Offshore wind energy in Europe: A cluster perspective

Masterproef voorgedragen tot het bekomen van de graad van

Master of Science in de Toegepaste Economische Wetenschappen: Handelsingenieur

Els Van Impe
onder leiding van
Dr. Johan Bruneel
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PERMISSION

Ondergetekende verklaart dat de inhoud van deze masterproef mag geraadpleegd en/of gereproduceerd worden, mits bronvermelding.

Els Van Impe
PREFACE

This master dissertation constitutes the pinnacle of my academic education at the University of Ghent. Those five years of Business Engineering education provided me with a solid knowledge base that will help me take the next step in my professional life. Therefore, I would like to thank some people in particular.

First, I would like to thank Dr. Johan Bruneel for giving me the opportunity to conduct this research and to guide me where necessary.

I would also like to thank the people I met during my Business Engineering study for giving me an experience to never forget and for helping me through the period of writing this dissertation. In particular, I am grateful to Arne and Leiv for critically reading my dissertation before handing it in.

The home front – my parents – gave me the opportunity to study. I would like to thank them, and my brother Bart, for supporting me during my studies and for always having confidence in me.

Els Van Impe
DUTCH SUMMARY

Bedrijven beseffen meer en meer dat ze door nauwe interactie en samenwerking voordelen kunnen ervaren van de kennis en expertise van andere bedrijven, zelfs al worden die als concurrenten beschouwd. Dit toenemende besef heeft geleid tot een omgeving waarin clusters een prominente rol gaan innemen in het verhogen van de performantie en in het verbeteren van de nationale concurrentiepositie. Algemeen worden clusters gedefinieerd als geografische concentraties van onderling verbonden bedrijven en instellingen in een bepaald domein. Doorheen de tijd doorlopen clusters verschillende evolutiefasen, van ontstaan en groei, over maturiteit en verval of heroriëntatie. De levenscyclus van een cluster is zeer contextafhankelijk. Met andere woorden, er bestaat geen algemeen geldend recept voor een succesvolle cluster. Doorheen onze literatuurstudie hebben we een aantal factoren geïdentificeerd die invloed hebben op de ontwikkeling van een cluster: diversiteit van organisaties, aanwezigheid van een ankerorganisatie, aanwezige kennis en kennisstromen, domein overschrijdende werking, relaties met dienstverlenende bedrijven, geografische nabijheid en cluster grootte en clusterbeleid.

De toenemende aandacht voor clusterwerking wordt doorheen deze masterproef verder bekeken in een context van offshore wind energie, en meer bepaald in Europa. Onze analyse beperkt zich tot die zes Europese landen met de hoogste geïnstalleerde offshore wind capaciteit, zijnde Het Verenigd Koninkrijk, Denemarken, België, Nederland, Duitsland en Zweden. Ons onderzoek gebeurt aan de hand van drie onderzoeksvragen:

- Waar kunnen geografische concentraties van offshore wind activiteiten geïdentificeerd worden in de geselecteerde landen? Kunnen we hier georganiseerde clusterwerking waarnemen?
- Nadat ‘best practices’ geïdentificeerd zijn, hoe zijn deze clusters ontstaan en geëvolueerd en op welke manier wordt de cluster geleid? Welke partijen en instellingen zijn hierbij betrokken?
- Wat zijn de ‘Key Performance Indicators’ voor de ‘best practices’ en kunnen deze ook ergens anders toegepast worden om clusterwerking in de offshore wind industrie te stimuleren? Met andere woorden, is er sprake van generaliseerbaarheid?

Om een antwoord te bieden op deze onderzoeksvragen, werd een empirische, kwalitatieve studie uitgevoerd aan de hand van secundaire bronnen.
Voor elk van de zes landen onder studie konden geografische concentraties van offshore wind activiteiten waargenomen worden. Voor het Verenigd Koninkrijk waren de offshore wind activiteiten hoofdzakelijk geconcentreerd in het oosten van Engeland. Ondanks hun enorme capaciteit wees ons onderzoek uit dat de prestaties op vlak van clusterwerking ondermaats waren door een gebrek aan binding tussen verschillende hoofdinstellingen, alsook een gebrek aan samenwerking door fragmentatie. Voor Nederland, België en Zweden was een gelijkaardig gebrek aan connecties tussen bedrijven en organisaties terug te vinden. In Denemarken kon een sterke concentratie van (offshore) wind activiteiten geïdentificeerd worden in de centrale gordel, meer bepaald in en rond de kuststad Aarhus. Sterke krachten, gegenereerd door autoriteits-, academische en industriële linken, houden de cluster samen. Gelijkaardige georganiseerde clusterwerking was terug te vinden in noordwest Duitsland, meer bepaald in de regio Bremerhaven/Bremen. Aarhus en Bremerhaven/Bremen werden dan ook uitgekozen om als ‘best practices’ verder te onderzoeken.

Na analyse blijkt dat beide offshore wind clusters in Aarhus en in Bremerhaven/Bremen een verschillend ontstaan kennen maar een gelijkaardige evolutie doormaken. De Aarhus cluster is meer op natuurlijke wijze ontstaan, terwijl de cluster in Bremerhaven/Bremen eerder een ontstaan kende vanwege maatregelen van bovenaf. Dit laat ons toe te besluiten dat de manier van ontstaan van weinig belang is voor het succes.

Verder werden volgende factoren gevonden als algemene basisprincipes voor clusterwerking: diversiteit van organisaties, aanwezigheid van een ankerorganisatie, aanwezige kennis en kennisstromen, domein-overschrijdende werking en relaties met dienstverlenende bedrijven. Deze factoren zijn generiek en kunnen dus toegepast worden in andere regio’s voor het uitbouwen van een offshore wind cluster.

Directe nabijheid bleek minder relevant in de case studie van Bremerhaven/Bremen doordat beide locaties 65 km uit elkaar liggen, maar er toch een optimale samenwerking en kennisdeling is. Het geheim zit hem in een sterke ankerorganisatie die het geheel optimaal samen houdt. Ook de grootte van de cluster leek voor beide case studies niet van belang voor succes.

Verder kwam naar voren dat het van belang is om de hele samenleving te betrekken bij de offshore wind aangelegenheid, meer bepaald bij het hele hernieuwbare energie onderwerp. Deze gedachte moet uitgedragen worden door de overheid zodat op die manier een klimaat van vertrouwen in het beleid kan ontstaan. Optimale integratie van top-down en bottom-up beleid werd ook als sterke succesfactor bevonden.
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<tr>
<td>AAU</td>
<td>Aalborg University</td>
</tr>
<tr>
<td>ABP</td>
<td>Associated Britisch Ports</td>
</tr>
<tr>
<td>ASE</td>
<td>Aarhus School of Engineering</td>
</tr>
<tr>
<td>BIS</td>
<td>Bremerhavener Gesellschaft für Investitionsförderung und Stadtentwicklung</td>
</tr>
<tr>
<td>BWE</td>
<td>Bundesverband WindEnergie (= German Wind Energy Association)</td>
</tr>
<tr>
<td>BWEA</td>
<td>British Wind Energy Association</td>
</tr>
<tr>
<td>CORE</td>
<td>Centre for Offshore Renewable Engineering</td>
</tr>
<tr>
<td>DECC</td>
<td>Department of Energy and Climate Change</td>
</tr>
<tr>
<td>DUWind</td>
<td>Delft University Wind energy research institute</td>
</tr>
<tr>
<td>Dvo</td>
<td>De Vlaamse Ondernemer</td>
</tr>
<tr>
<td>DWIA</td>
<td>Danish Wind Industry Association</td>
</tr>
<tr>
<td>ECN</td>
<td>Energieonderzoek Centrum Nederland</td>
</tr>
<tr>
<td>EEA</td>
<td>European Environment Agency</td>
</tr>
<tr>
<td>EEEGr</td>
<td>East of England Energy Group</td>
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<tr>
<td>EEDA</td>
<td>East of England Development Agency</td>
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<tr>
<td>EERE</td>
<td>Energy Efficiency and Renewable Energy</td>
</tr>
<tr>
<td>EPCI</td>
<td>Engineer-Procure-Construct-Install</td>
</tr>
<tr>
<td>EWEA</td>
<td>European Wind Energy Association</td>
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0 Introduction

Energy demand is rising at an ever increasing pace. This trend is also the case for fossil fuel demand. But, are fossil fuel consumption and the demand for energy intertwined? Are fossil fuels that indispensable for meeting raising energy demand? When looking around, we can definitely say that the strong relationship between energy generation and fossil fuels is already bursting for a while. Environmental awareness is boosting and people realize that a shift towards less polluting energy resources is inevitably. The quest for effective and efficient applications of renewable energy is infinite.

But why then choosing for wind energy? Wind energy is the world's main source of renewable electricity, of which most is generated on land. Even though onshore wind power has higher installed capacity, focus will be put on offshore wind energy. Offshore wind energy has a higher potential, just because of the larger scale applicability and the higher wind speed offshore.

Offshore wind energy is a very broad topic to discuss. Therefore, we had to identify some specific angles to be further explored in this master dissertation. As a lot of countries worldwide are active in the offshore wind industry, the geographical scope is the first point of refinement. Up until now, Europe has been the world leader in offshore wind energy, covering more than 90% of the world's offshore wind capacity. Given Europe's leading position, it seemed obvious to narrow down the offshore wind topic to Europe's borders. As discussing an entire continent is still too wide, we decided to limit the number of countries, based on their installed offshore wind capacity, resulting in the selection of six countries, being The United Kingdom, Denmark, Belgium, The Netherlands, Germany and Sweden, ranked from highest to lowest capacity. Besides having the highest installed capacity, all six countries are located in the North Sea area. The North Sea area is characterized by Europe's highest average wind velocities, turning this area into the perfect operating base for this master dissertation.
History is teaching us that the idea that companies can make it on their own becomes more and more outdated. Several authors and researchers have pointed out the increasing importance of collaborative networks and their potential of generating results that outperform the performance of individual players in the industry. Often, geographical proximity is a factor that fosters the formation of such networks. Clusters emerge when players in a collaborative network are locating close to each other. They feel they can benefit from other players’ knowledge and expertise through close interaction and collaboration, even when firms are considered to be competitors. Regional clusters are not only beneficial for their members. Clustering also brings numerous economic advantages for the region it covers, such as increased employment, and are thus presumed to enhance country competitiveness.

Clusters are especially important in high-technology sectors, which are strongly characterized by non-documentated (tacit) and complex knowledge and expensive or scarce resources and capabilities. Clusters can also serve as powerful engines for innovation fostering, which is a driving growth factor for high-technology industries.

As offshore wind energy is a high-technology sector, it appeared as very interesting to explore the offshore wind power topic from a cluster perspective. Hereby, we reached a second point of refinement. Exploration and analysis of the different factors driving cluster performance in offshore wind energy will proceed based on some research questions:

- Where can geographical concentrations of offshore wind activities be identified in the selected countries? Can we identify organized cluster activities here?
- Having identified best practices in offshore wind clustering, how did those clusters emerge and develop and how does management of those clusters take place? Which parties and institutions are involved?
- What Key Performance Indicators (KPI’s) are driving the best practice case studies and can those be applied elsewhere to foster the development of offshore wind clusters, i.e. we will research if generalizations can be obtained.
In order to provide some structure, this master dissertation was divided into three main parts. In total, these three parts consist of six chapters.

In part 1, we aim at drawing a theoretical frame of reference in which our research can be situated. Chapter 1 discusses the broad theoretical concept of clusters. We introduce the chapter by shortly outlining the historical evolution. Important in this chapter is to provide a clear definition of a cluster. Subsequently, we will describe the cluster concept as well as the different evolutionary phases of the cluster life cycle and the factors that can affect the development of a cluster.

In part 2, we will outline the context in which we will investigate cluster activities. Chapter 2 will give a broad and comprehensive overview of wind energy, discussing offshore wind energy in particular. Chapter 3 will further build on offshore wind energy but, the geographical scope is then limited to Europe. We will further mark the borders of our research in this chapter by making a well-considered selection of six countries that will be further subject of our research. We will provide an analysis of each country by means of some criterion that can lead us towards the detection of organized cluster activities. This analysis will be conducted with the help of empirical explorative research, more specifically by researching secondary sources. The chapter will end with an overview from which best practices in offshore wind clustering can be derived.

A more extensive analysis on offshore wind clustering in Europe is provided in part 3. In chapter 4, the best practices that were identified in the previous chapter will be deeper analyzed, thereby frequently referring to the literature review. First, the historical origin and evolution of each best practice will be described. Subsequently, the different success factors as identified in literature will be further analyzed. The analysis again is exclusively based on empirical explorative research. Consequently, we will look for success factors that can be generalized or that are rather atypical in chapter 5. We will end the chapter with some policy implications. Chapter 6 contains a general conclusion on our research, thereby providing a summarized answer on each of the research questions. We will end the chapter with some general recommendations for further research.
PART 1: LITERATURE REVIEW

1 Clusters

The first part of this master dissertation brings together all relevant literature on clusters, from historical evolution and definition to growth and development. It is worth mentioning that it is difficult to obtain generalization on clusters because of strong context dependency. There is also a great deal of variation in the way clusters are defined and described. As most literature supports the pioneering work of M. E. Porter, it is appropriate to consider Porter’s work as a main reference throughout the study of literature.

Historical evolution of the concept

Long before any existing interest in cooperation, firms were operating as sole entities in an industry or economy. Based on the neoclassical concept of perfect competition, demand was assumed homogenous for every industry’s product and consumers and firms were acting under conditions of perfect and costless information. The firm’s only objective was to maximize profit, using the resources of capital, labor, land, energy etc., which were assumed to be perfectly mobile. Firms competed by adjusting their produced quantity in the short run or their plant scale in the long run. Later on, focus shifted towards comparative advantages. (Hunt & Morgan, 1995). Comparative advantages, as first described by Ricardo (1891), refer to the concept that a country should specialize in producing and exporting only those goods and services that can be produced more efficiently, i.e. at lower opportunity cost. The production of goods and services is thus dependent upon different endowments of the factors of production, namely capital, labor and land (Ricardo, 1891).

The 1890s-1920s is the starting point of the recognition of regional cooperative networks, pioneered by Marshall. His definition of “industrial districts” is “a concentration of small businesses of a similar character in particular localities”
(Marshall, 1966 (1890)). In his work, Marshall points out that those industrial districts, through localization of industry, generate economies of scale, which are external to the firms but internal to the territory of the industrial district. Marshall also finds increasing efficiency for each individual firm of an industrial district.

After Marshall’s work, interest in clusters diminished (Rocha, 2004) due to increasing application of mass production methods that generated economies of scale (Armin, 2000). During the 1970s-1980s, a renewed interest in industrial districts came forward. The rigid mass production system in combination with a fast changing environment resulted in an unemployment problem. A shift from mass production to a focus on flexible production appeared to be the solution to the problem. The independent large firm-focus had to make place for regional network-based systems (Rocha, 2004).

Today, global markets, faster transportation and the development of communication technologies make that companies can source capital, goods, information and technology from around the world. One should expect that, given this evolution in accessibility of resources, the role of location in competition is vanishing. (Porter, 1998). As clusters are highly region and context dependent, Porter describes the fact that clusters are not unique but highly typical as paradoxal: ongoing competitive advantages in a global economy are increasingly embedded in local things that distant rivals cannot imitate, namely knowledge, relationships and motivation.

In today’s economy, access to inputs or the scale of individual enterprises are not driving modern competition anymore. Productivity is (Porter, 1998). And productivity relates to how companies compete. Nowadays, innovation is a driver for competitive advantage of firms, which in turn is driven by skills and knowledge. This competitive advantage can only be sustained by upgrading innovation on a regular base (Porter, 1990). Organizational learning is crucial for a firm’s development and acquiring knowledge from external sources is seen as being critical for firms to continuously innovate. (Tallman & Phene, 2007).
The chapter proceeds with the definition of a cluster and a broad description to further extend the understanding of the definition. Different stages within a cluster and the driving forces will be discussed in the life cycle section.

1.1. Definition

“Clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition” (Porter, 1998)

Porter’s definition includes three dimensions, namely a sectoral, a geographical and a network dimension. This is an extension of Porter’s definition of clusters in 1990, in which a cluster was defined as a sectoral cluster, primarily being an industrial rather than a territorial phenomenon.

With Porter’s 1998 reference to economic geography and socio-economics, the definition is more complete. Mentioning clusters in the proceedings of this work, this definition will be referred to.

1.2. Description

According to Porter’s (1998) definition, the existence of a cluster strengthens competitive forces within a geographic concentration in a particular field that benefits all different parties in that location. The dynamic improvement view tells us that a firm’s capacity to innovate and upgrade is crucial to leverage competitive advantage. This capacity strongly depends on the local environment a company is operational in (Porter, 1994). Porter (1994) highlights some attributes that are related to dynamic improvement, among them: “the presence of a continually improving pool of skilled employees, applied technology, tailored infrastructure, experienced sources of capital and other factor inputs that are specialized to a particular business; a core of sophisticated and demanding customers for the product, whose needs anticipate these elsewhere; a critical mass of local suppliers of those specialized components, and services that significantly influence product or process improvement in the
business, and the presence of other locally based competitors to motivate progress.” All these attributes interact with each other and are leveraged in a mutually reinforcing and cumulative way. This process leads to the emergence of clusters, in which industries are interconnected in a geographical concentration. Such an environment ideally promotes the exchange of specialized information, the creation of tight relationships and a faster pace of innovation. Furthermore, proximity enables cluster members to closely coordinate activities and integrate knowledge and inputs (Porter, 1994). The above mentioned attributes will be discussed in further detail under the section Life cycle, Driving factors in the development of clusters.

1.2.1. Porter’s Diamond of National Advantage

In his work, Porter (1990) proposes ‘The Diamond of National Advantage’ as a model to visualize the determinants of national competitive advantage (figure 1). Here, Porter starts from asking questions like ‘Why are some firms able to pursue consistent innovation?’; ‘Why are they constantly looking for ways to upgrade in order to sustain their competitive advantage?’ and ‘How do companies overcome the fear to lose that is accompanied by an aversion to change?’. The answer can be found in the diamond model that is composed of four interconnected forces: ‘Factor Conditions’, ‘Demand Conditions’, ‘Related and Supporting Industries’ and ‘Firm Strategy, Structure, and Rivalry’.

![Diagram of Porter's Diamond Model](image-url)
Each determinant individually and the diamond as a whole shape the national environment in which companies establish international competitive advantage (Porter, 1990). We will now shortly discuss the four attributes constituting the diamond.

**Factor Conditions.** This attribute refers to factors of production as pointed out in standard economic theory, namely labor, land, capital, infrastructure, resources etc., determining the trade flow. But, according to this standard economic theory, a nation will utilize those factors that it is well provided with, in other words, that it has inherited. According to Porter, those insights are incomplete and incorrect. Porter (1990) argues that industries create the most relevant factors of production such as skilled labor and a sophisticated R&D base, to name just a few. Moreover, the most important factors of production are highly specialized to the industry's specific needs and are related to considerable investments.

**Demand Conditions.** The composition and nature of domestic market demand gives an industry a better indication of emerging and advanced buyer needs. Demanding buyers in the home market also push companies to innovate faster, stimulating competitive advantage as mentioned earlier (Porter, 1990).

**Related and Supporting Industries.** The presence of internationally competitive related and supporting industries refers in the first place to home-based suppliers that provide access to components and machinery in a most cost-effective and efficient way. Moreover, those domestic related and supporting industries stimulate companies to innovate and upgrade. These effects result from tight networking relationships built through extended ways of communicating that are enabled by the fact that firms are located close to each other (Porter, 1990).

**Firm Strategy, Structure, and Rivalry.** The dynamics of the industry and the character of the firms' strategy are influenced by the national environment. Rivalry is determined by the management system and the organizational structure that are locally promoted. Strong local rivalry also drives innovation in the cluster, leading to further development of competitive sustainable advantages (Porter, 1990).
The effect of each attribute individually is often influenced by other attributes in the diamond. But, the determinants together also form a system through their self-reinforcing character. Particularly, local rivalry and proximity are responsible for the system nature of the diamond. Rivalry fosters innovation and upgrade in each attribute and proximity stimulates interaction between the different factors of the diamond. Another remarkable effect resulting from the diamond system is that a geographic concentration mostly houses more than one competitive industry. This enables geographic concentrations to establish themselves as clusters, in which competitive industries are interconnected through vertical as well as horizontal relationships, respectively represented by buyer-seller and customers-technology-channels relationships (Porter, 1990). The vertical and horizontal relationships interconnecting competitive industries cause that a cluster can actually be seen as an alternative way of outlaying the value chain (Porter, 1998).

Porter further discusses the role of government, without inserting it into the diamond model. Government is assigned the role of catalyst and challenger, encouraging companies to achieve higher levels of performance by intervening indirectly. Government has to elaborate policies that enable companies to gain competitive advantage by transferring and supporting the four attributes of the diamond (Porter, 1990).

Clusters stimulate competition as well as cooperation. Firms try to outperform each other in terms of low costs, quality, services and new products and processes, resulting in fierce competition. Hereby, companies are constantly under pressure to fasten the pace of innovation and improvement. But, besides competition, there is cooperation between cluster members. Competition and cooperation can coexist as both take place in different dimensions and involve different parties (Porter, 1998).

The quality of the local business environment heavily influences the way in which firms compete. The factors driving the quality of a specific business location are mostly related to clusters. A cluster enables each member to act like it had a larger scale or like it had built formal relationships. From this viewpoint, Porter (1998) discusses three ways in which companies can benefit from clusters affecting
competition: by increasing productivity, by driving the direction and pace of innovation and by fostering the establishment of new businesses.

Enhanced productivity is obtained because cluster members have better access to various resources. Companies can make use of a pool of skilled and specialized employees and suppliers, reducing both costs and effort. A cluster also fosters communication and coordination through close, informal relationships, increasing efficiency and productivity. Complementarities increase productivity as success of one firm can enhance performance of other cluster members. Governmental or public investments benefit all companies in a cluster, allowing them to more easily access institutions and public goods. Because of the strong pressure that results from domestic rivalry, cluster members keep their motivation high, desiring to constantly perform better. Performance is then easier to measure and compare because of equal circumstances within the cluster (Porter, 1998).

Clusters play a prominent role in fostering a firm’s ongoing capacity to innovate and upgrade resulting from competition and cooperation. Tight relationships enable companies to learn from each other. This learning is heavily promoted by proximity as companies have the opportunity to easily make site visits and engage in frequent personal contact. Porter speaks of ‘sheer pressure’, which is a combination of competitive pressure, peer pressure and constant comparison. Not only the ability to innovate enhances, also the pace of innovation increases because of higher flexibility to act fast on changing factors (Porter, 1998).

Third, a cluster is a fertile environment for new businesses. New ventures can benefit from the various advantages of the already established cluster like tapping into a highly specialized labor pool and serving an already existing large customer base, to name just a few (Porter, 1998).

All the above discussed factors that are supporting the importance of localization are captured in Porter’s (1998) main finding, namely “the enduring competitive advantages in a global economy lie increasingly in local things – knowledge, relationships, and motivation that distant rivals cannot match”.

10
1.2.2. Cluster insights according to Malmberg & Maskell (2002)

Various authors have researched the concept of clusters over the years in different ways. Broadly, two approaches can be recognized (Malmberg & Maskell, 2002). In the first approach, researchers try to investigate the historical origin and evolution of geographical concentrations. This topic will be further discussed in the section Life cycle. The second approach in localization literature is more oriented towards cost-reduction. Here, researches aim to explain the existence of clusters by investigating the various benefits obtained by its members. Malmberg & Maskell (2002) further identify three different mechanism that come to surface when considering literature according to the cost-reduction approach.

First mechanism is ‘reduced costs for producing and maintaining a dedicated infrastructure and other collective resources’. According to this mechanism, co-located firms benefit from sharing collective costs among the different firms in the cluster (Malmberg & Maskell, 2002). In his work, Marshall (1890) talks about economies of agglomeration. Agglomeration economies refer to advantages obtained by companies that are located close to each other. This geographical concentration of firms, Marshall identifies as industrial districts, in which external economies of scale are created. Those economies are external to the firm but internal to members of the industrial district. Part of these economies are realized by establishing tailored infrastructure (Malmberg & Maskell, 2002) as different cluster members have similar needs.

Another part of Marshall’s external economies is created through the second mechanism: ‘well-functioning markets for specialized skills’, as co-location of firms with similar needs fosters the development of a local labor market that pools specialized skills (Malmberg & Maskell, 2002). Marshall (1890) emphasizes the importance of a specialized labor market as he puts that employers tend to locate their business in an area where they have access to workers whose skills are specialized and tailored to the business’ needs while those workers naturally look for work in those areas where employers require their level of specialized skills. Krugman (1991) also argues that local labor markets – both from employer and employee perspective - perform better in areas where firms have similar needs.
Third mechanism of cost-reduction in localization economies is ‘reduced interaction costs for co-located trading partners’. Idea here is that firms that are located close to each other minimize their costs as transactions and shipments between cluster members are simplified because of shorter distances (Malmberg & Maskell, 2002). This mechanism was also mentioned by Porter (1998) in terms of better coordination and trust, which arises from proximity.

We clearly see that all of these mechanisms are more or less represented in Porter’s work, but, Porter’s view is more extended as he also discusses various aspects of productivity, innovation and new business creation besides the narrow view of cost-reduction.

1.2.3. Vital ingredient: innovation through spill-overs

Other authors also recognized the importance of innovation, often referring to knowledge spill-overs and the various opportunities of learning and adaptation, by which competitive advantage is created and sustained. Marshall (1890) already mentions the fact that proximity leads to the creation of close relationships, fostering the exchange of information and knowledge. Especially the exchange of complex or tacit (unwritten) knowledge is important as these kinds of information require frequent contact and close interaction to ensure common ways of understanding (Almeida & Kogut, 1999). The frequent interaction further stimulates firms’ willingness to collaborate through the creation of trust.

Knowledge and technology is often claimed as being regional. This is because knowledge is held by people and thus, mainly immobile. Saxenian (1994) conducted a research that concludes that people are more loyal to their business than to the company they work for but, they are also likely to stay in the area in which they conduct their business. This leads to the accumulation of knowledge and expertise in particular regions. Technological spillovers, defined as positive externalities of R&D developments, take place when the advantages of research efforts spill over from one to another cluster member. This is an extremely important aspect in clustering as evidence shows that firm’s performance is influenced by R&D spending of other parties in the cluster (Jaffe, 1986).
Storper (1997) also argues that relational assets of the regional economy are embedded in untraded forms of interdependency between economic agents. These relational assets result from the fact that a lot of drivers for local economic development are cultural or institutional, whereby routines of economic behavior are created that shape activities of production, entrepreneurship and innovation.

1.2.4. Downsides to clustering

So far, we primarily discussed different advantages and reasons for cluster existence, but, literature also identifies some downsides to the cluster concept. First of all, the supply side may experience some negative pecuniary externalities in terms of competition and congestion. Input market firms that serve the same local market and are located close to each other can experience strong price competition because of proximity. This competition reduces the pricing power of suppliers and may increase other costs like infrastructure or labor costs. The latter are referred to as congestion costs and are caused by excess demand for local resources like labor, land, public goods, etc. (Beaudry & Breschi, 2003). Furthermore, traffic congestions and higher concentrations of pollution are more likely to occur in clusters. This can eventually discourage other firms to locate their business in that specific area.

Another disadvantage is caused by the mechanism of technological spillovers, discussed earlier. Although technological spillovers are argued to foster growth and innovation within a cluster, proximity can make competitors reluctant to share information because of the risk of losing crucial organizational knowledge to nearby located competitors. Academic R&D results may be less likely to spill over because they may be sold to larger corporations who have better financial resources. R&D results may also be distributed to only a selected number of companies via so called club arrangements. It is further argued that smaller, innovative firms are more likely to subcontract their research projects to academic institutions because they are not able to finance it themselves (Breschi & Lissoni, 2001).

Breschi & Lissoni (2001) also recognize that even those firms and institutions that are most willing to share information, prefer to maintain some control over their knowledge flows in terms of establishing property rights or exclusionary
arrangements, transforming the apparently freely available knowledge flows into ‘private goods’ that are only accessible to those who engage in such relationships.

Several authors refer to the disadvantages of agglomeration as ‘diseconomies of scale’. The economies of agglomeration that initially attract businesses to a particular area eventually tend to erode (Pouder & St. John, 1996). Pouder and St. John (1996) further argue that firms’ competitive strategies in a cluster shift from being highly innovative in the emergence and growth stage of the cluster, towards losing innovativeness over time because firms tend to restrict their area of focus to cluster boundaries, rather than taking into account the whole industry.

Most of these disadvantages are generic, i.e. they affect the whole business rather than that they are sector specific (Beaudry & Breschi, 2003). We will now further outline the different stages and their accompanying characteristics in the life cycle of a cluster. We will subsequently discuss the driving forces for cluster success.

1.3. Life cycle

Once a cluster begins to form, it moves through different evolutionary phases. It is worth noting that it is extremely difficult to forecast and identify the emergence of a cluster before it occurs (Scott, 1992). Pouder and St. John (1996) made a nice comparison:

“In some ways, clusters of firms are analogous to forests of trees. Although one cannot anticipate exactly when or where the first seed will land within a field, once the seed is implanted, it is highly likely more trees will follow” (Pouder & St. John, 1996).

The evolution of a cluster is also highly uncertain. Some emerging clusters will eventually grow through a mechanism of a self-reinforcing cycle, whilst others remain relatively small or even disappear (Sölvell, 2008).

Different authors have researched the life cycle of a cluster in terms of stages and characteristics. Porter (1998) generally speaks of birth, evolution and decline, while Sölvell (2008) elaborates a more extended approach: The ‘hero phase’ is
characterized by one or a few entrepreneurial actors. After take-off, the cluster comes into the ‘maturity phase’, in which economies of scale play an important role as certain strategies will become dominant. Succeeding the maturity phase, two different paths are possible. First, the cluster can reorganize itself, resulting in the emergence of new technologies and firms. This stage is called ‘renaissance’. Or, the cluster can evolve towards decline and eventually end up into the ‘museum phase’, where dynamism is reduced to almost zero. This life cycle is represented in figure 2.

![Figure 2 The Cluster Life Cycle (Sölvell, 2008)](image)

Pouder & St. John (1996) take on a similar approach. They introduce the term ‘hot spot’ as a fast-growing geographic cluster of competing firms. This term is comparable to the definition of cluster, given at the beginning of this dissertation. Pouder & St. John (1996) divide the cluster life cycle into three evolutionary phases: ‘origination of the cluster and emergence of the hot spot identity’, ‘convergence of clustered firms’ and ‘firm reorientation’. They further distinguish the evolutionary path of clustered firms from that of non-clustered rivals. The growth pattern is displayed in figure 3.
Initially, clustered firms experience higher growth than non-clustered firms but, over time, clustered firms move into a decline phase because they experience resource diseconomies, competitive practices that isolate them from rivals outside the cluster, lower levels of innovation and loss of the dominant position in the industry. This decline path is not faced by outside competitors in non-clustered firms (Pouder & St. John, 1996). A jolt refers to an external shock, often followed by the need to carry through several industrial changes.

In the next section, we will present the different phases and their characteristics in the cluster life cycle, using the insights of previously mentioned authors interchangeably as they are largely overlapping.

1.3.1. Emergence of a cluster

Different occurrences can trigger the origin of a cluster. Porter (1998) sums several typical seeds for cluster emergence. A cluster can have its roots in historical circumstances or can arise from a particular demand or skill within a specific region. Sölvell (2008) distinguishes two ways to explain cluster emergence, namely natural factor advantages, i.e. region specific resources, and historical accidents. As a natural factor advantage in the modern economy, Sölvell (2008) refers to universities, fulfilling the role of ‘brain trust’, which can serve as a base for cluster emergence.
Both authors further mention the existence of a chance event that sometimes determines the origin and initial location of a cluster, although Porter (1998) argues that chance rarely offers the sole explanation for cluster success. A new cluster can also emerge as a result from the actions of one or a few innovative companies. This will eventually support the growth of other nearby competitors (Porter, 1998). This seed is referred to by Sölvell (2008) as the ‘hero phase’. ‘Heroes’ are successful entrepreneurs that cause subsequent entry of both downstream and upstream industries, ultimately leading to the emergence of a cluster.

Once the seed is planted, the cluster begins to build up critical mass, causing the cluster to grow. This process is strongly cumulative or characterized by path dependency, ultimately leading the cluster to be locked in (Sölvell, 2008). To support the growth of a cluster, Sölvell (2008) proposes several factors that exercise important influence: ‘sophisticated demand, factor specialization and upgrading, arising strategies of competition and cooperation, an institutional environment that fosters innovation and change, political actions, etc.’ The spontaneous spin-off and location factors help the cluster to take off in the first place and attract new start-ups – through agglomeration economies - that want to locate business near competitors. This process is promoted by numerous economic and institutional factors (Pouder & St. John, 1996).

1.3.2. Growth and development of the cluster

The further evolution and composition of a new born cluster is very unpredictable. Clusters can emerge and grow on a base of many small firms, competing and cooperating at the same time. But, it is also possible that one or a few large firms move into a dominating position in the cluster and become so called anchor organizations (Sölvell, 2008). As the success of the cluster further expands, qualified suppliers, skilled workers and aware investors are attracted to the region. The emergence of this kind of specialized network lowers the cost of entry for other firms as a result of agglomeration economies (Pouder & St. John, 1996). This self-reinforcing cycle causes the cluster to further expand. Porter (1990) speaks of the creation of local infrastructure and the expansion of supply of skilled labor and resources because of proximity of competitors. The number of competitors will
increase, many among them being created as start-ups or spin-offs from formerly successful firms. A cluster thus creates an environment that is characterized by an entrepreneurial spirit, fueling a culture of innovation and rapid change (Pouder & St. John, 1996).

In addition to attracting new players, a cluster further stimulates networking and emerging social capital (Sölvell, 2008). Porter (1998) speaks of ‘social glue’, binding clusters together so that members can gain access to important resources and information. In order to facilitate this access, personal relationships, face-to-face contact, a common sense of interest, and ‘insider’ status is required (Porter, 1998). Efforts are undertaken to build relationships, promoting further growth and holding the cluster together over time. The developing network of alliances among different industry members encourages an environment of creativity and idea exchange (Saxenian, 1994).

Pouder & St. John (1996) mention a cognitive dimension, characterizing the growth of a cluster. An emerging cluster causes similar cognitive frameworks and mental models to arise among managers and key technical employees, suggesting that they have similar industry experience and technical training. Norms will emerged through patterns of social and professional interactions, selection and training of human resources and cluster-wide accepted practices (Porac & Thomas, 1994). This will lead to similar values and perceptions among industry members, eventually resulting in the emergence of cluster-specific strategies and the establishment of the competitive rules of the game (Pouder & St. John, 1996).

Cluster expansion increases its influence with government and public and private institutions (Porter, 1998). Therefore, appropriate management of the cluster in terms of planning and policy involvement, is crucial. In the growth phase, both bottom-up and top-down initiatives cause a cluster’s structure to evolve over time towards that of an ‘organization field’ in which institutional forces easily find their way and promote homogeneity (Pouder & St. John, 1996).

A final important element in cluster growth is its linkages with international markets. A cluster must attract people as well as firms to continue to flourish. Therefore, a
continuously inflow of diverse people, incoming investments, imports of materials, components and products, and new technologies is required, leading to a dynamic cluster that is not isolated from the outside environment. In order to generate a cycle of ideas, skills and resources, cluster members should also engage in international activities, e.g. making international investments and exporting goods and services (Sölvell, 2008).

Facilitating the growth of a cluster, Porter’s ‘Diamond of national advantage’— as discussed in the description section – plays the role of growth engine. We clearly see that a lot of the above discussed aspects of growth can be found in the diamond. When all four factors (i.e. factor conditions; demand conditions; firm strategy, structure and rivalry and related and supporting industries) interact, upstream and downstream linkages will emerge within the right settings and the cluster will ultimately expand (Porter, 1990).

It is difficult to generalize the evolution of a cluster as clusters are likely to experience different patterns in their development with different actors taking the lead in the evolution. Some general success factors can be distinguished, i.e. extended university research, clear and supportive legislation (e.g. the Bayh-Dole act of 1980), the size of the economy in which the cluster is located, the ability to attract specialized skills from around the world and the availability of capital (e.g. venture capitalists) (Sölvell, 2008). We will take a closer look at the different success factors in the proceedings of this dissertation, more specific in the section Driving forces in the development of a cluster.

1.3.3. Reorientation or deterioration of mature clusters

Clusters experience their mature stage when moving through the convergence phase. The convergence period is characterized by long time spans of incremental change and adaptation in which structures, systems, controls and resources are elaborated, eventually resulting in increased alignment among industry members.

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1 The Bayh-Dole act of 1980 allowed universities and small firms to claim the right to inventions that resulted from federally funded research (Stevens, 2004).
The outcome is a higher level of inertia and a decrease in competitive vigilance (Tushman & Romanelli, 1985). Ultimately, as a cluster moves through the convergence phase, the economies of agglomeration that initially attracted firms to a specific region, start to erode. Firms will become indifferent in choosing their location of activity, having no preferences to start business within or outside the cluster. Homogeneity will cause a decline in the collective level of innovation within the cluster (Pouder & St. John, 1996).

When the convergence phase comes to its end, Pouder & St. John (1996) expect the following scenarios to occur:

- Firms within the cluster will no longer be able to distinguish themselves from local competitors, resulting in further homogenizing perceptions of strategic possibilities and actions (Reger & Huff, 1993).
- The homogeneous macro cultures will further get fostered by biased cognitive frameworks and mental models and the insularity it brings with (Abrahamson & Fombrun, 1994).
- Homogeneity and inertia will also be promoted by several institutional forces (DiMaggio & Powell, 1983).
- The deeply embedded structure will further encourage convergence, increase inertia and decrease competitive awareness, even though when competitors and market conditions change (Tushman & Romanelli, 1985).
- Cognitive frameworks and mental models eventually become more biased over time, resulting in the creation of competitive ‘blind spots’ (Porter, 1980).
- The increased homogeneity causes a decrease in the creation of innovation (Pouder & St. John, 1996).

As convergence continues, the cluster will ultimately lose its identity of a cluster because of stabilized growth and innovation. Thus, less advantages can be identified between industry members inside or outside the cluster (Pouder & St. John, 1996).

Sölvell (2008) talks about a more static phase that is experienced by mature clusters as mergers and acquisitions cause the number of firms to decrease and
significantly fewer new firms enter the cluster. Efficiency and economics of scale mainly characterize this stage.

Environmental jolt or shocks play an important role in the reorientation or deterioration of a cluster. Having experienced a long period of convergence, firms are more sensitive to this kind of shocks, e.g. a technological shift, emergence of new competitors or new ways of doing things, changes in demand, etc. (Pouder & St. John, 1996). The alignment of firms with their environment is a key determinant in whether firms—or the region in which they are located—will ultimately survive environmental shocks or not (Meyer, 1982). As a result of increased homogeneity, firms are likely to establish competitive information about their environment that is highly limited and biased (Abrahamson & Fombrun, 1994), influencing their ability to anticipate environmental shocks (Meyer, 1982) and ultimately causing clustered firms to react slower to shocks than non-clustered firms (Pouder & St. John, 1996).

Reorientation often goes hand in hand with a significant shift in strategy, structure and systems. Firms must burst through their deep structures to look further than their own limited boundaries. They have to adapt their basic premises and values about competition and the network of relationships and systems that form their field of operation (Tushman & Romanelli, 1985). It has been researched that organizations that are able to anticipate the need for reorientation and carry through radical changes, experience more successful realignment (Tushman, Newman & Romanelli, 1986), resulting in a higher likelihood of survival after an environmental jolt (Pouder & St. John, 1996). Firms that have become too much dependent on their cognitive frameworks and mental models and fail to recognize the need for realignment will probably not survive the occurrence of a shock (Pouder & St. John, 1996).

Sölvell (2008) identifies the ‘death’ of a cluster as the ‘museum’ phase. He also sums some characteristics that are likely to cause clusters to end up in this stage:

- Excessive concentration of organizations.
- Frequent direct government intervention.
- Radical technology shifts that emerge from outside the cluster.
- War and other extreme circumstances.
1.4. Driving forces in the development of a cluster

In this section, we will zoom in on the determinants in the development of a cluster. As mentioned earlier, the emergence and growth of a cluster is very context specific, which is also the case for its development. Not all determinants play an equally important role for each cluster. Throughout the years, a vast body of literature has been established and provides us with an extensive overview of more or less important determinants, characterizing the development of a cluster. In what follows, most relevant success factors will be further discussed.

1.4.1. Diversity of organizations

Diversity of organizations provides a varied mix that allows the emergence of practices, strategies, and rules. This organizational diversity suggests the presence of different selection environments. The resulting heterogeneity will eventually allow a cluster to survive any downturns that may occur in any environment (Powell, 2012). Powell (2012) further emphasizes that the structural position, categories and cognitive classifications of any domain influence the formation of ties in the other domains as well as firms’ eligibility to participate in the cluster. Pouder & St. John (1996) also mention the importance to not get trapped in homogeneity in order to avoid a decline in innovation and withstand the threads of environmental shocks. Heterogeneity gives a cluster the opportunity to get more acquainted with different domains, allowing members to get to learn new methods and ways of working, thereby stimulating innovation and creativity. In fact, organizational diversity contains an assembly process in which different recipes and norms arise and interaction among members results in the refinement of working methods. This process facilitates the internalization of the refined practices (Powell, 2012). More important is that the emergence of those diverse standards and rules will eventually lead to the elaboration of norms for measurable success (Grabher & Stark, 1997; Boltanski & Thevenot, 2006). Besides heterogeneity, a cluster also needs structure in order to not fall into chaos. To reap the benefits of organizational diversity, interaction between cluster members within an environment of mutual trust is of course indispensable (Powell, 2012).
Because of the diversity of organizations, one should make decisions on how the flow of information will be organized in order to create close ties among cluster members. It is important that a central organization takes to lead. This organization then functions as an anchor organization within the cluster. Further elaboration on the presence of an anchor organization will be provided below. Start-ups and spin-offs also form a dimension in diversity because they are innovative and therefore good actors in maintaining diversity. Start-ups and spin-offs are mostly tied to the region in which they are established and therefore relatively immobile. Furthermore, those new enterprises keep the pace of innovation high within the cluster with their entrepreneurial spirit, avoiding stagnation (Sternberg, 2003).

Organizational diversity is also linked to Leydesdorff’s (2005) Triple Helix Model, which emphasizes the dynamic relationships between universities, industry and government. This model will be further discussed in some of the sections below.

1.4.2. Presence of an anchor organization

An anchor organization is an organization that is well-connected and takes a central place in the cluster. The anchor organization mobilizes other cluster members and takes on a supportive role in collective growth. This can occur intentionally or unexpectedly, but important is that the anchor is a neutral partner in order to avoid subjective involvement. An anchor is often a university, a nonprofit institution, a venture capitalist or a lead firm (Powell, 2012). It’s the anchor’s task to facilitate connections between cluster members and foster field formation (Powell, 2012). Their role is crucial to the evolution and success of a cluster and for the maintenance of a fertile eco-system of companies that are linked to the anchor firm (Kamath, Agrawal & Chase, 2012). The seed of a cluster is often represented by one or two anchor firms that foster the growth of other smaller organizations in the region. The emergence of this kind of anchor organizations is highly difficult to forecast (Wolfe & Gertler, 2004), which brings us back to the previously discussed fact that the location of cluster origin is very unpredictable. Wolfe & Gertler (2004) further stipulate that the presence of anchor organizations in a region attracts allies as well as rivals to the cluster because they both want to closely monitor the anchor’s activities.
An anchor organization can be seen as a large, local firm that is strongly involved in R&D and has at least some absorptive capacity in a specific technological area. The presence of this anchor then supports regional innovation by fostering the diffusion of university research so that this kind of knowledge is more likely to be absorbed by member firms (Agrawal & Cockburn, 2003). Smaller firms may benefit from externalities that are created by an anchor. Those externalities are manifested in e.g. lower entry barriers for smaller firms that want to benefit from university research, lower costs and higher likelihood to grow and gain more profits in the future (Agrawal & Cockburn, 2003). Agrawal & Cockburn (2003) further suggest that these externalities, experienced by smaller innovative firms, foster vertical knowledge spillovers in the cluster. The pool of smaller innovative firms causes the impact of this kind of spillovers to increase and exceed the effect of mere direct absorption of university research by the anchor.

Anchor organizations have the capacity to both mobilize cluster members and guarantee that the organizational diversity is maintained (Powell, 2012). They thus guard the diverse practices, strategies and rules that emerge through the evolution of the cluster. In order to obtain this, anchors continuously recombine resources and activities, resulting in a competitive dynamism that is supported by relational feedback (Powell, 2012).

The danger with anchors exists when these central organizations intentionally try to dictate other firms' behavior by imposing their rules on them (Powell, 2012). Then, the competitive dynamism breaks and “800-pound gorillas” arise. Powell (2012) introduces the term “800-pound gorillas” to indicate anchors that aspire to dominate and control cluster activities. These anchors then fail the engagement of collective problem solving (Powell, 2012).

Several authors emphasize the role of a university as anchor organization. Adams (2005) supposes that the presence of one or more academic anchors within a cluster contributed to the success of many well-known high-tech regions such as Route 128 and Silicon Valley. The role of universities shifted from doing research and diffusing knowledge in a relatively independent environment towards a central role within the cluster, maintaining many linkages with other players (Adams, 2005). Adams (2005)
refers to the work of Leydesdorff (2005), in which a “triple helix of university-industry-government relations” is elaborated and the university takes on a key position within this model. The university's main focus in building a critical mass of knowledge in a specific region then lies in the elaboration of relationships with established firms in a particular industry that are based elsewhere (Adams, 2005). Actively supporting entrepreneurship appears to be a natural role for a university to foster the local industry but, it is not really a direct purpose. During their formative years, universities often experience budget concerns and have to rely on external financial resources. Thus, more important is that the academic anchor interacts with established high-tech industry players as those are primary providers of financial funding in exchange for talent and technology (Adams, 2005).

1.4.3. Present knowledge and knowledge flows

When discussing the different stages in cluster development, knowledge already appeared as an indispensable factor for cluster success. A vast body of literature emphasizes the role of knowledge and knowledge spillovers in clusters. The emergence of competitive advantages is for a large part supported by shared access to a pool of distinctive local knowledge (Wolfe & Gertler, 2004). This thought is based on the assumption that co-production and transmission of newly created knowledge takes place among parties that are located within the same region. Proximity allows cluster members to acquire crucial new knowledge that is most effectively obtained through interpersonal contacts and mobility of skilled labor (Wolfe & Gertler, 2004).

Proximity is not a standalone condition for knowledge spillovers in clusters. Knowledge also has to be transferred in an effective manner. Breschi and Malerba (2001) formulate it this way: “a key feature of successful high-technology clusters is related to the high level of embeddedness of local firms in a very thick network of knowledge sharing, which is supported by close social interactions and by institutions building trust and encouraging informal relations among actors”. Here, we recognize the critical role of anchor organizations as institutions that build trust and encourage informal relationships.
Breschi and Lissoni (2003) talk about ‘LKS’, which stands for ‘Localized Knowledge Spillover’. The idea behind LKSs is that the results of public funding will cause some knowledge externalities to emerge. Newly created knowledge is supported by a large pool of skills, institutions and best practices and this new knowledge will be transferred from the one firm to another through frequent interpersonal contacts. This eventually results in the phenomenon that only local firms will have access to that specialized knowledge base (Breschi & Lissoni, 2003).

Wolfe & Gertler (2004) point out that it is important to recognize different forms of knowledge spillovers. Many authors highlight the role of tacit or undocumented knowledge. This kind of knowledge is crucial because it is highly technological and specialized and only accessible by cluster members because it is transferred between regionally embedded firms (Wolfe & Gertler, 2004; Almeida & Kogut, 1999; Breschi & Lissoni, 2003). Another important type of knowledge according to Wolfe & Gertler (2004) is the knowledge held by highly qualified personnel. Graduates and researchers ensure a knowledge flow from research institutions to private companies while mobile labor further diffuses knowledge between the various member firms. This recombination of talent guards diversity and fosters the competitive dynamism.

A third type of knowledge flow mentioned by Wolfe & Gertler (2004) has to do with entrepreneurial skills. Small and medium-sized enterprises have to gain knowledge about external competitive market conditions in order to grow. This kind of knowledge involves entrepreneurial skills and market information and is transferred from the one to the other firm by formal or informal peer-to-peer mentoring and knowledge sharing, facilitated by civic associations. Here, again, local institutional factors come into play (Wolfe & Gertler, 2004). The fourth form of knowledge is embedded in specialized legal, accounting and financial firms and institutions that provide necessary support for each member firm within the cluster. This type of knowledge is considered infrastructural knowledge (Wolfe & Gertler, 2004).

Several other authors also made attempts to identify different forms of knowledge. Jenkins & Tallman (2010) distinguish two types of knowledge, both at the individual firm level and the cluster level. They introduce the notions component and architectural knowledge. Component knowledge is related to the technology of the
industry, thus mostly coherent and definable. This kind of knowledge can easily be transferred to those who have some understanding of the industry under consideration. Although, component knowledge can also be quite complex and/or tacit (Jenkins & Tallman, 2010). On the other hand, architectural knowledge is more related to the whole knowledge system and covers the domain of structures and routines for implementing component knowledge. It is often organization specific and private because architectural knowledge is typically complex and tacit. Therefore, architectural knowledge spillovers are often not accessible by other firms (Matusik & Hill, 1998). But, Tallman and Jenkins (2010) suggest that architectural knowledge spillovers can occur between firms in a cluster through close interactions.

The knowledge flows that foster innovation within a cluster both have local and global characteristics (Wolfe & Gertler, 2004). The success of a cluster is co-determined by the cluster’s ability to effectively build and manage a global network, containing several links to access relevant knowledge from around the globe (Bathelt, Malmberg & Maskell, 2002). A firm’s ‘absorptive capacity’ strongly determines its ability to access global knowledge via global linkages so that they can identify where external knowledge can be obtained and if this knowledge has potential value for the firm (Bathelt, Malmberg & Maskell, 2002).

1.4.4. Cross-network alignment

In previous section, we already mentioned the importance of building and managing a global network in which global channels facilitate access to knowledge that is external to a cluster and can be found in other, external networks.

Another aspect of cross-network alignment is facilitated by the transmission of ideas and models from one domain to the other domain within the cluster. This transfer generates a lever-effect as the transferred material gets enriched and recombined with domain specific knowledge in order to create new material (Powell, 2012). It is important that the transfer is absorbed by the social system of the cluster in order to allow activities to cascade from the one domain to the other. New material for innovation as well as for new institutional and organizational practices is then created (Powell, 2012). It is important that the feedback mechanisms that support
recombination are well understood. The cross-network links should result in normative understandings, providing firms with prescriptive information (Powell, 2012).

Cross-network alignment is also partly achieved through careers and mobility, transforming local standards into more network-wide standards that emerge from various connections across domains and networks (Powell, 2012). Just as diversity facilitates the adoption of more general, cluster-wide standards, so do cross-network transfers as new domains absorb practices, goals and standards from other domains or networks (Powell, 2012).

The Triple Helix Model as elaborated by Leydesdorff (2005) emphasizes the important role of cross-networking between three central actors in a cluster: university, government and industry. Especially the dynamic interconnections between those three key players are stressed. Those dynamic interactions have great impact on the knowledge creation within a cluster (Leydesdorff, 2005) and are very similar to the cross-domain channels as describes in this section. Knowledge spillovers together with their advantages, as mentioned in the knowledge section, also relate to the dynamic interconnections Leydesdorff (2005) talks about.

1.4.5. Relationships with service providers

Apart from the necessity to build relationships with established firms and research institutions that possess industry knowledge, service intermediaries are also put afore as being crucial to innovation within a cluster network. Service intermediaries are defined as “professional service organizations that provide firms with supporting services in areas such as accounting and finance, talent search, law and technology services (e.g., technology commercialization and brokering)” (Zhang & Li, 2010). Service intermediaries are available to everyone and are thus in the right place to facilitate the exchange of information among firms, both new and established (Wolpert, 2002). Zhang & Li (2010) find that ties with service intermediaries have significant positive impact on the product innovation of new ventures within a technology cluster. They argue that by connecting with service intermediaries, new firms obtain access to a network of various firms, organizations and industries and
thereby reduce their searching costs and expand their scope of external innovation search (Zhang & Li, 2010).

In their study, Zhang & Li (2010) identify four different types of service intermediaries that have a significant positive effect on product innovation of new firms within a technology cluster:

- **Accounting and financial service firms**: evidence from the Silicon Valley case shows that accountants also fulfilled consulting roles in structuring deals for firms, apart from their auditing and tax advising activities (Atwell, 2000). Accounting institutions offer high-technology services, tailored to the needs of start-up and high-technology firms (Bahrami & Evans, 1995) while financial service providers also help new firms to get in touch with other organizations that control financial resources (Schoonhoven et al., 1990).
- **Law firms**: law firms often adapt best practices, learn from new ideas and establish new ways of doing business (Wolpert, 2002). They provide firms with general business advice and legal guidance and like accountants, they also help firms in structuring deals (Suchman, 2000).
- **Talent search firms**: talent search firms allow people to move between firms, facilitating the establishment of social networks. Hence, new firms are allowed access to other firms’ knowledge (Zhang & Li, 2010).
- **Technology service firms**: these firms offer services in technology commercialization and brokering. With the help of these firms, new ventures have the opportunity to commercialize their innovation and attract funding to support future innovation. They also gain access to technological knowledge of other firms (Zhang & Li, 2010).

1.4.6. **Geographical proximity and cluster size**

Geographical proximity is an indispensable feature of a successful cluster, already discussed several times in this dissertation. The emergence of ‘economies of agglomeration’ is an important reason why firms choose to locate close to each other (Marshall, 1890). Those firms then experience several advantages such as reduced costs and easier and less costly exchange of knowledge, materials and labor (Porter,
Member firms benefit from economies of scale, which allow them to share collective resources and infrastructure and gain advantage from local knowledge spillovers, making further research and development more efficient (Audretsch & Feldman, 1996). Geographical proximity also facilitates networking between firms, which allows for imitation and improvement within the network (Baptista, 2000). Additionally, proximity is a characteristic of the system nature of Porter’s (1990) diamond, stimulating interactions between the different actors.

It is argued that the benefits of locating close to each other increase with the number of firms in that region (Arthur, 1990). Hence, it is suggested that organizational performance of firms located within a cluster increases with the size of the cluster (Folta, Cooper, & Baik, 2006). Agglomeration economies benefit firms in terms of innovation through patenting and the opportunity to attract alliances and private equity partners. But, diseconomies of agglomeration – i.e. disappearance of the marginal benefits – seem to emerge when cluster size exceeds 65 firms, resulting in a striking finding that firms are more likely to fail when a cluster grows in size (Folta, Cooper, & Baik, 2006). Performance thresholds of firms in larger clusters are different from those in smaller clusters, i.e. higher performance levels are required in larger clusters because of the larger pool of alternative business opportunities (Folta, Cooper, & Baik, 2006).

1.4.7. Cluster policy

The way in which a cluster is governed is an important element that co-determines the path a cluster takes through its life cycle. The cluster operates in a whole of rules and regulations. This is quite context specific, i.e. cluster organization and management is different for various levels, e.g. national, regional or local level, and depends on the country of subject. With the insights of Porter becoming more and more adopted by policy makers, the focus of doing business shifted from competition to cooperation and towards the organization of planning and constructing clusters.

Most clusters were not ‘planned’, tough they are ‘constructed’ in some kind of way because of the initiation of policies, affecting a cluster and its members in various kinds of ways (Sölvell, 2008). The structural and institutional context of a cluster and
the role of government of the country in which the cluster is located, eventually determines the approach to cluster policy (Sternberg et al., 2010). Sölvell (2008) distinguishes two different ways in which a cluster can have its origin and can be governed, i.e. via a top-down or a bottom-up approach.

A top-down approach emanates from the fact that clusters can play a vital role in a country’s competitiveness, directly contributing to national productivity (Porter, 1998). Governments therefore imposes policies and regulations (cluster policy programs). Political leaders implement laws and regulations through the elaboration of fiscal policies. To increase national competitiveness, government should encourage change, stimulate domestic rivalry and foster innovation by fulfilling an indirect, rather than a direct role and acting as a catalyst and challenger (Porter, 1990). Its purpose should be the fuelling of dynamism and upgrading among firms within clusters (Sölvell, 2008). Another approach is bottom-up. Here, local firms and academic and public institutions cooperatively develop cluster initiatives without government being directly involved. Civic leaders develop programs by engaging in dialogue and collecting resources via non-governmental organizations and cluster initiatives (Sölvell, 2008). Both approaches are illustrated in figure 4.
Sölvell (2008) further defines two types of cluster policies. On the one hand, there are micro-economic policies that have a more general effect on clusters. On the other hand, specific cluster policies put focus on particular clusters. One can distinguish different areas in the general cluster policy domain: science and innovation, competition, trade, integration, regional and social (Sölvell, 2008).

Cluster intervention can be justified for two reasons, i.e. two market failures. First, networking failures result in too little activities or investments because the concept of spillovers is not fully understood. Second, information asymmetries can cause business opportunities to be neglected resulting from a lack of dialogue and communication within the cluster (Sölvell, 2008).

In the above part of this dissertation, we made a clear and extensive exposition of the historical origin and definition of a cluster, as well as of the evolution through the life cycle and the driving factors behind the success of clusters. This comprehensive literature overview now allows us to move on to the next part of this dissertation, i.e. the analysis of offshore wind energy in Europe. In what follows, our analysis and discussion will be based upon the theoretical context that has been created above.
PART 2: CONTEXT: OFFSHORE WIND ENERGY

2 Wind energy

As already mentioned in the introduction, wind energy is the world’s main source of renewable electricity. But, wind energy is not a recent phenomenon in the field of renewable energy. Already since thousands of years before Christ, various nations around the globe made use of wind to propel their vessels. Some hundreds of years B.C., Chinese nations constructed basic windmills to serve as water pumps while in Persia and the Middle East, people applied windmills to grind grain (EERE, 2011).

Soon, the multidisciplinary applicability of wind energy developed over centuries and across the whole world. Windmills were used for various purposes, e.g. food production in the Middle East and Europe and draining lakes and marches in The Netherlands. Eventually, during the industrial revolution in the 19th century, windmills were applied to pump water and further developed to serve as electricity generators for households and industries in the long run (EERE, 2011).

The first windmill that served the purpose of electricity generation was built in 1887 in Glasgow, Scotland. Since then, the quest was on to develop windmills with increasing efficiency. Denmark was an early player in the wind energy industry, already having a Society of Wind Electricians, founded by Poul la Cour in the early 1900s. Over time, design changed to increase efficiency and the application scale shifted from small to large scale application in terms of wind farms (Guardian, 2008).

As can be derived from figure 5, over the years, the installed wind capacity knew an exponential growth, which proofs the continuously increasing interest and the potential of wind energy to dominate the renewable energy industry. Today, wind power is installed in more than 75 countries worldwide, of which about 24 countries have an installed capacity that exceeds 1000 MW (GWEC, 2013).
Before continuing discussing the topic of wind energy, it is important to outline some facts characterizing the industry, so that all subsequently mentioned figures and quantities can be situated in a realistic frame of reference.

As the earth’s surface is highly irregular, the radiation of the sun that enters the atmosphere causes some areas of the globe to warm more than others. Resulting from a natural process, air is then flowing from warmer areas to cooler regions (Offshore Center Danmark, 2010). This is shortly how wind emerges. Wind, or wind energy is the kinetic energy that originates from the movement of air (Grogg, 2005). Approximately one to three percent of solar radiation that reaches the globe is converted into wind energy, of which the biggest part is generated at high altitudes (Offshore Center Danmark, 2010). Subsequently, wind energy is caught by windmills and wind turbines to convert the wind into some form of power, e.g. mechanical or electrical power (Offshore Center Danmark, 2010). In what follows, we will only discuss those wind turbines that generate electricity. Here, an electrical generator converts the rotation of the turbine blades into power (Offshore Center Danmark, 2010).

A wind turbine, as we know it now, is a very complex construction containing over 10,000 different parts. Nowadays, the turbines usually have three blades, located at the front of the nacelle, in which all electronic and mechanical equipment can be found (Offshore Center Danmark, 2010). The nacelle and the blades are attached to a horizontal axis shaft (Grogg, 2005) and placed upon the tower (Offshore Center Danmark, 2010). Figure 6 visualizes the whole.
Figure 6 The wind turbine (Offshore Center Danmark, 2010)

The rotation of the blades, caused by the wind, makes the horizontal shaft turn around its axis. The horizontal shaft is connected to a generator via a gearing system. The turning shaft drives the generator, allowing it to produce electricity that can be sent down the tower to the electrical grid, through which the electricity can reach the consumer (Grogg, 2005).

Historically, the evolving wind turbine technology caused that, over the years, wind turbines became larger and got produced with lighter materials, leading to systematic capacity increase. Today, the average blade radius is about 100 meters and the average capacity of one windmill is approximately 3 MW (EWEA, 2013). Thus, an installed capacity of 1000 MW (1 GW) is reached by roughly 333 wind turbines. The wind turbine technology evolution is displayed in figure 7.

Figure 7 History of the size and capacity of wind turbines (EWEA, 2013)
2.1. Offshore wind energy

There are several advantages to offshore wind turbines relatively to onshore ones. To name just a few, wind speeds are higher at sea, there is more eligible space to locate the turbines and there are fewer parties that can have potential objections against the construction of wind turbines offshore than onshore, e.g. neighbors (Offshore Center Danmark, 2010). But, the other side of the coin is that offshore wind turbines involve a more complex - and thus more costly – construction as opposed to the relatively straight-forward and cheap process of building onshore turbines. For the installation of wind turbines at sea, more specialized vessels and equipment are needed as a matter of course (Offshore Center Danmark, 2010). Twenty three years ago, in 1991, world’s first offshore wind farm was constructed at Vindeby, Denmark and consisted of 11 wind turbines, accounting for a total capacity of 5 MW.

Today, about 5,415 MW offshore wind power is installed globally, accounting for 2% of total installed wind power capacity. More than 90% of global offshore capacity is installed in Europe (GWEC, 2013). Regarding European statistics, the average wind turbine capacity is 3.6 MW, with a capacity factor of 41%. For onshore turbines, this is respectively 2.2 MW and 24% (EWEA, 2013). Hence, it is crystal clear that offshore constructions are far more promising in terms of capacity. Yearly, almost 13,000 MWh of energy is produced from offshore wind turbines in Europe, providing green power to more than 3,312 European households (EWEA, 2013).

2.1.1. The supply chain

The offshore wind market is booming as governments communicate market promises that are supported by national programs, sparking of an increasing amount of interest in the industry and numerous new investments in plants and facilities. This evolution caused investor confidence to increase, resulting in the attraction of larger, more financially backed contracting parties to the industry. Because of these developments, there is an opportunity for the sector to benefit from cross fertilization of skills and knowledge from other offshore industries like the oil and gas sector (EWEA, 2011).
As more and more companies are attracted to the industry, adding new capacity and engagement, competition within the supply chain increases (EWEA, 2011). As mentioned in the literature study, intense competition fosters innovation and upgrade (Porter, 1998) and leads to further savings because of economies of scale.

The offshore wind industry also experiences the establishment of more long-term commercial relationships between leading project developers and their partners within the supply chain (EWEA, 2011). This trend is also an indicator for the emergence of clusters.

It is argued that the offshore wind industry has a more flexible supply chain as opposed to other industries such as the automotive or the onshore wind industry (EWEA, 2011). In what follows, we will discuss the evolution and involved parties within the supply chain of the offshore wind industry.

During its early years, the offshore wind industry was characterized by “Engineer-Procure-Construct-Install” (EPCI) contracts, in which the bigger part of offshore wind projects were arranged on the basis of a single major construction contract, leading to high levels of competition and a struggle for first-mover advantages. Soon, the industry realized that this kind of competition was not sustainable as major contractors barely succeeded in realizing acceptable profit and insolvency and buy-outs frequently occurred. The result was a switch from EPCI contracts towards multi-contracting, which allowed risks to be spread over multiple parties (EWEA, 2011). Nowadays, we notice renewed interest in contracts involving a larger scope and fewer contractors. Rationale behind is that industry players prefer minimizing interface risk, taking the contracting environment for the offshore wind industry back to the EPCI dominance. This could be justified as the industry is more mature now. With the increase in supply chain participation and competition, we assume the offshore wind industry to become more flexible (EWEA, 2011).

The EWEA (2011) lists a number of company types that are involved in the offshore wind supply chain. We will shortly discuss each of them. This can help the reader to adapt a more comprehensive view on the offshore wind industry.
Eight main categories of company types can be distinguished in the upper levels of the offshore wind industry (EWEA, 2011). Together with their possible allocations on site, they are displayed in figure 8.

1. **Wind turbine manufacturers.** Responsible for constructing and supplying the wind turbines.
2. **Structural manufacturers.** Accountable for developing and providing substructures, foundations, substations, etc.
3. **Electrical equipment suppliers.** Responsible for designing the electrical system and providing all electrical equipment.
4. **Marine contractors.** Responsible for offshore installation of various parts, e.g. wind turbines, substructures, stations, etc.
5. **Cable suppliers.** Accountable for supplying cables with market segmentation.
6. **Cable installers.** Accountable for installing cables.
7. **EPCI contractors.** Turnkey contractors in the offshore wind industry, mostly large construction firms or joint ventures.
8. **Port operators.** Responsible for providing facilities for manufacturing and/or assembly, fulfilling different roles from mobilization port during construction to operation and maintenance base during the rest of the projects’ life time.

![Figure 8 Possible offshore wind activity allocations for each of the supply chain actors (EWEA, 2011)](image-url)
Besides these main parties, there are numerous other, smaller contractors active in the offshore wind industry: “specialist design houses, certification authorities, project management companies, Health & Safety consultants, marine warranty surveyors, insurance providers and other minor contractors” (EWEA, 2011).

There is quite some flexibility in the offshore wind supply chain as different types of companies can be approached for providing similar goods and services. This provides a fairly fluid picture of the supply chain landscape of the offshore wind industry that can be attributed to the relative immaturity of the sector as opposed to some more mature and stable industries such as the automotive industry (EWEA, 2011).

We will now take on a more detailed perspective, zooming in on particular regions and countries to further elaborate the offshore wind picture. Purpose is not to extensively discuss the different success factors as elaborated in the literature review. Our goal in following chapter is to quickly identify some of the success factors that can turn a geographical concentration of offshore wind activities into an offshore wind cluster. Using this approach, we will be able to identify those regions that are eligible to serve as best practice. The more extensive research on success factors will be conducted in part three, in the study of best practices in offshore wind clustering.

3 Offshore wind energy in Europe

The previous section discussed the bigger picture of wind energy and zoomed in on offshore wind power, discussing its history and industry players. We will now further refine our scope of research in this chapter. Here, we will formulate an answer on research question 1:

✓ Where can geographical concentrations of offshore wind activities be identified in the selected countries? Can we identify organized cluster activities here?
We will first make a selection of countries that will be point of discussing. Starting point is Europe, of which some key facts of the offshore wind industry in Europe will be discussed, explaining the relationship with the reason for picking Europe as a frame of reference. Subsequently, we will focus on those countries with the highest installed offshore wind capacity. For each of those countries, geographical concentrations of offshore wind activities will be detected and analyzed. As geographical concentration is not synonymous with cluster, we will further investigate the existence of organized cluster activities, researching some of the key identification factors that were put forward in the literature review. Most important factor is the presence of a central body that fulfills the role of anchor organization, maintaining and stimulating the relationships between all cluster members. In particular, we listed 4 criteria that eventually will determine the cluster potential of the geographical concentrations: diversity, anchor organization, lobbying towards government and interorganizational links and spillovers. Remark that through investigation of the anchor organization, the value of each of the three other criteria can be revealed. The outcome of this investigation will serve as an input for the next part, in which some best practices regarding organized cluster performance will be further elaborated.

The reason to pick Europe as focal point for further investigation regarding offshore wind energy is obvious. To support this statement, figure 9 is included. Here, statistics confirm that 90% of all worldwide installed offshore wind capacity is located in Europe, followed by a 9% in China and 1% in Japan. The installed capacity in the rest of the world is negligible (EWEA, 2013).

![Figure 9 Global cumulative offshore wind energy capacity in MW (EWEA, 2013)](image)
Europe is thus world leader in offshore wind power, having an accumulated installed capacity of almost 5000 MW, taking into account all European countries.

The majority of offshore wind activities is concentrated in the North Sea area because of the highest European wind velocity in that region and to benefit from the potential that is available there. Following figure (figure 11) clarifies the above statements.

![Figure 10 Average wind velocity at hub height (EEA, 2009)](image)

In order to further refine the starting point of this master dissertation, it seemed appropriate to make a well supported selection of European countries. Currently, there are ten countries actively involved in offshore wind power activities. The proceedings of this dissertation will be marked out by picking six countries based on their installed capacity. Subject of research in the first part of this work will be the six biggest players in the offshore wind industry in Europe, excluding those four countries having the lowest installed capacity. Figure 11 supports the selection of those European countries that will be further discussed.

As can be derived from figure 11, the top six of countries having the highest installed capacity is made up by The United Kingdom, Denmark, The Netherlands, Germany, Belgium and Sweden, ranked from highest to lowest capacity. All are integrally part of the North Sea area, except for Sweden, which also has significant capacity in the Baltic Sea.
Furthermore, Northern Europe is elaborating plans to further develop its offshore wind industry by initiating and creating a transnational cluster that will cover the Northern region of Europe, in which offshore wind power is concentrated. This project was initiated in 2003 and given the name POWER (Pushing Offshore Wind Energy Regions) cluster. Its purpose is to guarantee Europe’s world-leading position in the offshore wind business (Ecofys, 2011). Officially, the POWER cluster is operational for four years now, but it has not harvested anything significant yet. Only some European countries are involved, but remarkably, not all top six European offshore wind industry players are listed as a member. This proofs the current ineffectiveness of the whole idea. As this concept is more a formal initiative than a cluster, we will not further discuss it. Our aim lies in the detection of real organized regional clusters and the identification and comparison of best practices.

All above mentioned refinements are summarized in following figure. Figure 12 serves as the starting base for the research in this work.
We will now zoom in on each country separately in the proceedings of this chapter, distinguishing geographic concentrations from clusters. Aim is to define the different economical and geographical situations and investigate the existence of organized cluster activity. Most important factor here is the presence of an anchor organization that coordinates activities, manages relationships with various parties and serves as a lobbying group towards authorities.

This chapter will conclude with a mapping of most important findings, listed per country. The overview will provide us the information we need for selecting the strongest organized clusters to execute further analysis.

3.1. United Kingdom

In 2008, The United Kingdom surpassed leading Denmark in terms of installed offshore wind capacity and maintained its number one position ever since. The
country has initiated an ambitious target to reduce carbon emission by 80% by 2050. As wind power is an important energy generator, it plays a major role in achieving this target. Of total installed capacity, offshore wind capacity covers about 32%. While almost 6.2% of Denmark’s electricity consumption comes from offshore wind power, UK’s generated offshore wind energy contributes for only 1.5% to the electricity net today. This figure is estimated to increase to 17% by 2020 (The Crown Estate, 2012).

The United Kingdom’s offshore wind industry in concentrated in the East of England, where over 500 companies in the energy supply chain are located (OrbisEnergy, 2011). Therefore, the East of England is named Britain’s offshore wind energy capital. The region is represented in figure 13.

![Map of offshore wind industry in South East England](image)

Figure 13 Offshore wind industry in South East England (EEDA, 2010)

Unlike in most countries, ports in the UK are mostly privately owned. This makes that investments in the ports have to come from the private sector and that ports aren’t really driven by governmental policies. Because port owners do business in a commercial environment that is strongly market-driven, a lot of port owners are not willing to make investments for the wind industry. Another problem is that project developers often do not want to sign contracts with port owners so that the latter party becomes reluctant for doing business. And, ports often just do not have enough
capacity. ABP (= Associated British Ports) is an organization that owns and operates 21 ports in England, Scotland and Wales. They try to more unify different port policies to smoothen business. But, most of the time, for each new project, project developers have to search for suitable manufacturing and construction sites, which are often found outside the port areas and are called waterside land with development potential. The port problem is an important issue that slightly holds back the offshore wind industry development. If the UK should invest more in clear communication between industry players, such as manufacturers and wind farm developers, and port owners, the willingness to cooperate would increase (DECC, 2009).

Many organizations claim that they bring together all different players to promote the wind industry. For example, the UK counts a lot of development agencies like the East England Development Agency (EEDA), OrbisEnergy (innovation and incubation center), the East of England Energy Group (EEGr) etc. Largest and most influential organizations are RenewableUK and The Crown Estate, hosting hundreds of members in the industry. Both organizations assert to act as a catalyst for the industry, creating favorable market conditions to invest in the offshore wind industry in the UK (The Crown Estate, 2012). They both aspire to maximize the benefits for the UK, supporting the development of its offshore wind industry in various areas through different activities, e.g. policy development, health & safety, supply chain & skills, economics & finance, grid infrastructure, technology etc.

RenewableUK, formerly named BWEA (= British Wind Energy Association), was established to serve as the body of wind and marine energy in the United Kingdom. The organization currently hosts about 644 members within the renewables industry. Since a couple of years, RenewableUK expanded its focus from wind energy to several other forms of renewable energy, on- and offshore. Purpose is to bring together different kinds of actors and improve the recruitment base by hosting events, working groups, etc. to foster the development of the industry. Aim is to give members, as well as the whole industry, the opportunities to benefit from the strong network (RenewableUK, 2011).

The Crown Estate is an organization, tasked by the Parliament, which promotes the development of the offshore wind industry in the UK and its supply chain. The
organization wants to create a favorable climate for investments in this sector. They are also responsible for the improvement of energy security and the creation of new jobs in the wind energy industry. The Crown Estate hosts several events where actors in the whole offshore supply chain can meet. They also initiate and coordinate projects regarding the installation of new wind farms by bringing together the involved parties. This takes place in different rounds. By now, the Crown Estate is operating the third round. Important is the strong relationships of The Crown Estate with the industry and with government. Hereby, synergies can be obtained (The Crown Estate, 2012).

A proposal exists to elaborate an offshore wind SuperCluster that covers the Humber estuary (figure 14). The Humber zone shows high potential for serving as a favorable environment for offshore wind power. Green Port Hull is perfectly positioned for the manufacturing and export of offshore wind turbines while the adjacent Alexandra Dock is highly suited for the logistics regarding the installation (CORE, 2011).

Figure 14 The Humber estuary; source: locations4business
Green Port Hull has a unique location as it lays within 12 hours sailing from the biggest wind farms of the United Kingdom. Another favorable port for locating manufacturers and suppliers along the value chain is the Able Humber Port with its Able Marine Energy Park, where facilities will be built and logistics will take place. Third is the Grimsby Port that will serve as operations and management center for the wind farms in the North Sea. The Humber area also houses a lot of academic institutions that will be responsible for research & development and education. It is challenging to further research the potential of this SuperCluster idea (CORE, 2011).

As a conclusion we can say that, in the United Kingdom, there is a strong but complex network with many actors within the offshore wind industry. Clearly, all supply chain partners are represented and they do have close relationships with each other but, there is an overload of organizations that is concerned with the central management of the offshore wind sector. The different organizations do not form an umbrella by centralizing information, rather they operate quite separately. This is also reflected in the fact that the different organizations mostly do not refer to each other in their communication. Therefore, sometimes the essence is lost because of the great fragmentation of information. The presence of different organizations that want to take the role of anchor organization leads to the phenomenon that there is no real anchor organization represented. This is an obstacle for the development of a real cluster in The United Kingdom.

3.2. Denmark

Denmark is clearly one of the best students in class. No other country has included so much wind power in its energy network as Denmark. They can proudly say that, in 2011, about 28% of consumed electricity was generated by wind power. Offshore wind energy accounts for about 6.2% of electricity consumption. Target is to integrate 50% of wind power into the electricity network by 2020 (DWIA, 2011). With its 20 years of experience in the offshore wind industry, Denmark possesses a lot of valuable skills and knowledge, which makes the country an example for other North Sea area countries and a world player in the wind energy sector. Furthermore, over one third of all wind turbines installed in the world have Danish origin.
Denmark is a first mover in the offshore wind energy industry as in 1991, the first offshore wind farm in the world was set up in Danish waters, namely in Vindeby (Offshore Center Danmark, 2010). From then on, Denmark continued introducing innovative technologies and building larger, more state-of-the-art offshore wind farms. Being a first mover absolutely contributed to Denmark’s success as a world leader.

The Danish Wind Industry Association (DWIA) is a strong network of diverse organizations that benefit from the wind industry. There is a strong emphasis on communication, collaboration and teamwork. The DWIA also hosts meetings and events, where information between members can be exchanged.

The DWIA bridges a variety of organizations like industrial companies (200+), educational and research institutions/centers, authorities etc. A non-exhaustive overview of the DWIA network is provided in appendix 2. Here, we can already clearly distinguish the diverse parties that are needed to take a cluster on the path towards success. The supply chain actors are represented in the inner circle while the more supportive partners can be found in the outer circle. Here, already several factors that are pointed out in the literature study can be identified at a glance.

- Present knowledge and knowledge flows in the form of educational and research institutions: e.g. Aalborg University, Aarhus University, Copenhagen University College of Engineering, Engineering College of Aarhus, University of Southern Denmark, Copenhagen Business School, Test Centre Østerlid, Test Centre Høvsøre, etc.; exhibitions and conferences.
- Cross-network alignment: e.g. Global Wind Energy Council, European Wind Energy Association, foreign embassies in Denmark, Danish embassies globally, etc.
- Relationships with service providers: e.g. Invest In Denmark, The Export Credit Fund, Agencies, etc.
- Cluster policy: The Alliance for Offshore Renewables, The Danish political parties, Ministry of Foreign Affairs, Local government Denmark, etc.
It guarantees effective communication so that every member can benefit from it. Educational institutions offer traineeships and master degrees in wind energy. The Talent Factory is established to bring together industry and students. Hereby, the DWIA wants to create a broader recruitment base for the wind industry and increase quality of the current/future workforce. In universities and other research centers, data is collected and analyzed in close collaboration. Results are available for every member of the DWIA to ensure that companies can maximally benefit from the newest knowledge. The DWIA also has several testing and demonstrating institutions on its member list to further stimulate the development and exchange of technology.

The DWIA is an excellent anchor organization that functions as a portal, a way to bring wind power companies in touch with each other and with government.

We further find evidence of cluster collaboration between offshoreenergy.dk and The Danish Wind Industry Association, aspiring to develop a national offshore cluster, involving members who have their activities in the offshore renewables industry.

When we take a closer look at Denmark, we see that The City of Aarhus, second largest city of Denmark, positions itself as the center of an even tighter network, namely The greater Aarhus area (figure 15). This network is seen as world’s tightest wind cluster and is located in the central belt of Denmark. About one third of all members of the DWIA are concentrated here. 11,000 of the 25,000 employees in the Danish wind industry work within one hour drive from Aarhus. Moreover, statistics point out that 87% of the combined turnover and export of wind power in Denmark is generated by activities of companies located in the Greater Aarhus area (Monday Morning, 2010).
Another natural cluster in Denmark is Hub North, counting over 80 companies in the Danish wind industry, mostly in the windmill sector. The aim of Hub North is to promote the North Jutland region in the wind turbine industry. Emphasis within this cluster is more put on the technical aspects of wind energy, thus more on manufacturing. Central is the port of Aalborg, with Aalborg University as research and education center. Also, the world’s biggest blade factory and test center are located in the cluster Hub North.

3.3. The Netherlands

The Netherlands positioned itself quite good in the European offshore wind industry. Although, the country does not have an established domestic wind turbine manufacturing market and cannot draw from a history of experience, they succeeded in setting up an offshore wind industry with remarkable capacity (Nederlandse Kennis Innovatie Agenda, 2010). In elaborating their own wind farms, The Netherlands did some extensive research and tried to learn from existing wind farms and developments in the industry.
Just like in the other countries, The Netherlands also has an organization that promotes the wind industry in its country, namely the NWEA (= Nederlandse Wind Energie Associatie). The organization wants to bring together the actors in the wind industry, on- and offshore, to foster developments within the Dutch wind energy sector. To succeed, the NWEA also hosts several events. The organization is also a member of wider Dutch umbrella organizations regarding sustainable energy as well as of the EWEA.

In the nineties, The Netherlands already installed two ‘offshore’ wind parks, Lely and Irene Vorrink (figure 16), in the northern lake Ijsselmeer, which is adjacent to the North Sea. The wind farms had little capacity of respectively 2MW and 16.8 MW (EWEA, 2010) but, the start for an offshore industry in The Netherlands was given.

Today, two Dutch wind farms are operational in the North Sea: Offshore Wind Park Egmond aan Zee and Princess Amalia Wind Farm, close to Ijmuiden (figure 16 and 17). Future plans for expanding the offshore wind capacity in the Dutch North Sea are ambitious. Numerous subsidies and construction licenses are already granted (figure 17).

Figure 16 Existing offshore wind farms in The Netherlands (own research)
1. Lely (Ijsselmeer, 1994)
2. Irene Vorrink (Ijsselmeer, 1996)
3. OW Egmond aan zee (2007)
The offshore wind industry is mainly concentrated in the Northern region of The Netherlands, where a close network emerged, resulting in a geographic concentration of offshore wind activities. Therefore, in 2010, an organization was set up to support the offshore wind business in this region. The organization was given the name Northern Netherlands Offshore Wind (NNOW), which is also the name of the cluster. Purpose is to stimulate offshore wind activities and bring together different actors along the supply chain like manufacturers, services, research and development and of course the government.

The port of Eemshaven, which is part of the bigger entity Groningen Seaports, plays an important role in the offshore wind industry. The port is perfectly located in the North of The Netherlands and has already proven its excellence as a logistics hub for the offshore wind industry because of the favorable accommodation and equipment. The port was responsible for the assembly and shipping of wind turbines for some large German offshore wind farms. Expected is that the port of Eemshaven will further develop to also perfectly serve the needs of the Dutch offshore wind
industry (Provincie Groningen, 2011). The province of Groningen, home to the port of Eemshaven and developing energy hub, is also positioning itself as a base for the further development of the Dutch offshore wind industry. Currently the port of Ijmuiden was used for the construction and assembly of the two operational wind farms in the Netherlands. This port also possesses favorable accommodation and equipment and is located a couple of kilometers from the current operational wind farms (Provincie Groningen, 2011).

Regarding operations and maintenance, the port of Harlingen is very suitable. The port is also perfectly located and equipped for import and export of large wind turbines across Europe. Together with the ports of Eemshaven, Ijmuiden and Den Helder, this region is called the Energy Valley (Provincie Groningen, 2011).

Research and development regarding the Dutch offshore wind industry is mainly concentrated in the Technical University of Delft and the ECN (= Energieonderzoek Centrum Nederland). The TU Delft established a specific interfaculty organization, the DUWind, with the purpose of obtaining close cooperation with the ECN to investigate optimal conditions for offshore wind power. The DUWind also provides specialized courses for students as well as for professionals aiming at establishing a skilled workforce and improving the knowledge of industry members.

To support the development of offshore wind power in The Netherlands, the Dutch government has set up a collective, subsidized program for research and development of offshore wind in the North Sea. The program was given the name we@sea and should help to meet the target of 6,000 MW Dutch offshore wind capacity by 2020. Another program that has been developed to foster the Dutch offshore wind industry is the “Wind Op Zee” program of the Dutch Knowledge Innovation Agenda (Nederlandse Kennis Innovatie Agenda, 2010). The KIA recognizes Northern Holland’s ambitions to become The Netherlands’ offshore wind hub, but it wants to support the industry in the whole country. The program “Wind Op Zee” is developed to support cluster development. It targets all domains of the supply chain and focuses primarily on the optimal dispersion of knowledge by means of knowledge spillovers and the creation of spin-offs (Nederlandse Kennis Innovatie Agenda, 2010). Remarkable is that the NNOW is mentioned in neither one program.
This means that its lobbying position towards the Dutch government is very weak. This can be explained by the fact that the cluster concept is still relatively young.

Further development of the offshore wind industry in The Netherlands is a big challenge as the industry is still quite in its infancy. The Netherlands has great potential and has the right initiatives to develop and sustain an offshore wind cluster but, as also recognized by the Dutch KIA, offshore wind energy is a totally new concept for The Netherlands and they have just taken off the development of the industry (KIA, 2010). The NNOW cluster also needs to further develop to become a strong network. The website of the NNOW only indicates some members in the construction and services sector but, little is mentioned about research and development. Although The Netherlands has very good academic and educational institutions as well as research and development centers with activities in the offshore wind sector, the link between these knowledge institutions and the industry needs to be strengthened. Therefore, The Netherlands cannot yet be considered as carrying out organized cluster activities in the offshore wind industry.

3.4. Germany

With its 31,332 MW installed capacity, Germany tops the ranking in the European wind industry (GWEC, 2013). From this total capacity, only 280.3 MW is installed offshore in the North and Baltic Sea (EWEA, 2013), by which Germany claims fourth place in Europe. Regarding offshore wind energy, Germany demonstrates high potential as a lot of German ports are equipped to serve the offshore wind energy sector (figure 18). The pink parts, well represented in the figure, indicate offshore research.

Figure 18 Diversified port infrastructure to supply offshore wind parks in Germany (Germany Trade and Invest, 2013)
A well-established central organization for wind energy exists, namely The German Wind Energy Association or Bundesverband WindEnergie (BWE). The organization hosts over 20,000 members and promotes the German wind industry. BWE is a strong network, providing tight links with industry as well as with government. The organization is also represented in transnational organizations such as the European Wind Energy Association (EWEA), the Global Wind Energy Council (GWEC) and the World Wind Energy Association (WWEA).

Offshore wind power activities are mainly concentrated in the Northwest of Germany because of its favorable economic policies and natural environment. The flat land, strong wind and closeness to the sea of the Northwest region makes it an attractive location for wind industry players to settle. Through combination of over 30 years of experience and knowledge with the concentration of wind industry actors in this region, a strong and tight wind technology cluster emerged (Boeckle et al., 2010). The wind energy cluster in the Northwest of Germany, having Oldenburg/Bremen/Bremerhaven as a center, was recently, in 2011, institutionalized under the name WindPowerCluster (WindPowerCluster, 2012). The region is represented in figure 19. By now, the cluster hosts over 300 organizations and institutions and reached a technological leadership position. Major players are displayed in figure 20. The majority of all German wind power players resides in four states in the Northwest region, namely Lower Saxony, Schleswig-Holstein, Bremen and Hamburg (Boeckle et al., 2010). Regarding offshore wind power, the ports of Brake, Bremen, Bremerhaven, Cluxhaven, Emden and Wilhelmshaven fulfill prominent roles in transportation, production, storing and assembly of components. Within this region, Bremen is central as estimates show that over 80% of all relevant cluster members work within 100 miles of Bremen (Boeckle et al., 2010).

![Figure 19 WindPowerCluster in the Northwest of Germany (WindPowerCluster, 2012)](image-url)
As can be derived from the cluster map in figure 20, the wind power cluster in the Northwest region of Germany provides numerous connections with industry as well as with government.

Germany has an extensive and influential wind energy association for the Northwest, the WAB (Windenergie Agentur Bremerhaven/Bremen), positioning itself as the voice of German's wind power network in the Northwest region. The WAB wants to foster the development of the WindPowerCluster in an attempt to help its members as well as Germany climb up the global wind ladder. The WAB provides expertise and information and promotes intensive communication between members through events, conferences, fairs, magazines etc. Organizing workshops to increase workforce quality is also an activity of the WAB.

The WAB collaborates with ForWind, the center for wind energy research in which knowledge is centralized, formed by the three universities of Bremen, Hannover and Oldenburg. ForWind not only partners with the Northwest cluster but is also a member of the European Wind Energy Association. Knowledge is thus shared on a very high level.
Germanwind is a subsidiary for innovation, set up by the WAB. Through this organization, the WAB wants to create a contact point, specialized in the further stimulation of innovations. Germanwind communicates opportunities towards WAB members, provides extensive information and is responsible for the initiation and coordination of innovative projects.

Since the foundation of the WAB in 2002, the WindPowerCluster developed itself in an institutional way along the more strategic attractive coastline in the Northwest of Germany. The WindPowerCluster combines 25 years of experience in onshore wind power with newer activities and technologies in the offshore wind domain (WindPowerCluster, 2012). Over the years, a highly effective network emerged, displaying strong links between the industry, research institutions, government and numerous service providers (Boeckle et al., 2010). Today, the WindPowerCluster has positioned itself as a real cluster and an example for other regions that are aiming at establishing and sustaining an offshore wind cluster. Figure 21 shows the development of the WindPowerCluster, as well as its ambitions for the future.

![Figure 21 Development of the WindPowerCluster in Northwest Germany (WindPowerCluster, 2012)](image)

Another strong network has emerged over the years in the Northeast of Germany, more specific in the state Mecklenburg-Vorpommern, near the Baltic Sea. A regional organization, the Wind Energy Network Rostock, was founded to capture the
advantages of the emerging cluster with focus on Rostock. Currently, the organization hosts almost 100 members (Wind Energy Network Rostock, 2011). Similar to the Northwest, the state Mecklenburg-Vorpommern forms the home base for a concentration of good and specialized knowhow and competencies. The region wants to elaborate these opportunities by creating an attractive environment for the offshore wind industry. Purpose is to offer a network of strong connections between industry players and the government, encourage research and development and elaborate a base for education and innovation, with the University of Rostock playing a prominent role. The port of Rostock is perfectly located for components manufacturing and logistics and further plans for expansion are already established (Wind Energy Network Rostock, 2011).

Currently, two German wind farms are operational in the Baltic Sea: the Baltic 1 and Breitling. These are displayed in figure 22.

Figure 22 German state Mecklenburg-Vorpommern and the operational wind farms in the Baltic Sea (own research)

There is clearly an attempt in this region to further develop the existing network into an offshore wind energy cluster but, when consulting the member list of Wind Energy Network Rostock, we mainly identify smaller regional companies, rather than big industry players, which are well represented in the WindPowerCluster. Also, few literature can be found on networking and cluster practices in the Northeast region, while a lot has been written on the outstanding position of the Northwest of Germany.
3.5. Belgium

Regarding the offshore wind power in Belgium, information is wide spread and no specific central organization can be found. Currently two wind farms are operational in front of the coast of Zeebrugge. These are represented on figure 23. C-Power is a consortium that was set up by different partners to develop and install the first offshore wind farm in Belgium, at the Thornton Bank in the North Sea. By now, phase 1 of 6x5 MW windmills is operational, another 48x6.15 MW was planned to be installed in 2012. C-Power has several development and manufacturing members in the offshore industry but, no academic links are mentioned at their website (C-Power, 2012).

The second wind farm is the biggest of the two with its 55 turbines, counting for 55x3 MW = 165 MW offshore wind capacity. The wind farm is located at the Bligh Bank in front of the coast of Zeebrugge. This wind farm is developed and operated by Belwind, and organization that was founded in 2009 and is owned by the Colruytgroep, PMV, SHV, Fonds voor gemene rekening Meewind en Rabo project equity. Belwind also has several partners, of which manufacturing and services, but also DUWind of the Technical University of Delft (Belwind, 2012).

For the development of the wind farms Rentel ( in figure 23) and Seastar ( in figure 23), eight Belgian companies joined together in Otary, a new knowledge center that should create the opportunity to unite the knowledge of the different parties to obtain synergies. Purpose is to bring together all players in the offshore wind industry that have activities in Belgium. Otary wants to bundle forces for the construction of two new wind farms at sea, starting in 2015 (Adriaen, 2011).
Regarding the offshore wind industry in Belgium, the region, including the port of Oostende, has positioning itself as the place to be for offshore wind energy. The port is perfectly suited as other nearby ports lack the capacity or accommodation to serve the offshore industry. The port of Oostende facilitates a quayside for heavy loads and large adjacent sites, which is favorable for offshore wind activities. AG Haven Oostende, the autonomous port company of Oostende, recently established a center for service companies that are specifically related to the offshore wind industry. Hereby, the company wants to further develop its ambitious plans as ‘energy port’. The new company center is part of the plan for developing a competence cluster for the offshore wind industry in Oostende (De Vlaamse Ondernemer, 2012).

Figure 23 Installed and planned offshore wind capacity in Belgium (MUMM, 2012)
The port of Oostende also houses some high tech companies in the new science park Greenbridge, located in the Plassendale 1 industry site, which was established by the University of Ghent. The science park is indicated on figure 24. One component of Greenbridge is the Incubator. Here, high tech start-ups are supported for the launch and further development of their company. The other part of the Greenbridge science park is the ideal operating base for research and development activities of more experienced companies. The science park really is a catalyst for innovation. Power-Link is a platform for knowledge that originated from the collaboration between AG Haven Oostende and the University of Gent. The platform uses the expertise of the University of Ghent and its partner academies to elaborate investment projects and raise public awareness by setting up educational and demonstrative projects. Therefore, Power-Link has the right profile to further develop as an anchor organization. Greenbridge and Power-Link are not exclusively focused on offshore wind energy but, the institutions definitely play a major role in Oostende’s development as offshore wind industry base (Greenbridge, 2012).

There is definitely no concentration of academic knowledge about offshore wind energy in Belgium. Universities of Ghent, Leuven, Antwerp and several other academic institution perform research projects on offshore wind. To make the knowledge fragmentation complete, a new R&D initiative is developed and housed in the port of Antwerp. The Offshore Wind Infrastructure Application – Lab (= OWI-Lab) develops and supports innovative initiatives that are related to the offshore wind industry in Belgium. Because Belgium lacks reliable and efficient test and monitoring
infrastructure for wind turbines, OWI-Lab wants to provide a solution to this problem. Here, the VUB (Vrije Universiteit Brussel) serves as an academic partner. Remarkable is that, while the concentration of offshore wind activities is growing in the region of Oostende, a new relevant facility is set up about 100 km further.

3.6. Sweden

When considering wind energy on- as well as offshore, Sweden has an accumulated capacity of 3,745 MW. But regarding offshore wind power, Sweden can only speak of a 163.7 MW capacity experience (EWEA, 2012).

The Swedish Wind Energy Association is an organization that aims at promoting the Swedish wind energy sector as well as bringing together industry players and offering them a strong network. The SWEA also actively makes efforts to create a favorable environment and communicates with the authority. Several conferences, seminars and other events are meant to raise awareness and improve industry knowledge. The SWEA manages the research program VINDFORSK, which is funded by the government. About two third of the budget is dedicated towards research institutions like universities (Björck, 2005).

There is a high potential for offshore wind energy in Sweden because of the long coastline but this potential is strongly restrained by the political climate. Permitting processes take a long time and are very cumbersome. The economic support is too low to successfully attract new, big players in the industry (Söderholm & Pettersson, 2011).

Currently, Sweden has five operational offshore windfarms, namely Bockstigen, Utgrunden I, Yttre Stengrund, Lillgrund and Gässlingegrund (in Lake Vänern). They are indicated with a green star (★) in figure 25.

The University of Uppsala performs research on wind power, especially on wind turbine design but, no evidence was found about specific offshore wind research. The University of Gotland also claims to perform some research after wind power, they even have a Center for Wind Energy (CVI). The center has some projects in
which it collaborates with industry members and other players in the Scandinavian region (Norway and Denmark). Several projects regarding offshore wind energy are set up.

The Chalmers University of Technology in Göteborg has, in cooperation with the Swedish Energy Agency and several partners from the wind turbine industry, established the Swedish wind power Technology Center. Aim is to create a Swedish wind turbine manufacturing industry because there was a remarkable absence of (domestic) wind turbine manufacturers in Sweden. Sweden lacked a good knowledge base and research center to further develop the wind industry and the recruitment base. Therefore, the center also offers educational programs. The initiative is by far the first initiative to bring together knowledge to foster the wind sector as before, knowledge was very fragmented and industry companies were hardly represented in Sweden. Research centers are indicated with a red star (★) on figure 25. Plans for building a center for testing and monitoring wind turbines in the North of Sweden are ready. Purpose is to measure the performance of wind turbines in a cold climate to optimize their design.

Coordination, manufacturing and assembly locations are different for each project. Even for the three wind farms that are located close to each other: Bockstigen, Utgrunden I and Ytte Stengrund, different locations were used for the different construction activities. Problem is that most large manufacturing companies do not have factories in Sweden, so manufacturing mostly takes place at the first available
site nearby, after which components are shipped towards closer assembly bases. For example, for the Lillgrund wind farm, concrete foundations were manufactured in Poland and shipped to Sweden along its coastline, while towers and turbine components were manufactured in Jutland, Denmark and transported to a nearby Danish assembly and shipping port (Vattenfall, 2008).

To come towards a conclusion, the wind energy sector and especially the offshore wind energy industry cannot benefit from a strong network in Sweden. When plans are initiated, wind farm developers have to bring together the different parties without relying on a network or on the knowledge of other projects. From a cluster perspective, little can be said as the offshore business is not developing in certain specific regions because a lot of resources are collected in foreign countries. The focus also lies more on wind turbines, rather than on the whole offshore wind industry. Sweden is working on it and tries to smoothen the business but regarding offshore wind, there is still a good deal of work to do.

3.7. Conclusion

From the primary research conducted above, we can confirm Denmark’s world leading position in wind power, on- and offshore, as well as its quite successful and promising efforts regarding cluster development and support. The same can be concluded from the research on Northwest Germany. At the same time, we can also exclude some countries from having implemented excellent cluster practices. The United Kingdom is an exception as it has a lot of capacity but, regarding cluster development, links and responsibilities are very fragmented, so not appropriate to include as best practice. We will end this chapter with a clear overview of each country’s assets or liabilities regarding offshore wind cluster development. Based on this mapping, we will zoom in on some best practices so that we can pool the success factors for offshore wind clustering.
<table>
<thead>
<tr>
<th></th>
<th>geographical concentrations</th>
<th>Diversity</th>
<th>Anchor organization</th>
<th>Lobbying towards government</th>
<th>Interorganizational links and spillovers</th>
<th>Cluster potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>The United Kingdom</td>
<td>East England = Britain’s offshore wind energy capital</td>
<td>A varied mix of organizations is represented</td>
<td>Very fragmented responsibilities</td>
<td>Via a separate body: The Crown Estate</td>
<td>Low because of fragmented central responsibilities</td>
<td>Medium because of fragmented information obstacle</td>
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<tr>
<td>Denmark</td>
<td></td>
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<tr>
<td>• Greater Aarhus Area</td>
<td>Denmark’s Central belt; Aarhus: Capital of wind energy</td>
<td>Varied mix of 1/3 of all DWIA members</td>
<td>DWIA, member of EWEA</td>
<td>Very high</td>
<td>Very strong: very effective communication</td>
<td>Very high</td>
</tr>
<tr>
<td>• Hub North</td>
<td>Northern Denmark</td>
<td>Diverse mix; focus on windmill industry</td>
<td>Hub North, member of DWIA</td>
<td>Very high</td>
<td>Very strong: very effective communication</td>
<td>High for wind turbine industry</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>Northern region of The Netherlands</td>
<td>Low, some members in manufacturing and services</td>
<td>NNOW, no member of NWEA (NWEA is member of EWEA)</td>
<td>Very weak</td>
<td>Weak because of low experience level</td>
<td>Still in the infancy phase</td>
</tr>
<tr>
<td>Germany</td>
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<tr>
<td>✓ WindPowerCluster</td>
<td>Northwest of Germany: Bremerhaven/Bremen</td>
<td>Varied mix, 80% within 100 miles from Bremen</td>
<td>WindPowerCluster, partner of WAB (WAB is member of BWE and EWEA)</td>
<td>high</td>
<td>Very strong: very effective communication</td>
<td>Very high</td>
</tr>
<tr>
<td>✓ Wind Energy Network Rostock</td>
<td>Northeast of Germany</td>
<td>Varied but missing some key industry players</td>
<td>Wind Energy Network Rostock; no member of BWE/EWEA</td>
<td>High on regional level</td>
<td>Medium: cluster still in development phase</td>
<td>medium</td>
</tr>
<tr>
<td>Belgium</td>
<td>Oostende</td>
<td>No evidence</td>
<td>No official anchor, Power-Link UGent has the right profile</td>
<td>medium</td>
<td>Weak: cluster still in development</td>
<td>Still in the infancy phase</td>
</tr>
<tr>
<td>Sweden</td>
<td>Activities scattered over the whole country</td>
<td>Weak, missing big manufacturers</td>
<td>SWEA: communication with industry &amp; government</td>
<td>High but not very attractive political climate</td>
<td>Weak because of geographical dispersion</td>
<td>low</td>
</tr>
</tbody>
</table>

Table 1 Overview of the cluster potential for offshore wind energy in the six European countries
The overview in table 1 immediately allows us to answer research question 1:

- Where can geographical concentrations of offshore wind activities be identified in the selected countries? Can we identify organized cluster activities here?

Here, the identified geographical concentrations, as well as the most important factors regarding cluster development in the offshore wind energy in the six selected European countries are displayed. We only included those factors, being the most important to identify the cluster potential. Important to note is that the overview is very qualitative and based on primary basic research with the purpose to select best practices that can be further investigated in detail in the next part. We included four selection criteria. As a first selection criterion, we investigated the presence and activities of an anchor organization, fulfilling the role of central knowledge platform or network partner and bringing together all relevant knowledge and resources in one central body. The members/partners from the anchor organization provided us with a first indication on diversity and its ties with government allowed us to draw some initial conclusions on its lobbying position within governmental institutions. As a fourth criterion, visible interorganizational links and spillovers was included.

From the overview, we can conclude that in Denmark and Germany, offshore wind cluster potential is very high. For Denmark, we will focus on the central belt, more specifically on The greater Aarhus Area. Regarding Germany, we will limit our scope of analysis to the WindPowerCluster in the Northwest as this is the only region in Germany where we could identify organized cluster activities. We will compare our empirical findings to what we have found in literature.

After having discussed these two best practices in the next part, we will summarize the factors that contributed to the success of these clusters. We will conclude with some recommendations to initiate or further expand cluster development in offshore wind activities.
PART 3: STUDY OF BEST PRACTICES IN OFFSHORE WIND ENERGY CLUSTERING

4 Analysis of best practices in offshore wind energy clustering

In what follows, we will thoroughly analyze the offshore wind cluster in Central Denmark and in Bremerhaven/Bremen with the help of the theoretical framework as proposed in the literature review. First, we will provide a description of the cluster under study to create a general starting base for further analysis. Discussing the origin of the cluster is part of the description. Subsequently, we will analyze the evolution of the cluster as well as the factors that made the cluster a success, by which we will try to frequently refer to the information we collected in literature. All of this research work exclusively occurs by means of explorative research.

4.1. Analysis of the offshore wind cluster in Central Denmark

4.1.1. Description and origin

In Denmark, wind energy, on- as well as offshore, is an important source of energy for the whole country and wind power activities are spread all over the country. The offshore wind industry is part of Denmark’s entire wind industry. We identified a higher concentration of wind power activities in the region around the city of Aarhus, second largest city of Denmark. This region is called The greater Aarhus area and is the world’s most dense concentration of wind power companies. Estimated is that 87% of Denmark’s entire turnover of wind energy is realized in this area (Monday Morning, 2010). Therefore, The greater Aarhus area, located at the east coast in the central belt of Denmark, will be our point of focus.

About hundred years ago, Denmark made its first attempts to harness energy from wind. The story starts with Poul La Cour, who built a first wind turbine in 1891. His project was funded by the Danish government and meant the start of a long history of
Danish wind power (Vestergaard et al., 2004). After the oil crisis in 1973, some craftsmen started to build wind turbines and became pioneers in the development of The Gedser turbine, a widely known Danish concept. After the second oil crisis in 1979, the Danish parliament decided to subsidize 30% of the construction costs of wind turbines (DWIA, 2010). This is the point in history when the Danish wind market really took its start. Several local companies started to manufacture wind turbines in Denmark. Some of them grew to become part of world’s leading wind turbine suppliers, e.g. Siemens Wind Power and Vestas Wind Systems. Siemens Wind Power is located in Brande, while Vestas is located in Aarhus. As can be seen on figure 26, both reside in Denmark’s central belt, in The greater Aarhus area.

Here, we clearly identify the ‘hero phase’ as described by Sölvell (2008). In this phase, the origin of Denmark’s wind industry is characterized by the entrepreneurial actions of some players such as Poul La Cour, Siemens and Vestas. These can be classified as historical accidents, mentioned by Pouder & St. John (1996) and Sölvell (2008) as a possible seed for clustering. The fact that wind is abundantly available in Denmark is a second factor that explains the emergence of the cluster. This factor was mentioned by Sölvell (2008) under region specific resources.
Offshore wind power had a later start because of the more complex environmental conditions at sea. The Danish offshore wind industry has its origin in the 1990s, when the two first movers in the wind industry, Bonus (now Siemens Wind Power) and Vestas, decided to construct the Vindeby offshore wind farm (DWIA, 2010). With Siemens and Vestas also being the first movers in the offshore wind industry, we can conclude that the offshore wind industry is developing as a part of the entire Danish wind industry that is mainly concentrated in The greater Aarhus area.

The growth of the wind industry business in The greater Aarhus area, as well as the favorable political climate, attracted more and more interested parties to the area, resulting in the emergence of a cluster.

4.1.2. Evolution of the cluster as opposed to the theoretical framework

In what follows, we will discuss the evolution of the (offshore) wind cluster in central Denmark, trying to identify success factors and referring to literature.

After the oil crises in the 1970s, Denmark developed the ambition to become self-sufficient with energy. The entire society became concerned with the potential of renewable energy and as wind was the most eligible renewable energy source, it became a political priority. The Danish politics had, and still has, strong believe in the development of the Danish wind industry (Monday Morning, 2010).

Because of the favorable political climate and the growing potential of the business, more qualified suppliers, skilled workers and aware investors got attracted to the region, resulting in a tight specialized network that offers agglomeration economies, as explained by Pouder & St. John (1996). The world’s strongest wind industry supply chain is currently located in Central Denmark. According to DWIA statistics, over 14,000 jobs of all 25,000 Danish wind turbine jobs are located in Central Denmark. Furthermore, estimated is that 11,000 wind industry employees work within one hour’s drive from Aarhus (Monday Morning, 2010).

The developing Danish wind industry felt the need to create ‘social glue’ (Porter, 1998). Efforts were undertaken to build relationships to further foster the business’
growth. And today, the (offshore) wind industry in Denmark is still growing so, there is no need to speak of reorientation or deterioration.

In what follows, we will discuss the driving forces in the development of Central Denmark as (offshore) wind cluster and identify those factors that contributed to its success, keeping in mind our literature findings.

4.1.3. Driving forces in the success of Central Denmark’s offshore wind cluster

In our literature study, we identified some determinants in the development of a cluster. We will pay attention to those factors that played a crucial role in Central Denmark’s success in cluster development and compare our empirical findings to those in literature.

Diversity of organizations

Regarding diversity, there are four dimensions that should be represented in a cluster, i.e. scientific, industrial, financial and supporting dimension.

The greater Aarhus area can rely on a broad scientific base. Several academic and other scientific institutions are headquartered in and around Aarhus. Some examples are Aarhus University, The Engineering College of Aarhus, Aarhus School of Engineering (ASE), Navitas hub for innovation, education and energy, Aarhus School of Marine and Technical Engineering, INCUBA Science Park, etc. More information on the available knowledge and the facilitation of knowledge flows is provided further in this dissertation.

Regarding the industrial dimension, diversity is widely represented as a lot of different sectors can be identified in The greater Aarhus area, e.g. transportation, maritime sector, electricity, consulting etc. Point is that all these different sectors are only partly involved in the (offshore) wind industry such that, when the industry should experience a downturn, the cluster is likely to survive (Powell, 2012). The biggest concentration of supply chain actors in the global wind industry can be found in Aarhus and its surrounding area. Wind turbine
manufacturers and suppliers and other value chain actors are represented in appendix 1. As can be seen, a lot of different sectors are represented but, numerous companies operate in similar domains, resulting in strong rivalry. This fierce competition is crucial for a cluster to further grow and develop (Porter, 1998).

In literature, we found that start-ups and spin-offs play a crucial role because of the innovative characteristics. Therefore, several science parks and incubators are set up in the area. An example is the INCUBA Science Park, which is an incubator for start-ups in the IT, bio-medico, cleantech and food industry. Estimated is that INCUBA houses around 120 small-and medium sized innovative enterprises.

In providing financing services, the science parks also play an important role as they help businesses in raising capital through their intensive relationships with venture capitalists and other finance providers. Furthermore, the government is an important factor in providing capital as they grant large subsidies in order to further develop the (offshore) wind industry in Denmark. As can be remarked from the pillar ‘financing and insurance’ in the second figure of appendix 1, six companies are included, of which big companies in the wind industry such as Gamese and Siemens. This indicates that those players also provide funding for the industry. Appendix 1 further reveals the presence of other supportive businesses for the wind industry in Aarhus’ region, e.g. consulting and certification, financing and insurance, marketing analysis and exhibition services etc. Furthermore, the City of Aarhus, and more specific Business Aarhus as the official service unit for businesses in the Aarhus area, also creates a broad basis for supporting business development, e.g. setting up businesses, providing information about investments, finding specialized skilled labor, providing connections with knowledge, research and educational institutions etc.

When formulating a conclusion about the diversity of the (offshore) wind cluster, we can say that the cluster is complete regarding the presence of different companies and institutions. In this way, heterogeneity is created, resulting in higher levels of innovation and creativity (Pouder & St. John, 1996).
Presence of an anchor organization

The Danish Wind Industry Association (DWIA) is the voice of the wind industry in Denmark. Although its members are dispersed all over the country, a higher concentration of members can be found in the Aarhus region (figure 27).

Figure 27 Headquarters of individual DWIA members in Central Denmark (DWIA, 2013)

The DWIA is a neutral partner in the support of the wind industry, thereby not favoring a specific region in order to avoid subjective involvement. Neutrality was emphasized by Powell (2012). To connect cluster members with each other, the DWIA hosts several events such as conferences, company visits, wind farm tours etc. In facilitating access to R&D and industry knowledge, the DWIA established ‘The Talent Factory’ as a link between companies, students and educators. Regarding knowledge sharing about wind energy, Aarhus University takes on a better position with its Technology Transfer Office, fostering university-industry interaction, including research collaboration and technology transfer through commercialization. As Aarhus University is a member of DWIA, all DWIA members are allowed access to the university’s knowledge so that industry information is more likely to be absorbed by numerous different companies and institutions (Agrawal & Cockburn, 2003).

Furthermore, Leydesdorff (2005) emphasizes the anchor’s relationships with government as one aspect of the university-industry-government relations in his
Triple Helix Model. The DWIA is engaged in such relationships as can be derived from the network and collaboration overview that is represented in appendix 2. Here we notice the presence of ministries, the Ministry of Foreign Affairs (with Invest in Denmark being a part of it), Local Government Denmark, The Danish political parties etc. The DWIA holds a relative good and stable lobbying position within Danish governmental institutions as the whole Danish political and social environment is concerned with green energy and wind power in particular.

**Present knowledge and knowledge flows**

Wolfe & Gertler (2004) argue that competitive advantage is obtained and supported by shared access to a pool of distinctive knowledge. Central Denmark possesses highly specialized knowledge and knowledge flows between cluster members are intensively supported. Distinctive knowledge in The greater Aarhus area is provided by a broad scientific base, created by the University of Aarhus and other different scientific institutions.

Recently, The Engineering College of Aarhus and Aarhus University have joined forces to establish Aarhus School of Engineering (ASE) in order to develop a stronger technical and scientific engineering environment. Scientific institutions also collaborate with big industry players like Vestas and Siemens Wind Power to create specialized programs that focus on wind power, e.g. ASE offers a summer school focused on wind turbine design (Monday Morning, 2010).

A new hub for innovation, education and energy, Navitas, will be operational in Aarhus in 2014. It will provide accommodation for The Aarhus School of Engineering, Aarhus School of Marine and Technical Engineering and INCUBA Science Park, facilitating education, laboratories and entrepreneurship. Navitas will not only serve the (offshore) wind industry but is meant to cover the whole aspect of green energy. Furthermore, scientific wind energy research is not restricted to the Aarhus area as more scientific links exist with institutions from outside Central Denmark. E.g. cooperation takes place with Aalborg University's (AAU) Wind Energy Structures and Technologies that is located in Northern Denmark’s wind turbine cluster Hub North. AAU plays an important role in
knowledge sharing, innovation and research collaboration (Monday Morning, 2010).

Furthermore, Wolfe & Gertler (2004) emphasize that crucial new knowledge is most effectively obtained through interpersonal contacts. We then talk about tacit knowledge, and mobility of skilled labor, by means of highly specialized knowledge and entrepreneurial skills. We could not investigate the level of interpersonal relationships, nor could we identify specific knowledge flows because these are very hard to detect as they are embedded in close, informal cooperation between cluster members. We also could not gather data about the mobility of skilled labor in Central Denmark.

What we could identify is that there are several opportunities for cluster members to engage in informal contacts. Wind industry members meet at DWIA events, talk to each other at the different Science Parks or have informal contacts at Aarhus University’s Technological Transfer Office, where small as well as big companies are involved in technology transfer processes. Which information and knowledge is being transferred is something we do not know but, the existence of informal relations contributes to success of high-technology clusters (Breschi & Malerba, 2001).

Furthermore, The greater Aarhus area applies a strong cooperation model, i.e. the triple helix model of business-science-politics relations, extended with a fourth helix, being the civil society. This model strongly promotes the flow of knowledge between the different domains (Monday Morning, 2010) and will be further discussed under cross-network alignment.

**Cross-network alignment**

Cross-network alignment covers cross-domain relationships, as well as relationships between cluster members. First, regarding cross-domain relationships, we can clearly confirm that the DWIA is a global network. Not only does the DWI have world leading companies in the wind industry, e.g. Vestas, Siemens Wind Power, Gamese etc., on its member list, we were also able to
identify other global relationships such as with Danish embassies globally and Invest in Denmark (appendix 2).

Invest in Denmark is part of the Ministry of Foreign Affairs, which has excellent global links. Invest in Denmark promotes the Danish wind industry abroad in order to attract foreign investments. The organization also closely collaborates with the DWIA in promoting the Danish wind industry. E.g. they jointly elaborate industry reports and organize events, e.g. the yearly Offshore Wind International Business2Business event.

Regarding scientific research, collaboration occurs between different research institutions from Central Denmark and other research institutions outside The greater Aarhus area. Aarhus University intensively works together with Aalborg University, which is a key player in Hub North, the wind turbine cluster in Northern Denmark.

Furthermore, the DWIA and its members also cooperate with other sectors in the renewables industry as the whole social and political scene in Denmark supports the principal idea that CO₂ emissions should be reduced and the development and implementation of renewable energy resources should be further explored. In the DWIA network, we find institutions like energynet.dk, Climate Consortium Denmark, The Alliance for Offshore Renewables, etc. (Appendix 2).

Cross-networking is found in Central Denmark's application of the Triple Helix Model (Leyesdorff, 2005). The greater Aarhus area modified the model towards a collaboration model between four actors: business-science-politics-civil society. A fourth ‘helix’ was added to the initial model, i.e. civil society, covering all different stakeholders in society (Monday Morning, 2010). The fourth helix refers to the involvement of Denmark’s whole society. This involvement is not just passive. Today, about 2,000 of 5,200 Danish wind turbines are owned by local syndicates. These local syndicates financed the construction as citizens were given the opportunity to buy a share. The model is represented in figure 28.
The study of Zhang & Li (2010) provided us with four types of service intermediaries that have a significant positive effect on the development of a technology cluster, i.e. accounting and financial service firms, law firms, talent search firms and technology service firms. As already discussed in the factor diversity, we found that all of these supportive service providers are represented in the cluster. Moreover, we found that within the DWIA network, almost 50% of all legal and financial member firms are located in Central Denmark, more specifically, around 27% can be found in and around Aarhus (DWIA, 2013).

**Geographical proximity and cluster size**

Geographical proximity is no longer an issue to discuss here as we already mentioned that 87% of Danish wind industry turnover is generated in The greater Aarhus area, covering a limited radius of 75 kilometers from Aarhus. We could not have access to quantitative data, proving increased performance due to the proximity but, as The greater Aarhus area shows some evidence of being an excellent performer in the wind industry and in cluster development, we can assume that interactions are stimulated because of proximity.

The greater Aarhus area is home to 60 companies that are directly involved in the wind industry (Monday Morning, 2010). When adding the indirectly involved companies such as service intermediaries etc., the number of cluster members
largely exceeds 65. According to literature, this could be harmful and cause diseconomies of agglomeration to emerge (Folta, Cooper, & Baik, 2006). Here, The greater Aarhus area seems to be atypical as opposed to literature as the area’s performance is really world class.

**Cluster policy**

The Danish government strongly recognizes its indirect role as a catalyst and challenger in cluster policy. Apart from the direct incentives such as financial support, The Danish Agency for Science, Technology and Innovation and The Danish Energy Agency set up programs to foster innovation and enhance national competitiveness in the wind industry. An example of such a program is ‘The Danish Innovation policy programme of Innovation Network’. The purpose of the program is to guide unexperienced companies within clusters so that they can have access to specialized knowledge through knowledge spillovers. The program aims at increasing company’s individual innovativeness (figure 29) with the ultimate goal to increase cluster performance as well as national economic performance (Danish Agency for Science, Technology and Innovation, 2011).

At the regional and local level, similar initiatives can be found. The Aarhus City Council launched a proactive climate strategy with the ambitious goal to become carbon neutral in 2030. Here, wind power is on top of the agenda. The strategy consists of several programs and initiatives, all aiming at creating a favorable green business environment and enhancing relationships within the area (Monday Morning, 2010).
Examples of cluster initiatives at the local level can be found at Aarhus University. Knowledge exchange is one pillar of the university and the Technology Transfer Office is the most important initiative. Hereby, the university wants to stimulate the commercialization of relevant research in Central Denmark.

4.2. Analysis of the offshore wind cluster in Northwest Germany

4.2.1. Description and origin

Bremen is located about 50 km inland from Germany’s Northwest coastline, along the river Weser. As Bremen could not be reached anymore by larger vessels, a new port near the coast was established in 1827, i.e. Bremerhaven. Today, the region Bremerhaven/Bremen grew into a very successful offshore wind cluster, having around 185 member organizations on its list. The cluster was established in 2002 with the purpose to promote wind power developments in the Northwest of Germany. The network is based on two working areas, i.e. supporting offshore wind power developments and attracting investments to the region (de Vries, 2009).

After Bremerhaven experienced some hard economic times, the city council decided that Bremerhaven’s city port needed to be revitalized to reverse the decline. Bremerhaven succeeded in attracting some major shipping lines and took a strong
position into the maritime industry. Putting the city’s strengths together, i.e. a strong maritime technological knowledge base and a skilled and specialized workforce, Bremerhaven decided to further focus on offshore wind power (de Vries, 2009).

We can clearly see that the origin of the Bremerhaven/Bremen offshore wind cluster is primarily based on the presence of region specific resources and skills, rather than that it originated from the entrepreneurial activities of ‘heroes’ (Sölvell, 2008). It was also more a decision of policy makers to further develop the offshore wind activities in the region, in other words, a top-down initiative. As the region succeeded in attracting some important industry players, the offshore wind cluster further got strengthened because other player’s interest to locate in the region also increased.

4.2.2. Evolution of the cluster as opposed to the theoretical framework

Four manufacturers/assemblers, i.e. REpower Systems, PowerBlades, Multibrid (now AREVA) and Weserwind, are responsible for Bremerhaven/Bremen’s initial success (de Vries, 2009). The companies’ facilities are located close to each other as can be seen on figure 30.

Figure 30 Location of the four orchestrators of the offshore wind cluster in Bremerhaven (BIS, 2012)
These key orchestrators provided the region with a strong initial supply side for the offshore wind industry. Over time, the wind technology supply chain further developed through the incorporation of a large number of specialized actors and grew into a healthy competitive and cooperative environment (Boeckle et al., 2010). The supply chain is represented in figure 31.

Among those specialized actors are two wind turbine suppliers, i.e. PowerWind and Windpower, and two research and development facilities, i.e. Deutsche Windguard and Frauenhofer Center for Wind Energy and Maritime Technology (Boeckle et al., 2010). These initial partners truly added value to the cluster network and contributed to the success it is harvesting today.

The Bremerhaven/Bremen offshore wind cluster is still growing today and has not reached its maturity point yet. This can be derived from the fact that new jobs are created in the region at a rate that is increasing every year (de Vries, 2009). Furthermore, technology keeps expanding and more and more new companies decide to join the network.

4.2.3. Driving forces in the success of the offshore wind cluster Bremerhaven/Bremen

Similarly to the discussion of The greater Aarhus wind cluster, we will take a closer look at each of the success factors that we have found in our literature review. Of course we will find some commonalities but, more important is investigate if other ‘atypical’ drivers can be found.
**Diversity of organizations**

Even though the offshore wind cluster Bremerhaven/Bremen was primarily the home base for major wind turbine manufacturers/assemblers, the network grew into a very diverse web of companies. The cluster map in figure 32 shows us that all relevant players are represented and that the diversity is more than complete. The number of companies that are included in the network are indicated between brackets.

![Figure 32 Wind Technology Cluster Map Northwest Germany (Boeckle et al., 2010)](image)

**Presence of an anchor organization**

One of the most influential local wind associations can be found in Germany’s Northwest region. The WAB (Windenergie Agentur Bremerhaven/Bremen) fulfils a key role in providing and distributing expertise, information and best practices regarding the offshore wind industry (Boeckle et al., 2010). The WAB represents the offshore wind industry in business as well as in politics. The organization gives its members the opportunity to develop their network of contacts by setting up and joining conferences, trade events, seminars and thematic working groups, and thereby functioning as a neutral partner. The employees of the WAB fulfil the role of business developers, helping (new) companies to develop a business strategy in the offshore wind sector (WAB, 2012)
Present knowledge and knowledge flows

Knowledge in terms of research and development is mainly concentrated in the University of Bremen, which is together with the universities of Hannover and Oldenburg a member of the broader research consortium ForWind. ForWind combines scientific know-how and research in the wind industry and is a respected cooperation partner in the offshore wind cluster in Northwest Germany. ForWind also offers educational programs in the wind power domain.

Another important institution regarding knowledge is Fraunhofer Institute for Wind Energy and Energy Systems Technology IWES that is located in Bremerhaven. Fraunhofer IWES closely collaborates with the universities of the ForWind consortium regarding applied research and development in the domain of wind energy. Furthermore, Fraunhofer IWES accommodates several extensive testing and experimental facilities, laboratories and equipment.

Important is that extensive knowledge flows are facilitated between the knowledge institutions and the industry. Here, the WAB comes into play, facilitating knowledge flows and providing the ‘glue’ to bind the network. This is important as Bremen and Bremerhaven are located about 65 km from each other. 30% of all wind industry employees work in Bremen, of which 80% is highly educated, while the other 70% wind industry employees work in Bremerhaven but, only 20% of them is highly educated. This strong division between innovative, knowledge intensive labor and lower educated labor reveals the crucial role of a knowledge flow facilitator to bridge the distance between the two regions (Bruneel, 2011). This is visually represented in figure 33.
The WAB excellently fulfills this role and facilitates knowledge spillovers through elaborating multiple initiatives to foster the exchange of tacit, as well as non-tacit knowledge between the partners.

**Cross-network alignment**

The WAB, as voice of the offshore wind power cluster in Northwest Germany is well aware of the global industry it is operating in. The WAB conducts market research and analysis of developments in international markets in order to keep its members informed about international activities in the offshore wind industry. The WAB is member of the European Wind Energy Association. Moreover, several members of the WAB can be found of the EWEA’s member list.

In the cluster map that is represented in figure 32, we can identify Leydesdorff’s (2005) Triple Helix Model as links are provided between research institutions, governmental institutions and the industry. We already mentioned that the WAB takes on the crucial role in facilitating and supporting knowledge flows between those three domains.

**Relationships with service providers**

Professional service organizations are well represented in and around Bremerhaven. Under ‘support services/functions’ in figure 32, several 100 companies are registered. The WAB has initiated and coordinates four working
groups, i.e. Formation of Businesses, Service and Operations, Logistics and Installations and Law. In each of the working groups, staff of member companies can exchange information on their working area in an informal way. We see that all service intermediaries as proposed by Zhang & Li (2010), i.e. accounting and financial service firms, law firms, talent search firms and technology service firms, are more or less represented in the WAB’s network and in the offshore wind cluster.

**Geographical proximity and cluster size**

Estimated is that over 80% of all relevant players in the offshore wind power cluster are located in a radius of 160 km around the city of Bremen (Boeckle et al., 2010), with the majority of employees concentrated in Bremen and Bremerhaven. This is a large distance for establishing informal relationships and we already identified the possible issues as the majority of highly educated labor is found in Bremen, while most of the lower educated employees are concentrated in Bremerhaven (see figure 33). The fact that Bremen and Bremerhaven are located around 65 km from each other is very atypical for obtaining cluster benefits. Just because of the strong position of the WAB in the offshore wind cluster, both regions are excellently ‘glued’ together so that knowledge exchange occurs in a highly efficient manner.

Again, we cannot confirm literature’s findings that a cluster’s benefits diminish when its size exceeds 65 members. The WAB represents more than 350 companies and institutions and though, the organization is an example regarding cluster performance.

**Cluster policy**

German government already developed a wide ecological awareness since the 1980s. Ever since, Germany is engaged elaborating favorable economic policies in the domain of renewable energy (Boeckle et al., 2010). In the origin section, we already mentioned that the establishment of the offshore wind cluster around Bremerhaven was a political decision based on favorable resource conditions. To
support industry growth, German government decided to directly influence the demand side by guaranteeing all renewable energy producers access to distribution networks as well as guaranteeing an attractive price for the generated energy (Boeckle *et al.*, 2010). This national governmental policy created a strong early demand for the offshore wind industry and immediately set the direction towards the emergence of a tight network. Germany’s standards and procedures for wind farm authorizations, operations and decommissioning are well developed due to its years of experience in on- as well as offshore wind power (Portman *et al.*, 2009). The national goals are also supported by public policies that directly target the supply side such as favorable feed-in tariffs, premiums, green certificates and subsidies (Portman *et al.*, 2009), e.g. for 2011, the offshore industry was granted a 5 billion euro credit program of the government owned bank KfW Bankengruppe to further support the development of the industry. The KfW also provides low interest loans for some technologies (Ecofys, 2011).

Regional support is provided by Bremerhaven’s economic development agency BIS (Bremerhaven Gesellschaft für Investitionsförderung und Stadtentwicklung) and by the state of Bremen itself. BIS cooperates with business, research and educational institutions and government and administration in Bremen and Bremerhaven. Financial support on the regional level is provided by the state of Bremen, which announced in 2012 to invest another 30 million euros in the development of the offshore industry in Bremerhaven, after already having invested 25 million euros in the previous year. Those investments are made to support R&D in the offshore wind cluster Bremerhaven/Bremen.

Local cluster initiatives are plentiful. We already mentioned the working group initiative of the WAB, in which different companies with similar activities in the region can exchange knowledge and ideas. The University of Bremen has elaborated a transfer strategy with the goal to transfer ideas, research findings and human resources to the economy and the society in general.

As a conclusion, we can say that there is a quite healthy balance between top-down and bottom-up initiatives, creating an excellent innovative environment for the offshore wind industry in the Bremerhaven/Bremen region.
4.2.4. Limitations and challenges

Although Bremerhaven/Bremen is often cited as a success story in regional development for offshore wind power, the cluster experiences some challenges that, in the long run, can stifle innovation.

Regarding funding, Germany has an underdeveloped venture capital system that cannot provide sufficient funding for entrepreneurial companies. This issue can hold back innovation growth. Furthermore, the German economy strongly relies on exports and export surpluses are often being transferred abroad instead of being reinvested in domestic industries, resulting in a low FDI (Foreign Direct Investment) rate (Boeckle et al., 2010). Despite these challenges, there is currently no shortage of funding for the German offshore wind industry in Bremerhaven/Bremen because of the stable national and regional support system but, in the long run, governments may decrease financial support and then, a well-developed venture capital market and a higher FDI rate can further take care of funding needs.

5 Discussion of best practices: success factors and policy implications

In this chapter we will discuss and compare both best practices in order to identify general and atypical success factors in offshore wind clustering. We will end the chapter with some policy implications.

5.1. General success factors

Both discussed best practices have a different origin. The origin of a cluster is indeed difficult to forecast but, as we compare the offshore wind clusters in The greater Aarhus area and Bremerhaven/Bremen, we conclude that it is crucial that some favorable factor conditions are represented, e.g. natural resources such as wind, knowledge, etc. or a favorable economic/political climate. In both cases, if the origin is natural or initiated top-down, the attraction of some big industry players to
the region was the seed for the emergence of an offshore wind network. So, we can say that the type of origin is not really a significant determinant in cluster success.

Diversity of organizations is an essential factor in the development of a cluster. Both cases show a high level of diversity in their network as the scientific, industrial, financial and supporting pillars are all well-represented. Diversity should be created and sustained by national, regional and local policy makers by pro-actively attracting diverse parties to the cluster. Diversity can only pay off if the knowledge of the diverse parties effectively and efficiently flows from the one to the other party. Here, we see that both clusters perform outstanding in facilitating knowledge flows. Important is also that in both cases, (offshore) wind knowledge was already present because of several years of experience in the industry. The offshore wind clusters from both cases have an excellent anchor organization that has a strong lobbying position regarding political issues and provides extensive links with the diverse actors in the network. Among those links, relationships with service providers can also be classified. The level of development of the anchor organization is definitely a success factor for an offshore wind cluster as the anchor fulfills the role of ‘gluing’ the whole together. The anchor also ensures cross-network alignment. In Central Denmark, as well as in Northwest Germany, the anchor organizations have taken the role of positioning their regional offshore wind cluster in the global wind industry by engaging in global relationships. We also identify that both clusters apply the Triple Helix Model of university-government-industry collaboration. The greater Aarhus area even takes it a step further by adding the civil society to the collaboration network.

We can conclude that the factors diversity, anchor organization, present knowledge and knowledge flows, cross-network alignment and relationships with service providers are all ingredients that need to be integrated to come towards a well performing cluster. These factors are all not context specific so they can be generalized towards more industries and countries.
5.2. Atypical success factors

During our study of best practices in offshore wind clustering in Central Denmark and Northwest Germany, we found some factors that did not immediately confirm our findings in literature.

First, in the Bremerhaven/Bremen case, we found that there is a large distance between the knowledge concentration in Bremen upstream and the labor concentration in Bremerhaven downstream the value chain and though knowledge is effectively and efficiently exchanged. Here, geographical proximity seems to be less significant. The real success factor in clustering is the anchor organization WAB for this case. The WAB really ‘glues’ both regions together as if they were just located next to each other.

Also, for both clusters, cluster size largely exceeds 65, which was indicated as the point from which marginal benefits seems to disappear.

The secret ingredient here is that geographical proximity and cluster size seem to be less significant, as long as the network is strongly kept together by the forces of an anchor organization.

Remarkable element that came forward in Denmark, as well as in Germany, is that civil society is involved in the offshore wind cluster operations. In both countries, renewable energy is high on the agenda and policies are aligned with this idea. This makes that renewable energy sources became a country wide concern. In The greater Aarhus area, the civil society was even added as a fourth helix to the Triple Helix Model of collaborative relationships between university, industry and government. Through local syndicates, Danish citizens were able to buy a share and thereby co-finance the construction of wind turbines. This strong national, regional and local believe, together with an aligned policy are success ingredients for the development of an offshore wind cluster. Policy implications will be discussed in next section.
We can conclude that a strong anchor organization, rather than immediate proximity, and a strong national, regional and local belief in the industry are principal success factors that further expanded the success of the offshore wind clusters in Denmark and Germany, on top of the general cluster drivers.

5.3. Policy implications

Cluster policy is very context specific, though we see quite some similarities between the offshore wind cluster in Denmark and Germany for each level, i.e. national, regional and local. Both countries have a similar approach on which we can base our recommendations towards other nations that aspire to support offshore wind clustering in their country.

As literature makes a distinction between top-down and bottom-up approaches (Sölvell, 2008), we rather define an integration of both approaches in both cases. Porter (1998) mentioned that government should fulfill an indirect role as a catalyst and challenger, rather than a direct role. But, in both cases, government plays a direct as well as an indirect role. The direct involvement of government is not a bad thing as can be concluded from the best practices study. In both Denmark and Germany, government applies fiscal policies to foster the offshore wind industry. Both countries provide feed-in premium or tariffs. Germany even imposes low interest rates on loans for offshore wind projects. In this way, both countries can attract foreign investment as well as more industry actors and stimulate the business to grow. Recommended is that governments use fiscal policy, e.g. through elaborating attractive tax systems, to build a strong financial market in the regions of subject. In this way, venture capitalist can be attracted and (export) surpluses can be reinvested in the industry. This was mentioned as a challenge for the Northeast German offshore wind cluster.

The direct involvement should be combined with an indirect involvement through the establishment of innovation and collaboration stimulating programs so that even inexperienced industry players can upgrade performance. The innovation and
collaboration programs make sure that the monetary support is effective and efficient. This integration is a strong success factor in the Danish and German story.

Important to support cluster activities in the offshore wind industry is that national and regional governments create reliable expectations for policies and support schemes. By building trust and pursuing a pro-active and enabling stable policy, governments create a fertile business environment and help unlocking investments. The offshore industry’s believe in government is not only affected by its offshore wind policy but by the whole renewable energy policy. E.g. when a country wants to terminate some fiscal support mechanisms for another renewable industry than the wind industry, this decision will have an indirect impact on the offshore wind industry as investors will lose faith in the governments’ believe in renewables. Denmark’s and Germany’s strength here is that they do have strong believe in renewable energy and that this is actually aligned with their decisions and actions by means of stable policies.
6 General conclusion and recommendations for further research

6.1. General conclusion

More and more, companies feel that they can benefit from other companies’ knowledge and expertise through close interaction and collaboration, even when those companies are considered competitors. This increasing awareness has led to the fact that clusters will play a prominent role in increasing performance and enhancing country competitiveness. Generally, clusters can be defined as geographic concentrations of interconnected companies and institutions in a particular field. Over time, clusters move through different evolutionary phases, from origin and growth over maturity and decline or reorientation. Cluster life cycles are very context specific. In other words, there is no predefined recipe for building a successful cluster. In literature, we identified some factors that influence the development of a cluster: Diversity of organizations, presence of an anchor organization, present knowledge and knowledge flows, cross-network alignment, relationships with service providers, geographical proximity and cluster size and cluster policy.

The increasing interest in cluster development is further investigated through this master dissertation in the field of the offshore wind industry. Wind energy is the world’s main source of renewable electricity and can be divided into two main categories, i.e. on- and offshore wind energy. Since some decades, the offshore wind industry experienced high growth as its potential is much higher than onshore wind power.

Combining the increasing interest in cluster development and the growth of the offshore wind industry, purpose of this master dissertation is to analyze offshore wind cluster development in Europe as Europe is covering more than 90% of the world’s offshore wind capacity. We restricted our analysis to those six countries, having the highest installed offshore wind capacity, i.e. The United Kingdom, Denmark, Belgium, The Netherlands, Germany, and Sweden. The analysis occurs by means of three research questions:
Where can geographical concentrations of offshore wind activities be identified in the selected countries? Can we identify organized cluster activities here?

Having identified best practices in offshore wind clustering, how did those clusters emerge and develop and how does management of those clusters take place? Which parties and institutions are involved?

What Key Performance Indicators (KPI’s) are driving the best practice case studies and can those be applied elsewhere to foster the development of offshore wind clusters, i.e. we will research if generalizations can be obtained.

We aimed at answering these research questions by means of conducting an empirical qualitative study. Information was gathered by consulting papers, articles, reports, etc. that were available over the internet. In what follows, we will shortly summarize our main findings for each of the research questions.

Where can geographical concentrations of offshore wind activities be identified in the selected countries? Can we identify organized cluster activities here?

For each of the six countries under study, we identified geographical concentrations of offshore wind power. The United Kingdom’s offshore wind industry is mainly concentrated in the East of England. Although The United Kingdom has huge capacity, we could not identify organized cluster activities here as we remarked a lack of connection between the different guiding institutions as well as a lack of cooperation efforts due to fragmentation. The Netherlands, Belgium and Sweden showed a similar lack of interorganizational links. Denmark and Germany clearly performed better regarding organized cluster activities. In Denmark, a concentration of (offshore) wind power activities was identified in its central belt, more precisely in and around the coastal city of Aarhus. Strong forces hold the cluster together, including governmental, scientific and industry links. For Germany, the same characteristics could be identified in the Northwest region Bremerhaven/Bremen.

Given this primary analysis, we decided to further investigate the situation in Denmark’s Aarhus area and in Northwest Germany and elaborate two best practice case studies on these geographical concentrations of offshore wind energy.
Having identified best practices in offshore wind clustering, how did those clusters emerge and develop and how does management of those clusters take place? Which parties and institutions are involved?

To provide an answer to this question, we started by taking a closer look on the origin of both offshore wind clusters. In Denmark, the cluster knows a more natural origin while the Bremerhaven/Bremen offshore wind cluster was initiated with the help of a top-down approach. They both knew a similar growth pattern, having developed a fertile business environment for large industry players, as well as for new entrepreneurial companies and numerous other diverse firms. We investigated each of the different factors that were proposed in literature as having an influence on the development of a cluster so we could identify which parties and institutions were involved in the whole cluster development process. The analysis in this part of this master dissertation was used to identify general success factors and try to look for more atypical factors that were not emphasized in literature to provide an answer to the last research question.

What Key Performance Indicators (KPI's) are driving the best practice case studies and can those be applied elsewhere to foster the development of offshore wind clusters, i.e. we will research if generalizations can be obtained.

In answering this research question, we compared the analyses of the two best practice case studies, both to each other and to findings in literature to look for general and more atypical success factors in the development of The greater Aarhus area and Bremerhaven/Bremen offshore wind clusters.

We found that diversity of organizations, presence of an anchor organization, present knowledge and knowledge flows, cross-network alignment and relationships with service providers are all basic ingredients that should be represented when aspiring to develop a cluster. These factors can be generalized and elaborated on in other regions that want to initiate and develop an offshore wind cluster.
The more atypical factors that can explain the success of the offshore wind cluster in The greater Aarhus area and in Bremerhaven/Bremen relate to geographical proximity and cluster size, the involvement of the whole society and the way in which cluster policies are integrated.

Geographical proximity and cluster size does not seem to be relevant factors in offshore wind cluster success. Of course, geographical proximity is a basic ingredient for a cluster but, we found that it is not necessary that cluster members are located immediately next to each other to effectively and efficiently obtain knowledge spillovers and networking benefits, as is shown in the Bremerhaven/Bremen success case, where Bremerhaven and Bremen are located about 65 km from each other. The secret ingredient here is a strongly developed anchor organization that ‘glues’ the whole together. In both success cases, cluster size does not seem to contribute to or detracts from success.

Another explaining factor in the success of both case studies is the involvement of the whole society as this fosters industry support. Furthermore, the integration of cluster policies can also be responsible for explaining part of the success. Government is directly as well as indirectly involved with clear and stable initiatives and integration and communication takes place between national, regional and local levels. This is a necessary ingredient as in this way, government builds trust with the industry and other stakeholders and can create reliable expectations for policies and support schemes. As national, regional and local governments execute a pro-active role, domestic as well as foreign investments will be unlocked.

6.2. Recommendations for further research

In our research, we only made use of secondary sources such as articles, papers, reports, etc. that were publically available. This makes that our analysis and the resulting findings are not based on quantitative data. It is recommended that in further research, quantitative data is gather to investigate cluster advantages. Examples here are data on innovativeness by means of patenting, data on start-ups and spin-offs, general performance data of companies in a cluster, etc. Benefits for
companies that operate within the boundaries of a cluster can be further researched by means of questionnaires and interviews. In this master dissertation, it was impossible to conduct this kind of research as it crosses national borders and it is very time consuming. It is also recommended to investigate and compare performances of companies in a cluster and companies outside the cluster. In this way, the reasons for joining a cluster can be revealed and benefits for members can be deeper analyzed.

We only investigated organized cluster activities in the offshore wind industry in Europe. It can be interesting for further research to expand the scope towards more industries in order to try to identify success factors for different industries and investigate if these success factors can be generalized. Also can the scope geographically be expanded towards e.g. the US and China, in which (offshore) wind power is gaining increasing attention.
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APPENDICES

Appendix 1: Value chain of the wind energy cluster in the Aarhus region

Wind turbine manufacturers and suppliers in the wind energy value chain in The greater Aarhus area

Other value chain actors in the wind energy cluster in The greater Aarhus area

Appendix 2: Overview of some extensive networks and collaborations the DWIA provides for its members

Source: DWIA, 2011