wide diffusion of wind power capacity and prior accompanied innovation dynamics was the feed-in law that was introduced in 1991. Nine years later, in 2000, the *Renewable Energy Act (Erneuerbare-Energien-Gesetz/EEG)* came into force. The law was modified in 2008. The figure below describes the legal framework for wind energy development and the amount of installed capacity related to this.

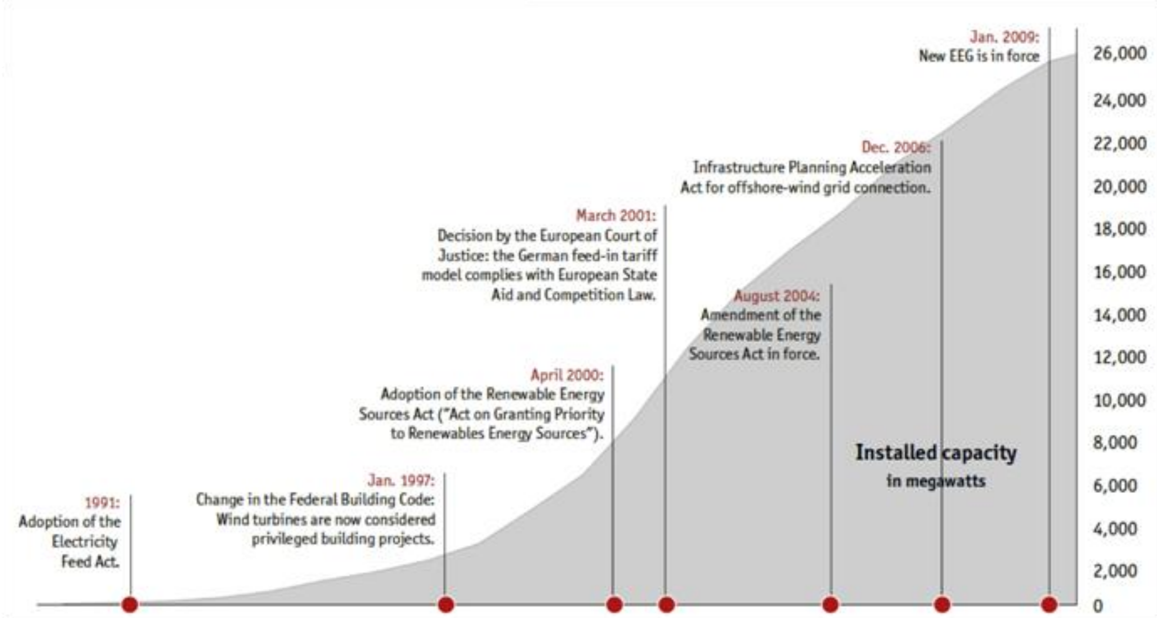

Figure 4: Wind energy in Germany – Political milestones (German Wind Energy Association BWE, 2010).

The German energy providers have never been satisfied with the feed-in mechanisms, because they claimed that these are in conflict with the rules of the Single Market. Nevertheless, in 2001 the European Court of Justice ruled that the feed-in support schemes are not violating the objectives of the Single Market.

In 2009, research in wind energy was expanded by the opening of the *Fraunhofer Institute for Wind Energy and Energy System Technology IWES.* Located in Bremerhaven, the institute provides the possibility to corporate in joint R&D projects with the universities of Hannover, Oldenburg, Bremen and also with industrial partners (Fraunhofer IWES, 2010). The federal state of Lower Saxony finances this cluster with around €12Mio in the upcoming years (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2010).

3.3 Danish Wind Energy Sector

The total number of employees in the entire wind energy industry was about 24.700 at the end of 2009. In 2008, around 5.5000 wind turbines have been installed with a total capacity of 3.160MW. This corresponds to 19.7% of domestic energy supply or the consumption of about 2.03million Danish households, which accounts for almost half of the population (EREC, 2009).

As in Germany, also Denmark established a dynamic research and production network in wind energy after the oil crises in the 1970s. This included a bottom-up movement, strongly oriented on entrepreneurs and cooperatives. Denmark´s policy priorities in the development of wind energy technology had been the following (Meyer, 2005):

I. Long-term government support for research, development and demonstration
II. National test and certification of wind turbines
III. Government sponsored wind energy surveys (wind atlas)
IV. Favorable feed-in tariffs
V. Investment subsidies until the mid-80´s
VI. Government energy planning and targets
VII. Local ownership of wind turbines and careful selection of sites.

However, when the liberal-conservative government came to power in 2001, the policy support schemes for wind energy have been abolished. The new government introduced a shift from the previous feed-in model to a certificates trading model. The power is sold on the liberalized electricity market, where the market price is set by the Nordic power exchange *NordPool* (Danish Wind Industry Association, 2010). The government relied on the assumption that the TGC scheme would be the standard scheme in Europe, and that the feed-in tariff model would be abolished by the ECJ in the ruling of 2001 which was not the case in the end.

The Danish Wind Industry Association describes Denmark as “global centre for industry and knowledge of wind technology” (Danish Wind Industry Association, 2010b). Manufacturers, suppliers, consulting companies, power companies as well as universities and research facilities all work together in joint projects. In the *Megawind* partnership, one can find public-private cooperations between state, business, knowledge institutions and venture capital to accelerate innovation processes in a number of technology areas.

In chapter 5 it will be examined how the European, German and Danish policy strategies can be applied to the innovation dynamics in the wind energy sector.

4. Methodology

This chapter provides a short description of the methodology that is used for studying the role of support policies on the innovation dynamics in the wind energy sector. A more detailed outline of the methodology is attached in Appendix D.

The study uses a qualitative approach, namely semi-structured interviews and the review of secondary literature. The units of analysis are the different policy instruments supporting the innovation dynamics in the wind energy sector. Those are outlined in chapter 2. The units of observation are the units where the data are derived from and include the actors involved in the innovation chain. The research framework follows a five-folded path to collect and analyze the data. This framework is outlined below. The research process which is followed to collect and analyze data is outlined below.

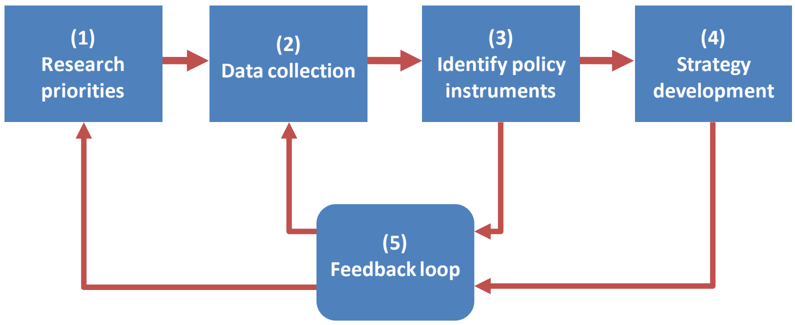

Figure 5: Research Process

The research priority, which is to see which support policies facilitate the innovation dynamics in the wind energy sector, will be underlined with the data obtained in the literature and the semi-structured interviews. Combining this with an identification of the policy instruments that are currently working, this is used to develop conclusions about which instruments are the most effective ones. Throughout all stages of the research framework there is a constant feedback loop.

The interview partners have been selected on the basis of non-probability sampling and include actors from the triple helix sketched out in chapter 2. The group of interview partners comprises one representative from the European Parliament, two representatives from the wind turbine manufacturing industry, and one representative from a research center. The small sample size of four interviewees yields some threats to the reliability of the study. However, more interviews could not be conducted due to time restrictions and the amount of pages that are supposed to be written. This makes the thesis rather an empirical illustration than a full empirical testing.

The recorded data will be analyzed in a three-folded path which was developed by Miles and Huberman (1994). This includes data reduction, data display and conclusion drawing/verification.

5. Analysis

The analysis of the thesis will be related to the several concepts underlined in Chapter 2 and underpinned with findings from the wind energy sectors in Europe, Denmark and Germany. These findings are retrieved from the literature review as well as from the semi-structured interviews.

First, the different industries will be placed in the several innovation concepts to give the reader a framework in which light to see European, Danish and German innovation dynamics for the wind energy sector. This serves to make clear in the later step how the support policies came about and what influence they have on the innovation chain. The analysis will always relate to the stages of the innovation chain and include the actors of government, industry and university. Positive as well as negative effects of the support policies on the innovation dynamics will be identified.

5.1 The Wind Energy Sectors in the Light of the Innovation Concepts

In the European Union, wind energy is seen as a crucial point to the fight against climate change. As Schumpeter, who pointed out that the introduction or optimization of existing technologies is vital for innovation, the EU sees the development of wind energy technology as one objective to make Europe more competitive. The *Research Framework programmes* provided by the EU as well as national research strategies have to serve this goal. In the Technology Roadmap of the SET-Plan which is outlined in Appendix C one can find the targets set for wind energy technology, the investments into research and innovation and the collaboration efforts with other network partners. However, as indicated by the interviewee from the EU Parliament, application for subsidies from the Research Framework Programmes is often a complex undertaking and thereby more oriented on the rather bigger consortiums in the wind industry. Smaller companies, or the supply industry, face a disadvantage in this respect because they get rather lost in the administrative and complex process.

Schumperter´s concept of the optimization of productive means can be illustrated with an example from the *Forwind* joint research center of the universities Hannover, Oldenburg and Bremen which work on the reduction of noise in the existing wind turbine technology. The research triangle *Forwind* was described by one interview partner as a strong research centre for wind power technologies. However, it was also noted that a restructuring of the German research landscape is necessary. In 2008, basic research on wind technology was conducted at 170 institutes in 60 universities nationwide which investigated all different aspects of technology (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit , 2008). This leads to a fragmentation of the research where it is not clear what is going on where.

Hence, the *Forwind* research triangle, as well as the newly established *Fraunhofer Institute for Wind Energy Technology and Energy System Technology IWES* was described as good examples of research concentration in Germany.

Those research institutes also illustrate Arentsen´s (2010 forthcoming) description of moving away from innovation as an isolated act that is solely related to the industry. The innovation process is moved to such joint research centers which conduct basic research, subsidized by governments and industry to come up with optimized and sometimes also groundbreaking technologies. The *Danish National Advanced Technology Foundation* is one example where publicly invested money is used to develop a new sort of blade technology. The production of the most important wind turbine component will become more cost efficient in the future. A budget of €8.3m is allocated to this project including partners from the business and university sector (The Danish National Advanced Technology Foundation, 2008).

Since the project is enforced by the *Danish National Advanced Technology Foundation* which was founded by the Danish government, one recognizes here the *Systems of Innovation* approach outlined in Chapter 2 where the role of the government is to contribute to the enhancement of innovation. As indicated by one of the interview partners from the industry, the government can also play a facilitating role by bringing different industry partners together. If a wind turbine manufacturing company is looking for new strategies, for example in electricity storage technologies, a government´s national support program can make it possible that those two industry partners come together and work in joint collaboration.
However, it was also mentioned by all interview partners that this kind of collaboration is only working out if it consists of acquired knowledge that stays "in house". If a company can identify and modify a problem itself, this collaboration is not desired because then the knowledge is dispersed easily to other actors and the level of competition is decreased. Here, the government representative called for mutual guidelines and a judicial framework for collaboration so that the issue of Intellectual Property Rights can be managed effectively and therefore allow for more flexibility in joint research projects.

Looking at the overall market picture one can state that Germany and Denmark have used all variables of *Porter´s Diamond* in an efficient way making the two countries market leaders in wind turbine technology. The ambitious targets set by both governments (Demand Condition) to enhance the use of low-carbon technologies reflect the pressure on the industries to innovate continually. Both countries were able to provide capital for research in wind technology, thereby also creating a pool of skilled workers in the industry (Factor Condition).

Interview partners from the industry mentioned a strong connection to the supply industry (Related and Supporting industry). Finally, Germany´s and Denmark´s wind turbine manufacturers could establish a strong domestic market position which also enables them to have one of the highest market shares worldwide.

However, governments not only follow facilitating roles by bringing together the several actors in joint research programs, they also step in when it comes to market failures. This can be illustrated by an example from the German large-scale wind plant project called *GROWIAN* which was the largest wind turbine plant that was ever built before. Nevertheless, the technology was not successful due to failures in manufacturing and system integration. The project was seen as economic failure but lessons have been drawn for the future wind technology development (Runci, 2005).

5.2 Support Policies and the Innovation Chain

In the following it will be outlined how the different policy instruments mentioned in chapter 2 can be applied to the innovation chain by giving examples from literature study and the semi-structured interviews.

Support for RD&D is mostly applied in *Basic Research and Development* as well as for *Technology R&D.* Here a distinction should be made between a more open way of conducting research in the first phase, where knowledge can be easily distributed at low costs, and technology research that is conducted “in house”, because then the companies are moving closer to the innovation *output* and are therefore not willing to share the acquired knowledge. In the first instance, funding takes place from a private-public partnership. The research triangle *Forwind* is such a research centre which conducts basic research and accompanies industry related projects. In the later phases of research, as mentioned by an industry representative, the companies are not interested in high amounts of subsidies from the governments because they rather keep the knowledge about the technologies to themselves. It was also mentioned, that governments can be able to create a stable framework for the industry to operate in, but that they are not able to influence the technology push by indicating which sorts of technologies have to be developed. From the industry perspective, it is stated that questions about the “optimum” of technologies are better regulated via the market-pull mechanisms because industry partners are more capable of judging which technologies are more effective. The European SET-Plan priorities of developing “large scale turbines in the range of 10-20MW” (see Appendix C) especially for offshore application (European Commission, 2009a) is therefore of not much relevance to the industry.

In the following phase of the innovation chain *Market demonstration and Commercialization*, it is relevant to the industry that the governments create testing places and enhance an easy authorization procedure. The Framework Programs of the European Union not only cover the research phase but also some demonstration projects. However, as stated by the representative of the EP, the limited budget of the EU makes it not possible to finance a lot of demonstration projects.

In the last phase, it is important that the governments create market incentives for the sector by applying support policies such as feed-in tariffs, quotas/TGC schemes or tenders. States take a supportive role in the market penetration of new wind technologies. The government representative indicated this phase as highly important and claimed that *"the best and the most innovative technologies are not capable of being successful on the market without the appropriate political and legal frameworks".*

As an overall picture, one can recognize that Germany and Denmark follow the principles of technology push and market pull equally strong. The governments as well as the Commission of the European Union can be seen as "customers" that develop specific targets for low-carbon technologies. In order to achieve these goals in time, industries have to push for the most innovative technologies. How the instruments for achieving these targets have been applied will be outlined in the next step.

5.3 Application of the Support Policies

The various support policies for the wind energy sector are used in different ways throughout the European Union. Currently, 27 Member States operate 27 different national support schemes which can be found in Appendix E.

Considering the innovation chain developed by Grubb, the industry representatives have indicated that most countries have decided to use policy instruments that either regulates the price or the quantity produced by wind energy which represents the market pull of the innovation chain. Since wind technologies are indicated to be mostly a sort of incremental innovation, where the foundations of basic research were laid years ago, technology push mechanisms like R&D subsidies relate mostly to the optimization of those technologies. The governments play a vital role in both, technology push and market pull.

Having a look at the countries Figure 6, one can recognize that those countries using feed-in tariffs as a support policy achieve higher effectiveness in comparison with countries that use quota/TGC-systems or other incentives. Denmark has achieved the highest effectiveness in all Member States. However, as will be outlined below, Denmark could not install much new plants due to shifts in policies.

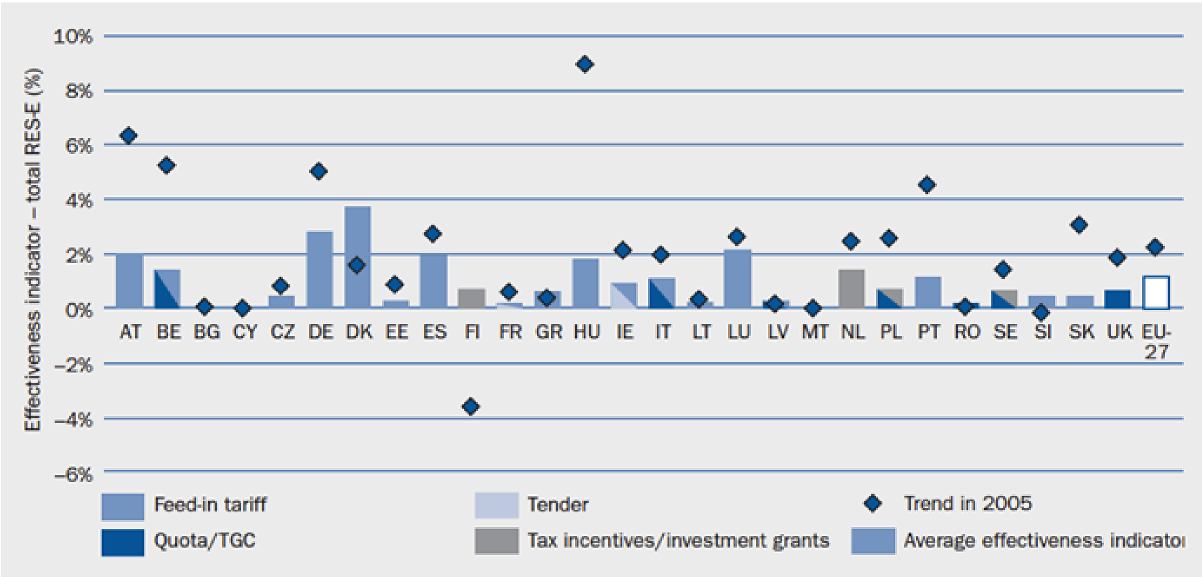

Figure 6: Policy effectiveness of total RES-E support for 1998-2005 (EWEA The Economics of Wind Energy, 2010).

However, it is not only the use of this mechanism which made Germany and Denmark leaders in wind technology; it was also an early awareness of the use of this technology and its consequences. As the government representative indicated, the oil crisis of the 1970s had severe economic impacts on Germany and Denmark. Consequently, both countries promoted the use of wind energy early to reduce the risks that are associated with energy dependence. The first successful steps for the promotion of wind energy technology were laid down and the governments developed an environmental rationale to investment into wind power. The local ownership strategy in Denmark and investment subsidies raised the awareness in the population to promote the use of wind energy which in turn stimulated the innovation process.

Whereas Germany still sticks to the use of feed-in tariffs, the Danish national expansion of wind energy stagnated due to a shift in renewable energy policies. The shift was accompanied by a change of government in 2001. The Energy Act from 1999 introduced a modification from the previous feed-in model to a proposed market price and premium for wind onshore and a tendering system for wind offshore as can be seen in Appendix B. The Danish government followed this idea because it thought that the premium and TGC scheme would be the standard support system in the EU, keeping in mind the disputes about the feed-in schemes in Germany. As earlier stated, the ECJ decided in 2001 that this model does not violate the objectives of the Single Market. Thus, the decision of a shift of policy mechanisms was based on wrong assumptions. As a result, the change in Denmark has brought up much uncertainty for private investors because they don't know how the market will develop over the next years. As indicated by one of the interviewees from the industry, a fixed-feed in tariff is a way for the industry to know what will happen in the future. For the innovation process this means that investments into new technologies can be guaranteed over a longer time period, making it also possible to work on market failures because of the awareness of a long-term stability in the sector.

Industry representatives indicated that a basic problem of the certificates scheme is that prices are not predictable for the long run, due to political uncertainties or planning bottlenecks. This makes investment in the technologies unstable. An argument that was put forward for the support of TGC schemes is that the market determines the amount of subsidies thereby saving money and making investments more efficient.

From a political point of view, tender systems are indicated to be acceptable because the costs of the scheme can be predicted. Nevertheless, the competition in the system can lead to low prices, which reduces the effectiveness of this policy instrument. If all conditions for the tenders are not known before the competition starts, the industry will not start to develop projects, because it can face the risk of changing circumstances. Like in the quota based TGC schemes, the investors can be confronted here with unpredictable conditions, too.

Because support of RD&D is a rather "indirect" instrument, the effectiveness of this instrument is evaluated in terms of awareness rising of new technologies and the confidence that is put into the innovative developments. Therefore, RD&D support policies can be seen as being effective because they make a strong contribution to the development of research in wind technology and are a necessary policy instrument to support the continuous process of innovation that is so essential for the sector´s competitiveness. The high awareness level of wind technology in Denmark and Germany serves as an example which stimulated early investments into research and development.

As wind energy is considered to be a rather mature technology compared to other renewable energy technologies, the investments into research and development are dominated by the industry that accounts for three quarters of the total investment. Corporate and public investments take place in countries that also have the highest wind energy share, thus Germany, Denmark and Spain. However, the EU subsidies for the innovation of wind technologies remained rather limited under the 6th Framework Program. This is outlined in Figure 7 on the next page.

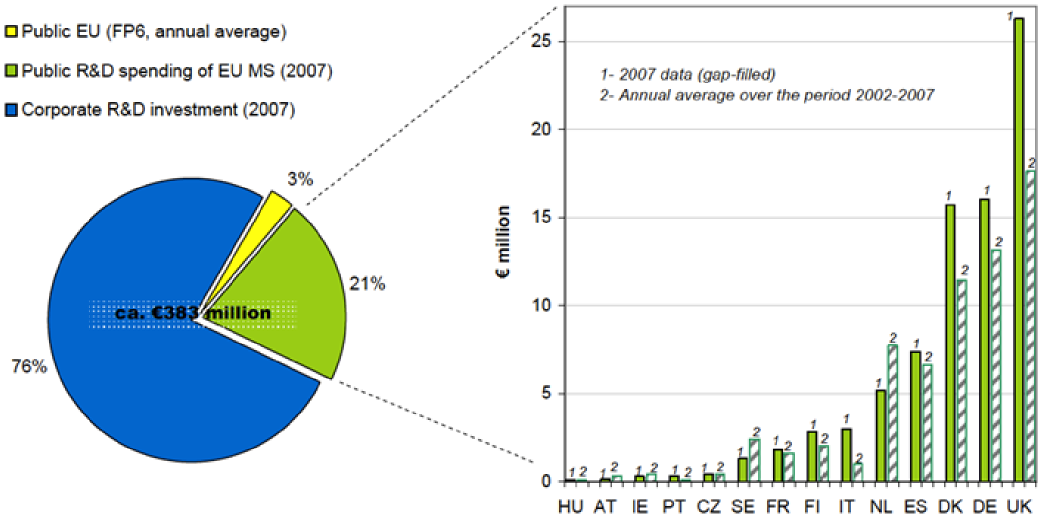

Figure 7: Approximate R&D investment in wind energy from industry and public sectors (European Commission, 2009b).

As stated by the EU representative, the idea of stability and transparency in the wind energy sector is also beneficial for the working together of the triple helix actors. If the actors know that stability is guaranteed over time, the industry/government is more likely to invest in the cooperation of research. In addition, the government can also work with the industry on demonstration and testing projects in the long run, calculating the risks of possible market failures and drawing lessons for future innovation strategies.

However, the expenditure on R&D should not be used as the single measure of innovation. This is because R&D measures the inputs that influence the innovation process and thus it reveals innovation activity rather than innovative success (Joumatte & Pain, 2005). Therefore, the number of patent applications for the wind energy sector will be taken into account, since “patents are reflecting the innovative performance of a firm” (Johnstone et al., 2009). From the figure below, one recognizes that Germany and Denmark have been the two leading European countries in patent application. Both countries could enhance their position in the late 1990s. Weighting the counts by a country´s GDP, this yields a measure of patent intensity. The data are retrieved for the years 1978-2005. Here, Denmark has the highest innovation output (41.25) and Germany ranks in the top five (10.32).

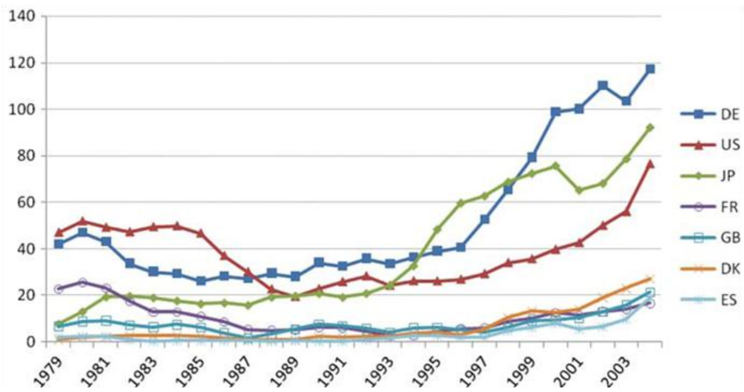

Figure 8: Number of EPO patent applications for renewables by country

Administrative and regulatory barriers

Next to the policy instruments outlined above, the government plays also an essential role for the innovation dynamics in terms of administrative and regulatory barriers. The EP representative already stated that the application procedure for the Framework Programmes is a rather complex process, favoring the bigger consortiums. This can be seen as administrative barrier which hampers the innovation dynamics of smaller companies and the scientific branch. Another point mentioned by an industry representative is the need for a fast authorization procedure when it comes to demonstration or testing projects. Regulatory and administrative barriers can slow down the process of continuous and strong growth in terms of the innovation dynamics in the wind energy sector. Finally, the EP representative pointed out that administrative barriers exist when it comes to getting building permits for wind farms. Those barriers vary from country to country, ranging from a few months to several years. In order to achieve the renewable energy target of 20% by 2020, this has some implications for the innovation process. In countries where the application procedure takes a long time, the wind turbine manufacturers have to plan well ahead in order to have the needed turbines to achieve this target.

6. Conclusions

The goal of this research was to give an empirical illustration of how European and national support policies influence the innovation dynamics of the wind energy sector and which policy instruments are perceived to be effective for driving innovation in the wind energy sector. The thesis elaborated on the support policies of the EU, Germany and Denmark to show how they came about, how they can be applied to the innovation chain and which of these policy instruments seem to facilitate the innovation dynamics. With the help of semi-structured interviews and secondary literature review, the following main research question was answered:

"In what ways is innovation in the wind energy sector influenced by EU and national support policies and what are their effects on the innovation dynamics?"

Concluding, innovation in the wind energy sector is mainly influenced by these four policy instruments: Feed-in tariffs, tender or bidding systems, tradable green certificates (TGC) - based quotas, RD&D support.

The first three policy instruments influence the market pull of the innovation chain. Feed-in tariffs put an obligation on electric utilities to purchase electricity produced by wind energy in their service area. The tariff is granted for a certain time period, usually 15-20 years. In a tender or bidding system, a defined amount of capacity (desired level of electricity, growth rate over time and level of long term price security) is launched by a government. Contracts are given to the most cost-effective projects and the winners of the bidding rounds receive a guaranteed tariff over a specific time period. In a tradable green certificate –based quota system, a certain quota of electricity by wind energy is set by government. At a settled date, the producers have to submit the required number of certificates to demonstrate compliance. Because some producers achieve higher percentages, the surplus of kWh is sold on a stock market in the form of tradable green certificates.

Support for RD&D is a mechanism that influences the technology push of the innovation chain. The nature of the support can be of short, medium and long term investment and can be derived from both the public and private sector.

In general, the effect of the different support policies to promote innovation in the wind energy sector varies across the Member States. Whereas some countries have a high level of maturity of policy instruments which were established already in the 1990s, other systems have fairly young support mechanisms established in 2003 or later, which is due to their accession date to the European Union.

From the analysis it turns out that feed-in policies are evaluated as the most efficient support schemes to promote the use of electricity generated by wind energy. All interviewees acknowledged that this kind of support policy provides a long term framework which is a prerequisite for planning and developing new technologies. The German case of continuously adapting feed-in law is a good example of the importance of modification which can have positive effects on the adaptation of new knowledge insights.

The actors taking part in the innovation chain valued the security and transparency of feed-in mechanisms as high, making investments into future technologies predictable. The long-term certainty in the sector leads to strong incentives to innovate and to establish cooperate relationships. In contrast, quota or tender systems have been evaluated with only showing marginal effects. Volatile market prices have a negative outcome on investors´ confidence and are thereby working in a contrary way than feed-in tariffs. Tender systems are desirable when the industry knows about the full range of policy conditions. If this is not the case, and future adaption due to changing circumstances become necessary, participation decreases. Even if the costs of the schemes are predictable in the first instance, competition in the bidding rounds can lead to very low prices which reduce the effectiveness of this policy instrument. Innovation strategies are therefore rather hampered than facilitated by a process that can lead to an uncertain outcome. The effectiveness of quota systems with Tradable Green Certificates is perceived to depend on the penalty that is introduced for non-compliance. If the penalty is not higher than the actual price to pay there will be no incentive to participate. Since the trade with certificates is done on stock exchanges, the prices are highly volatile making the systems uncertain for investors. For the innovation process this means that future outcomes and needs are not predictable. Nevertheless, the quota system is also a transparent system making it possible to evaluate the sales of the certificates.
Of course it should be noted that tender or quota systems also have their advantages when one is considering the renewable electricity market. But this study concentrates on the effects on the innovation dynamics and therefore the different policy instruments are examined in this light.

The use of RD&D support is of high relevance to the innovation dynamics in the wind energy sector. Cooperate investments from the national level seem to be on a good way, whereas the EU suffers from a limited budget and therefore only allocates a restricted amount which was indicated by the EU representative in terms of allocation for demonstration projects and limited amounts of the FP6. The high number of patents in Germany and Denmark reflect the innovate performance of the sectors. Together, with the influence of feed-in tariffs which guarantee fixed prices, this has a positive effect on the innovation dynamics.

The efforts for joint collaborations can be evaluated as being good, with the examples of *Megavind, Forwind* and the *Fraunhofer IWES.* Both Germany and Denmark strive to create strong knowledge-intensive bases for wind technology. However, some systems are rather fragmented and need to develop a common national strategy rather than working isolated from each other.
Another crucial aspect that is important for the innovation dynamics is the exchange of knowledge between university and industry. A need for more flexibility can be established by the introduction of a judicial framework that is guiding mutual exchange of knowledge thereby safeguarding the intellectual property of both parties. RD&D investments also seem to be very important in terms of keeping the knowledge inside the country and making the wind energy sector an attractive place to work.

Considering the role of the actors in the innovation chain, it can be concluded that the overall joint collaboration is on a good way. The governments set legal frameworks in which new technologies can be developed and which give the industry guidelines of how to achieve the targets that are set. Research centers provide a good foundation of workers and knowledge and are an essential condition to the first phase of the innovation chain. Problems arise when the industry is facing administrative or regulatory barriers, for example when it comes to the application for demonstration procedures or the setting up of wind power plants. The timeframe is prolonged and hampers the innovation process because uncertainties in the system arise. Another problem that occurs in the sector is when governments try to establish targets about the technologies themselves, like an optimum size of wind turbines. Since the industry and customers are better able to decide on these issues because they know what the markets/customers want, governments should not concentrate on developing specific technological targets.

Learning from “best practices” in other countries as stated out in a Commission´s Working Document (European Commission, 2008) is sometimes not desirable. They tend to “homogenize” the distinction of different programmes and it is often ignored what can be learned from programmes that have the worst practice (Rose, 2005). Rose stated seven possibilities that can have an influence on lesson-drawing between different nations. Those include: A program should not be distinctive in most of its characteristics; suitable institutions, great correspondence of resources between governments, an uncomplicated cause and effect structure of a program, a small scale of change, great degree of interdependence and a great uniformity of values (Rose, 2000).

In this respect, there is of course no policy instrument that fits equally to all member states. Certainly, there is one lesson that can be drawn from the application of the several support policies. It is of high relevance to create an assured long-term stability so that investments are guaranteed and the innovation process is facilitated. This was the case with the German feed-in scheme. Denmark is a good example of how a system can become unpredictable to investors and therefore also the innovation dynamics when the support scheme changes. RD&D investments seem to be a powerful tool not only in developing the newest technologies but also in creating a pool of skilled workers which also determines and affects the innovation dynamics in the wind energy sector.

The following recommendations are derived from the findings during the analysis and will include lessons that can be drawn from the best and worst practices in the wind energy sector in order to be able to facilitate Europe´s leading role in wind technology.

7. Recommendations

In order to keep their strong position and market share of wind energy, it is of utmost importance that the Member States of the European Union don't rely on the successes they achieve because they might miss out on the chance to hold on to the strong position. Once support policies are implied, it is therefore not enough to depend on how they work out for the innovation dynamics but also to monitor their compliance with the overall system and adapt them continuously. Hence, the following recommendations have been derived:

∞ **Create certainty for investment in innovation:** The interviews clearly showed that innovation dynamics are driven by environments that promise a long-term stability. If the actors know what will happen in the future, as with feed-in tariffs, they rather tend to invest in new innovations, calculating possible market failures and establish long-term partnerships with actors from other branches. Because the innovation process in the wind energy industry is connected to a certain time period that also considers testing, demonstration and possible optimization, it is of high relevance that predictable conditions for investors are established. Market circumstances that lead to volatility are therefore not preferable for the facilitation of innovation dynamics. If investments in wind energy technology need to be sustained, there have to be security on returns to the investors. Feed –in tariffs provide a long term guarantee in this respect.

∞ **Strengthen joint collaborations:** Moreover, joint collaborations along the whole innovation chain should be strengthened between industry and university by creating policy instruments that allow for more exchange of knowledge thereby protecting the intellectual property that is generated. This overcomes the problem of fragmentation not only between universities themselves but also throughout the whole innovation chain. The goal is to generate the most valuable knowledge for industry, university and government.

∞ **Removal of Administrative and Regulatory Barriers:** Another crucial point that has an influence on the innovation dynamics is the removal of administrative and regulatory barriers which should facilitate the support of innovation rather than hampering it. A European wide body should encourage a simple and transparent mechanism which allows for fast application procedures that are only administrated by one national organization.

∞ **Less governmental interference on technology specific objectives:** Since the industry actors are the ones that know how the markets work and what the customers need, it is not desirable that governments set targets for technology specific objectives, like the size of a wind turbine. It is recommended that governments concentrate their responsibility on creating a stable legal framework in which the support policies can operate effectively.

∞ **Mutual learning on policy instruments:** Member States not only have to monitor the effectiveness of their *own* support policies continuously, they also have to adapt a strategy of mutual learning. This can be achieved by a stronger exchange of experiences such as in the *International Feed-in Cooperation* where until now only Germany, Spain and Slovenia form a partnership. It is recommended that all Member States have to be obliged to join this sort of network. It has to include not only political representatives but also university and business experts so that a forum of knowledge and advocacy is created. All those actors are engaged in the innovation dynamics and can therefore not be ignored when it comes to the exchange of experiences.

∞ **No harmonization of policy instruments:** However, the aforementioned point should not lead to the conclusion that a joint network means a harmonization of policy instruments as a possible outcome. Harmonization of support policies is not a desirable recommendation because the innovation dynamics and the maturity of technologies differ from member state to member state. Moreover, each country has its own characteristics of an electricity market and public policies rely on different goals, such as more environmental or more industrial approaches. It is recommended that instead of following a harmonization, countries should rather *incorporate* solutions that are drawn from best and worst practices.

∞ **Focus on industry policy:** Nowadays, energy policy and industry policy go hand in hand. With the rise of competition, especially from Asia, member states should allow for more industry policy in the wind energy sector. For the innovation dynamics this means that the countries should keep their wide pool of knowledge workers but also keep educating future qualified labor, thereby avoiding the possibility of brain drain.

Besides the recommendations that have been given in terms of the support policies, it is also concluded from the experience of the German and Danish wind energy sectors, that the effectiveness of the support policies are accompanied with a high level of awareness about wind energy and its consequences. It is a crucial aspect of success to raise this level of awareness in countries where the share of renewable energies is still lagging behind.

8. Limitations

As mentioned previously, the effectiveness of the various policy instruments is studied in the light of their influence on the innovation dynamics in the wind energy industry. The judgment is therefore only based on the impact of the support policies on the innovation chain.

Any positive or negative effects they have on the electricity markets were not studied in more detail. Hence, the conclusions are only of relevance for the innovation dynamics, any other roles these support policies might play for the renewable electricity markets are not considered.

The study focused on the support policies working in Denmark and Germany and in addition it used also information how the EU is supporting the innovation dynamics in the wind energy sector. Concentrating only on two countries is making the findings not reliable if one could also consider all 27 Member States of the European Union. Best and worst practices could be identified more easily and more reliable results could be derived. However, due to time restrictions, the Bachelor thesis did not allow for such an outspread research. This is also the case for the limited sample size that was used to conduct the semi-structured interviews. Furthermore, the interview partners were not willing to answer all questions, especially those that could intervene with their competitive advantages. It must be repeated that this research is an empirical illustration rather than a full empirical testing.

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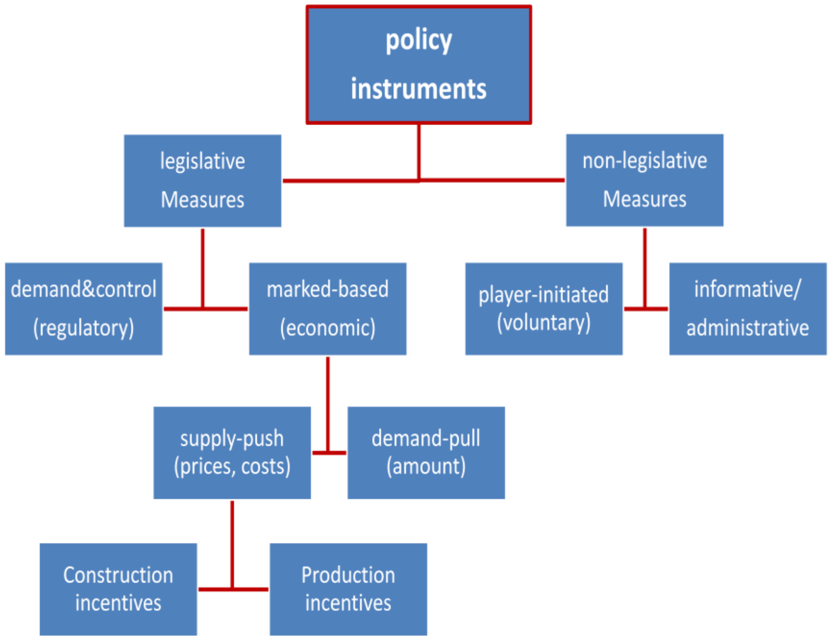
Appendix A

Typology of the support policies for the wind energy sector (Enzensberger et al., 2002)



The set of policies can be divided up into *legislative instruments* and *non-legislative instruments.* The former one is implemented by governmental authorities whereas the latter ones are employed by any actor that is interested in supporting the future market penetration. Since this thesis has the goal to come up with a policy recommendation of how to improve the use of policy instruments for the overall European wind energy sector, special focus will be laid on the *legislative instruments.*

Those can be further divided in *demand and control mechanisms (or regulatory instruments)* and *marked-based (or economic instruments).*

Regulatory instruments put emphasis on regulations made by law that force market players to reduce their "entrepreneurial options to the set of behaviors defined to be acceptable for the state authority" (Enzensberger et al., 2002). On the other hand, *economic instruments* try to deliver incentives to the market players to stimulate economically attractive behavior. This can be achieved for example through some kind of financial support for specific actions. In contrast to the regulatory instruments, the market gets greater freedom and long-term developments can be fostered in the market place.

The authors state further that *economic instruments* characterize the most important class of policy instruments when renewable energy projects need to be promoted. Those instruments can be distinguished into *supply-push* and *demand-pull approaches.* "Policy instruments following a supply push approach influence the market price for green electricity or production costs in a broader sense". As an example one can consider fixed feed-in tariffs, investment subsidies and certain tax advantages. "Quota model (…) represent a typical demand pull approach. The instrument fixes a certain demand by obliging market players along the supply chain to make sure that a fixed percentage of the total electricity generation (or consumption) is covered by green electricity. In these cases, the market price for green electricity is a free variable and subject to market mechanisms." (Enzensberger et al. 2002)

Finally, the *supply push approach* can be divided into *construction incentives* and *production incentives.* The former one concentrates on the building of power plants through tax advantages or subsidies. This runs the risk to end up in installations with little productive efficiency. The latter policy instrument leads to the stimulation to take up the development of efficient projects, which "results in a higher output of clean energy per supporting capacity involved" (Enzensberger et al., 2002).

Appendix B

Overview of the Main RES-E Support Schemes for Wind Energy in the EU-27 Member States as implemented in 2007 (EWEA The Economics of Wind Energy, 2010)

COUNTRY	MAIN SUPPORT INSTRUMENT FOR WIND	SETTINGS OF THE MAIN SUPPORT INSTRUMENT FOR WIND IN DETAIL
Austria	FIT	New fixed feed-in tariff valid for new RES-E plants permitted in 2006 and/or 2007: fixed FIT for years 1-9 (76.5 €/MWh for year 2006 as a starting year; 75.5 €/MWh for year 2007). Years 10 and 11 at 75 per cent and year 12 at 50 per cent.
Belgium	Quota obligation system with TGC; combined with minimum price for wind	Flanders, Wallonia and Brussels have introduced a quota obligation system (based on TGCs). The minimum price for wind onshore (set by the federal government) is 80 €/MWh in Flanders, 65 €/MWh in Wallonia and 50 €/MWh in Brussels. Wind offshore is supported at the federal level, with a minimum price of 90 €/MWh (the first 216 MW installed: 107 €/MWh minimum).
Bulgaria	Mandatory Purchase Price	Mandatory purchase prices (set by State Energy Regulation Commission): new wind installations after 01/01/2006 (duration 12 years each): (i) effective operation >2250 h/a: 79.8 €/MWh; (ii) effective operation <2250 h/a: 89.5 €/MWh.
Cyprus	FIT	Fixed feed-in tariff since 2005: in the first five years 92 €/MWh based on mean values of wind speeds; in the next ten years 48-92 €/MWh according to annual wind operation hours (<1750-2000h/a: 85-92 €/MWh; 2000-2550h/a: 63-85 €/MWh; 2550-3300h:/a 48-63 €/MWh).
Czech Republic	Choice between FIT and Premium Tariff	Fixed feed-in tariff: 88-114 €/MWh in 2007 (duration: equal to the lifetime); Premium tariff: 70-96 €/MWh in 2007 (duration: newly set every year).

COUNTRY	MAIN SUPPORT INSTRUMENT FOR WIND	SETTINGS OF THE MAIN SUPPORT INSTRUMENT FOR WIND IN DETAIL
Denmark	Market Price and Premium for Wind Onshore; Tendering System for Wind Offshore	Wind onshore: Market price plus premium of 13 €/MWh (20 years); additionally, balancing costs are refunded at 3 €/MWh, leading to a total tariff of approximately 57 €/MWh. Wind offshore: 66-70 €/MWh (i.e. Market price plus a premium of 13 €/MWh); a tendering system is applied for future offshore wind parks, balancing costs are borne by the owners.
Estonia	FIT	Fixed feed-in tariff for all RES: 52 €/MWh (from 2003 - present); current support mechanisms will be terminated in 2015.
Finland	Tax Exemptions and Investment Subsidies	Mix of tax exemptions (refund) and investment subsidies: Tax refund of 6.9 €/MWh for wind (4.2 €/MWh for other RES-E). Investment subsidies up to 40 for wind (up to 30 for other RES-E).
France	FIT	Wind onshore: 82 €/MWh for ten years; 28-82 €/MWh for the following five years (depending on the local wind conditions). Wind offshore: 130 €/MWh for 10 years; 30-130 €/MWh for the following 10 years (depending on the local wind conditions).
Germany	FIT	Wind onshore (20 years in total): 83.6 €/MWh for at least 5 years; 52.8 €/MWh for further 15 years (annual reduction of 2 is taken into account). Wind offshore (20 years in total): 91 €/MWh for at least 12 years; 61.9 €/MWh for further eight years (annual reduction of 2 taken into account).
Greece	FIT	Wind onshore: 73 €/MWh (Mainland); 84.6 €/MWh (Autonomous Islands). Wind Offshore: 90 €/MWh (Mainland); 90 €/MWh (Autonomous Islands); Feed-in tariffs guaranteed for 12 years (possible extension up to 20 years).
Hungary	FIT	Fixed feed-in tariff (since 2006): 95 €/MWh; duration: according to the lifetime of technology.
Ireland	FIT	Fixed feed-in tariff (since 2006); guaranteed for 15 years: Wind > 5MW: 57 €/MWh; Wind < 5MW: 59 €/MWh.
Italy	Quota obligation system with TGC	Obligation (based on TGCs) on electricity producers and importers. Certificates are issued for RES-E capacity during the first 12 years of operation, except biomass which receives certificates for 100 per cent of electricity production for first eight years and 60 per cent for next 4 years. In 2005 the average certificate price was 109 €/MWh.

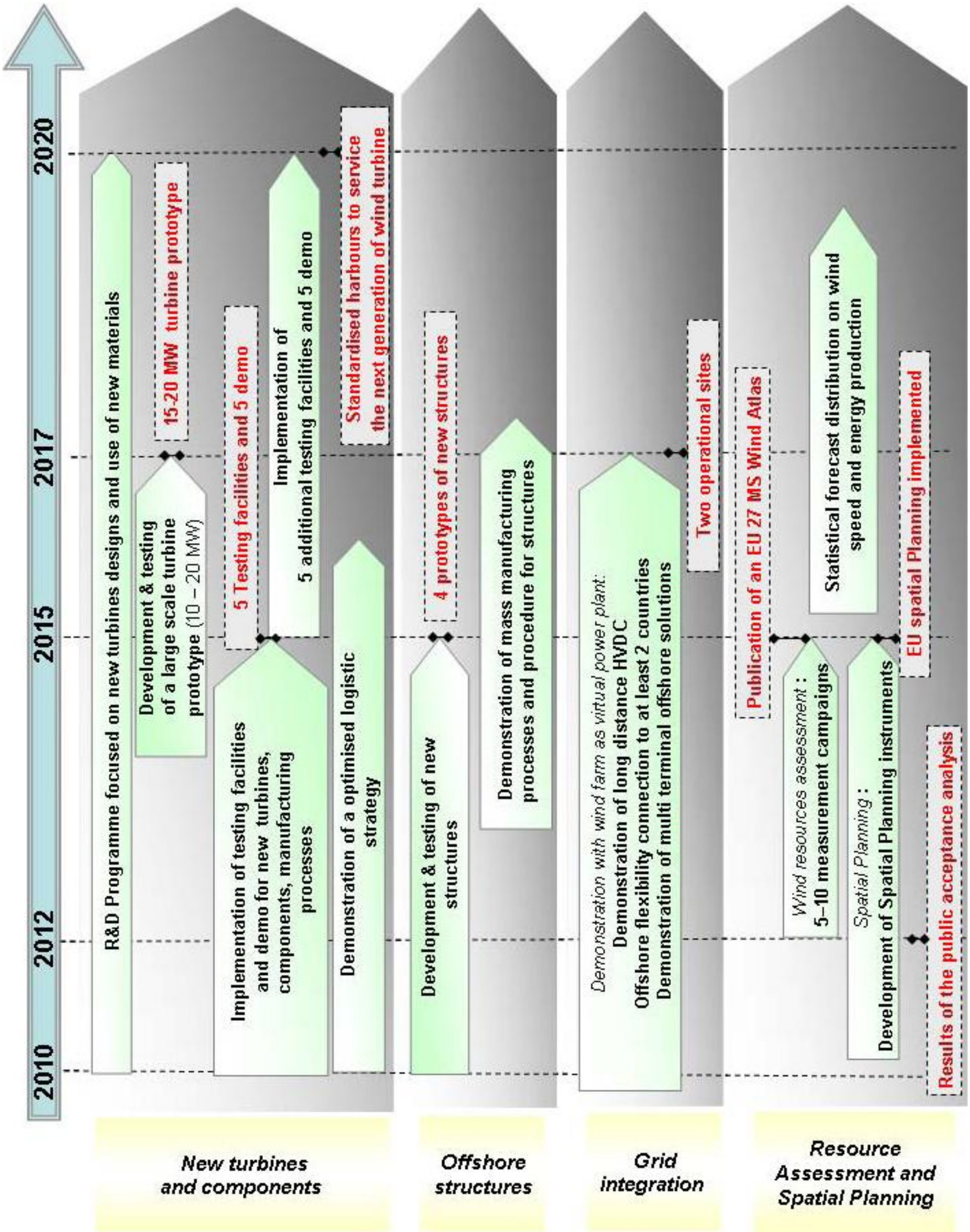
COUNTRY	MAIN SUPPORT INSTRUMENT FOR WIND	SETTINGS OF THE MAIN SUPPORT INSTRUMENT FOR WIND IN DETAIL
Latvia	Main policy support instrument currently under development	Frequent policy changes and short duration of guaranteed feed-in tariffs (phased out in 2003) result in high investment uncertainty. Main policy currently under development.
Lithuania	FIT	Fixed feed-in tariff (since 2002): 63.7 €/MWh; guaranteed for ten years.
Luxemburg	FIT	Fixed feed-in tariff: (i) <0.5 MW: 77.6 €/MWh; (ii) >0.5 MW: max. 77.6 €/MWh (i.e. decreasing for higher capacities); guaranteed for ten years.
Malta	No support instrument yet	Very little attention to RES-E (also wind) support so far. A low VAT rate is in place.
Netherlands	Premium Tariff (0 €/MWh since August 2006)	Premium feed-in tariffs guaranteed for ten years were in place from July 2003. For each MWh RES-E generated, producers receive a green certificate. Certificate is then delivered to feed-in tariff administrator to redeem tariff. Government put all premium RES-E support at zero for new installations from August 2006 as it believed target could be met with existing applicants.
Poland	Quota obligation system. TGCs introduced end 2005 plus renewables are exempted from excise tax	Obligation on electricity suppliers with RES-E targets specified from 2005 to 2010. Poland has an RES-E and primary energy target of 7.5 per cent by 2010. RES-E share in 2005 was 2.6 per cent of gross electricity consumption.
Portugal	FIT	Fixed feed-in tariff (average value 2006): 74 €/MWh; guaranteed for 15 years.
Romania	Quota obligation system with TGCs	Obligation on electricity suppliers with targets specified from 2005 (0.7 per cent RES-E) to 2010 (8.3 per cent RES-E). Minimum and maximum certificate prices are defined annually by Romanian Energy Regulatory Authority. Non-compliant suppliers pay maximum price (i.e. 63 €/MWh for 2005-2007; 84 €/MWh for 2008-2012).
Slovakia	FIT	Fixed feed-in tariff (since 2005): 55-72 €/MWh; FITs for wind are set that way so that a rate of return on the investment is 12 years when drawing a commercial loan.
Slovenia	Choice between FIT and premium tariff	Fixed feed-in tariff: (i) <1MW: 61 €/MWh; (ii) >1MW: 59 €/MW. Premium tariff: (i) <1MW: 27 €/MWh; (ii) >1MW: 25 €/MWh. Fixed feed-in tariff and premium tariff guaranteed for 5 years, then reduced by 5 per cent. After ten years reduced by 10 per cent (compared to original level).

COUNTRY	MAIN SUPPORT INSTRUMENT FOR WIND	SETTINGS OF THE MAIN SUPPORT INSTRUMENT FOR WIND IN DETAIL
Spain	Choice between FIT and premium tariff	Fixed feed-in tariff: (i) <5MW: 68.9 €/MWh; (ii) >5MW: 68.9 €/MWh; Premium tariff: (i) <5MW: 38.3 €/MWh; (ii) >5MW: 38.3 €/MWh; Duration: no limit, but fixed tariffs are reduced after either 15, 20 or 25 years, depending on technology.
Sweden	Quota obligation system with TGCs	Obligation (based on TGCs) on electricity consumers. Obligation level of 51 per cent RES-E defined to 2010. Non-compliance leads to a penalty, which is fixed at 150 per cent of the average certificate price in a year (average certificate price was 69 €/MWh in 2007).
UK	Quota obligation system with TGCs	Obligation (based on TGCs) on electricity suppliers. Obligation target increases to 2015 (15.4 per cent RES-E; 5.5 per cent in 2005) and guaranteed to stay at least at that level until 2027. Electricity companies which do not comply with the obligation have to pay a buy-out penalty (65.3 €/MWh in 2005). Tax exemption for electricity generated from RES is available.

Appendix C

European Industrial Initiative on Wind Energy – A Technology Roadmap

(European Commission, 2009a)



Appendix D

Detailed Description of Methodology

Research design

This study will use qualitative methods; namely semi-structured interviews and the review of secondary literature. Using a qualitative approach means to use methods to observe social research data without changing them to numerical format. The researcher is able to make claims based on the collection of open-ended, emerging data with the primary intention of developing themes from the data. The unit of analysis which is the major entity to be studied (Yin, 2003), are the policy instruments influencing the innovation chain for the wind energy sector. The unit of observation, which is the units one obtains data from, are the parties involved in the innovation process. The study includes an inductive method. In the first step, observations are made in order to find a pattern between variables and develop tentative conclusions in the end (Babbie, 2004).

Research framework

Albert (2003) presented a five step process adapted from Peltier and Schribrowsky which shows a microsegmentation model in the industrial commodity market. Although this study focuses on the wind energy sector, the aforementioned framework is used because it is generally applicable and serves to derive on a structural approach which generates valid results.

The process follows five steps. *Establishing research priorities* is the first step. Here, the research design and the theoretical framework are developed to study the role of policy instruments on the innovation dynamics in the wind energy industry. The outcome will be presented in chapter 2 and 3. The second step in the research process is the *Data collection*, which will be done through semi-structured interviews with parties that are involved in the innovation process and a secondary literature analysis. In the third step, *Identification of policy instruments,* the processing of the data takes place, whereby the data are analyzed and unique characteristics are identified. The outcome will be presented in chapter 5. In the fourth step, *Strategy Development (or Policy Recommendation)*, it will be identified how policy instruments drive innovation and which support mechanisms are the most effective ones for the wind energy sector. From this, the answer to the main research question will be derived. The last step, the feedback loop, is used during all steps in the research process in order to verify the previous obtained results and use their contribution to the following steps.

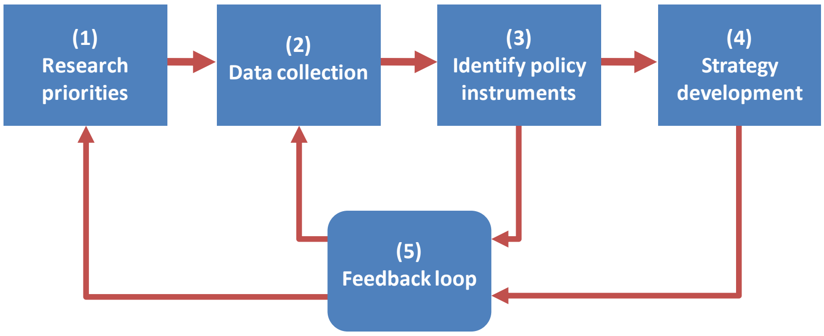


Figure 1: Research Process

Research activities

In order to obtain the necessary information, several research activities are performed. The theoretical questions are answered through literature research. The more practically oriented questions are answered mainly by semi-structured interviews and with the help of the input of the secondary literature. The review of secondary literature starts already at the first stages of the study in order to get acquainted with the topic and the unity of analysis. This gives insights which will be used during the interviews. However, it does not give enough detailed information about the effect of the policy instruments on the innovation dynamics and how the different actors perceive the processes. Specific information will therefore be retrieved through semi-structured interviews. This type of interview has open ended questions, making it more flexible and information can be obtained that could not have been foreseen. The personal involvement during the interviews makes it possible to judge the quality of the answers and to clarify matters that are not clear.

Method of data collection

The interview

The content of the interviews is based on the findings on the literature study. The questions that have been asked can be found in the Appendix. The primary topics discussed during the interviews relate to the previous identified policy instruments and their influence on the innovation chain. In contrast to the standardized interview, which uses a formally structured schedule of questions, this type of interview will be semi-structured. A set of questions will be developed before the interviews, but the number of them is not limited. A framework of topics and groupings will be developed to give an orientation in advance. This type of interview offers the advantage to be flexible during the interview and adapt to the environment and the respondents. New questions can be brought up that establish during the interview and are not in the framework. In the interview it should be made sure that the researcher sticks to the overall framework and doesn't deviate too much from the original ideas which can lead to answers that are in the end not relevant for the study anymore. Therefore, the prior developed framework of topics and issues serves as the orientation in the interviews.

Sampling method

This sampling method will rely on non-probability sampling. Non-probability samples offer the benefits of not requiring a list of all possible elements in a full population. The study population will include two actors from the wind industry, two actors from wind research field and the one actor from the government. The small sample size makes reliability difficult. The study sample is chosen according to purposive sampling which is also called judgmental sampling. This is done because of the following reason. When the population is chosen, the researcher is using the knowledge about the sample to include units that represent this population. Before choosing the population it will be made sure that the units display certain attributes which should be included in the study. With non-probability sampling, the researcher must take into account that there is limitation to the generalizability of the findings and a limitation to an accurate and precise representation. Although only a small number of units will be included, those will be heterogeneous instances. Purposive sampling of heterogeneous instances offers the advantage to find causal relationships easier and generalizability will be increased compared to using only typical instances (Shadish, Cook, & Campbell, 2002). Concentrating only on typical instances would make the finding of interview partners also more difficult. This gives the researcher greater flexibility to choose from a wider pool of units that represent certain attributes which are interesting for the research.

Data analysis

Miles and Huberman (1994) present a method for qualitative data analysis that will be used in the thesis. It is suggested to follow a three folded path which consists of data reduction, data display and conclusion drawing/verification.

After each meeting, the data will be reduced by making a summary of the most important points that have been mentioned during the interview. With this step the researcher is able to focus and abstract the data. The acquired data can also be coded and linked to the concepts of the study with the help of indicators. This is mentioned by Miles and Huberman as a second step to reduce data. Data display will occur in a table, which shows the links between the collected data to specific concepts. The last step suggested by Miles and Huberman (1994), which is conclusion drawing, involves the recognition of relevant relationships for the study which have to be identified from the data display.

Appendix E

Evolution of the main policy schemes in the EU-27 (EWEA The Economics of Wind Energy, 2010)