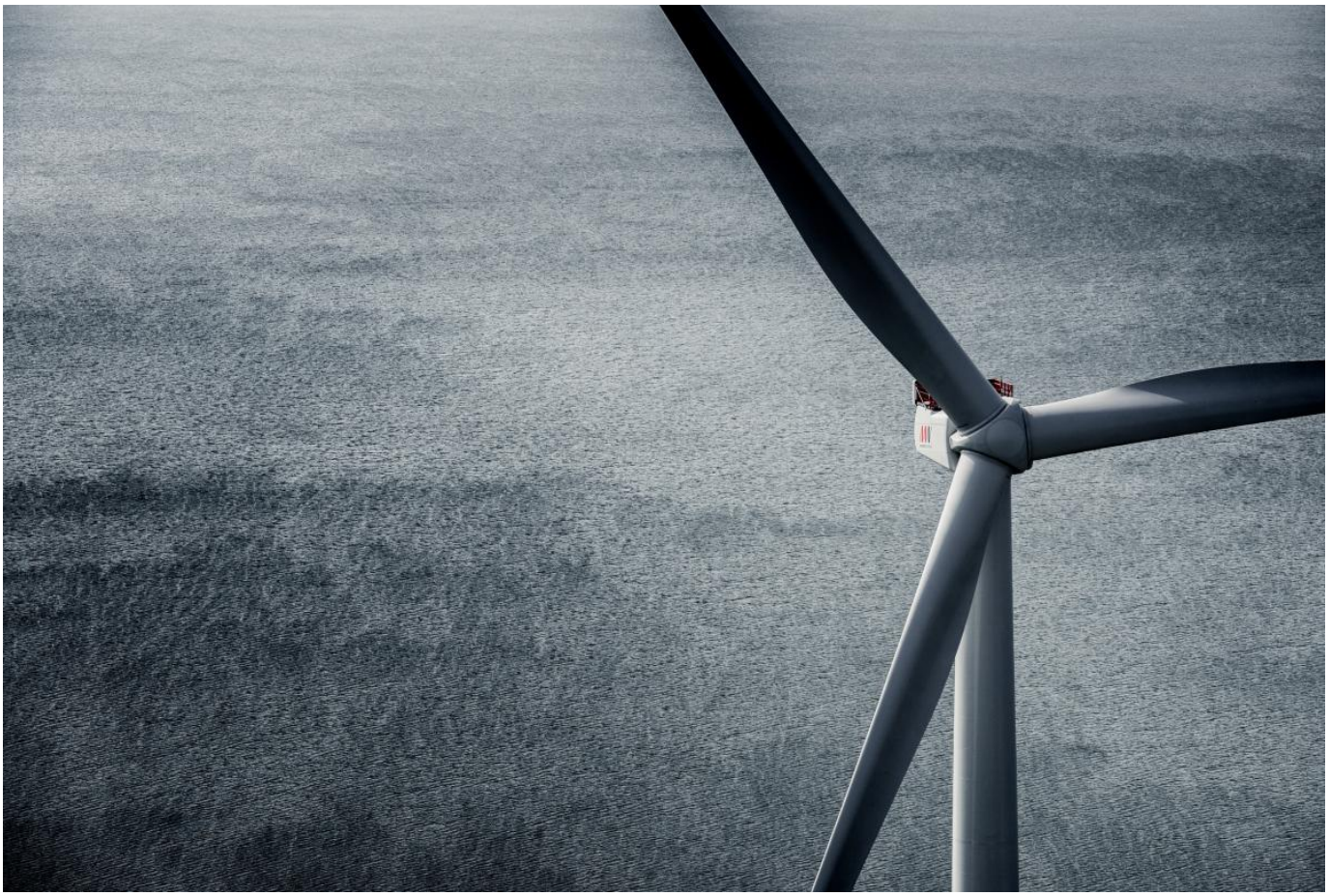
The Danish Wind Cluster

The Microeconomics of Competiveness



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May 3rd 2017

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1 Introduction

In one of the most noteworthy Danish novels Lykke Per (Happy Per) by Nobel Prize winner Henrik Pontoppidan from 1904, the main character Per, a young engineer, arrives to Copenhagen in the latter part of the 19th century. Departing the old world when leaving his very conservative Christian family, he has vast ambitions for Denmark in the new world of industrialization and scientific breakthroughs. Per's masterplan is to help Denmark overcome its agriculture dependency and lack of natural resources by creating a big port, canal systems and use alternative energy from wind and water to push forward industrialization.[1] [2]

Unfortunately, Lykke-Per never succeeds to materialize his vision. But if he flew across Denmark today, he would see massive offshore wind-farms and tons of onshore mills below him. All helping Denmark overcome its eternal problem of having very few natural resources – except for the wind. In 2015, wind energy covers 42% of the Danish electricity consumption on average. On windy days, wind energy surpasses 100% of the electricity demand.[3] Danish companies such as Vestas (turbine manufacturer) and DONG Energy (developer of offshore wind farms) are global leaders within the wind sector. In fact, the whole value-chain is present in the Danish wind cluster, which is the leading cluster in the world. The cluster employs around 30,000 people in Denmark and its share of Danish exports is around 5%. In this paper, I will analyze why the cluster became so successful but also investigate which challenges the cluster faces going forward.

I will begin the paper with a profile of Denmark focused on the endowment, the history and general characteristics. Next, I will analyze the competiveness of the Danish economy. As Denmark is such as small country this is important to access the wind cluster in section 4. Here, I will touch upon the cluster's history, present a cluster map and analyze the performance. At last, I will discuss potential threats to the cluster and finish with recommendations to help maintain the cluster's edge.

2 Profile of Denmark

Denmark is the smallest of the Nordic countries only covering up 42.931 square kilometers. It consists of the peninsula Jutland and 1419 islands. It borders Germany to the south, has Norway to the north and Sweden to the east across the belt (figure 7). Denmark is surrounded by the sea and extremely flat with a high point at only 170 meters above sea level. Moreover, it has very few natural resources apart from the North Sea oil and gas which adds up to around 5% of exports (figure 2). [4] [5]

Denmark dates back to the Viking age 850-1050 AD. During that period, the Danish Vikings robbed and raided all over Europe, went to Greenland and Newfoundland as well as they ruled over England from 1015-1034 AD. Ironically it was also during these years that Denmark became Christian.[6] [7] The Danish Kingdom had its pride under the Kalmar Union from 1397 to 1527, where Queen Margrethe of Denmark led the kingdoms of Sweden and Norway along with what today is Finland, Greenland, Iceland, the Shetland Islands and the Faroe Islands. Struggles between the Swedes and Danes culminated in the Bloodbath of Stockholm in 1520 where the Danish King Christian the 2nd killed around 100 Swedish noblemen. That led Sweden to leave the union in 1523, while Norway remained a part of Denmark together with the lower part of Sweden, Iceland, the Faroe Islands and Greenland[8]

In the 16th century Denmark turned to Protestantism and benefitted hugely from controlling Øresund, the belt between Denmark and Sweden, which controls the entrance into to the Baltic Sea. From the castle Kronborg (where Hamlet by Shakespeare takes place), Denmark earned a significant part of GDP by taxing ships passing. During the 17th century, Denmark fight continuous wars against the Swedes and eventually loses all of its eastern provinces to the Swedish King.[9] The lost wars against the Swedes results in absolutism where the Danish King centralizes power and weakens the noble. Through its colonies in India, Ghana and at what is now the American Virgin Islands, the economy thrives in later part of the 18th century. Then the big decline starts. In 1807, the British bombs Copenhagen and destroys the enormous fleet. They fear that Denmark will ally with Napoleon after his victory against Prussia. In 1813 Denmark goes bankrupt, in 1814 it losses Norway and finally in 1864 Denmark loses its German duchies after a defeat to Bismarck of Prussia. Yet, this period is also known as the Golden Age due to the richness of the cultural life in Copenhagen. Artists put Denmark on the map, HC Andersen writes his fairytales, Søren Kierkegaard develops his existential philosophy and HC Ørsted discovers the electro magnetism. It is also in 1849 that Denmark gets its constitution. However, it does not become a real democracy until 1901.[10]

In the 1880's, the economy changes from being based on exporting grains to instead export animal products mainly butter and pork. The agriculture remains the dominant sector of the Danish economy through the two world wars where Denmark is occupied by Hitler from 1940 until the war ends. In the 1950's the industrial sector surpasses the agricultural sector as share of GDP, and the economy grows significantly until 1973.[11] Now, 1.1% of the economy is agriculture, 23.4% is industry while services are 75.5%.[12]

Today, Denmark is known a constitutional monarchy where her Majesty Queen Margrethe the Second is the head of state. While Greenland and the Faroe Islands have self-government, they are both still a part of the realm. Denmark has a parliamentary multi-party system where no party has had single majority since 1909. Instead parties work together and often across coalitions when making larger reforms. The system is stable as Denmark has only had 6 prime ministers between 1982 and 2017, compared with 8 for Sweden and 20 for Italy. Denmark's population is 5.7 million and very homogenous. The share of the population non-western background (mostly Muslims) has increased significantly over the last 30 years from 1% in 1980 to 8 % of the population in 2015.[13] [14]

Denmark has been a member of the EU since 1973. Though Denmark is not a member of the Eurozone, the Danish Crown has been pegged to the D-mark and later the Euro since 1982. The Danish economy is the 37th largest in the world at 295 billion USD, and the 16th richest country with a GDP/capita of 45,709 USD.[15] Denmark is a very open economy where trade is at 101% of GDP and the trade surplus at 8% of GDP. The main export destinations are Germany (14%), Sweden (11%), the US (9%), UK (7%) and Norway (5%), and exports are fairly complex (Figure 2)[16] Finally, Denmark has a social welfare states where high taxes fund free health care, education and cheap child care. Hence, the public sector is 54% of GDP which is the fourth largest in OECD after France, Finland and Greece[17] Next, we turn to the current state of the Danish economy.

3 Competiveness of Denmark

In analyzing the competitiveness of Denmark, I will use the Institute for Strategy and Competiveness at HBS's (ISC) framework. It segments the overall competiveness of a country into macroeconomic and microeconomic competiveness (figure 3 for ranking).[18] After briefly reporting the overall ranking, I will analyze Denmark's macroeconomic competiveness. I conclude the section by using the Porter's diamond framework to access the microeconomic competiveness of the Danish economy.[19] The assessment is both based on the ranking by the ISC as well as reports on the Danish economy.

For overall competiveness, Denmark is ranked 9 by the ISC in 2015, sliding back from being number 1 in 2008. Same picture repeats itself in the World Economic Forum's (WEF) Competiveness Index where Denmark was number 3 in 2008/2009, but now is number 12[20] Hence, the overall competiveness is strong though the slipping trend is worrying.

3.1 The macroeconomic competiveness

The Danish economy has grown significantly since the 1960's latest by 1.6% in 2016 which makes Denmark the 16th highest richest country in the world (Figure 1). The macroeconomic conditions are very strong in Denmark (Figure 3). When it comes to macroeconomic stability, Denmark has a triple A rating by all big credit agencies. That is due to the low debt at 39% of BNP (EU average is 83.5% of GDP), stable budgets and low unemployment at around 6%.[21] [22] This year, Denmark also paid its last foreign currency loan and now has no more foreign-denominated debt.[23] Denmark has been considered a safe-haven along Switzerland through the Euro crisis. The Danish Central Bank has fought fiercely to maintain the peg to the EURO responding to the big inflow of capital by printing and selling DKK as well as they introduced negative deposit rates to the lowest point in the world along Switzerland at negative 0.75 in 2015.[24] Moreover, its political system is stable with effective public institutions and strong rule of law (Figure 3)

When it comes to the final macro parameter of human development, Denmark scores high in many ratings. Though the life expectancy is lower than among its neighbors (80.8 years versus 82.3 in Sweden and 82.9 in Iceland), Denmark ranks 5 in the Human Development Index,[25] 3 in the Social Progress Index,[26] and was number 1 in the Happiness Index in 2013, 2014 and 2016.[27] These rankings reflects the quality of life with high social security, generous unemployment benefits, high social trust, little crime and low inequality. Moreover, Danes are helped in managing their work/life balance with one year of paid maternal leave which can be split between the husband and the wife, a 37-work hour week, 5 weeks of paid vacation for all per year, as well as free healthcare, childcare and education.[28]

3.2 The microeconomic competiveness

Turning to the microeconomics, Denmark is ranked 13 by the IFC in 2015 (figure 3). That is an improvement from its rank as number 18 in 2012 but a deterioration from its rank as third in 2008.[29] However, in the ease of doing business index by the World Bank, Denmark is still ranked third. [30]

In the sub-segment of company operations and strategy Denmark ranks 9 reflecting its competitive companies that are well-managed and internationalized. Yet 50% of exports are from only 100 firms suggesting that SME's could be exporting more.[3132] In regards to the national business environment, Denmark ranks 14 overall. This can be split into Michael Porter's Diamond framework with the four elements, we now turn to. For an overall assessment, please see figure 4.

Factors

One strength of the Danish factor conditions also essential for the wind cluster is the skilled work force ranked 6 in higher education and training by WEF in 2016.[33] Furthermore the labor participation is high with 80% of 16-64-year-old enrolled in the labor force, 82% for men, 77% for women.[34] Yet, the average Danish worker works much less per year than the OECD average though it is compensated through higher productivity which I will touch upon in the next section.[35] Furthermore, the infrastructure is strong, as well as its research institutions particularly within wind energy.[36]

Still, Denmark could be better commercializing its publicly funded research which is also the case for the wind cluster.[37] Likewise, more scientists and engineers are needed. As the Danish students receive free education and support from the state while studying, very few think of future employment and income when they decide what to study, compared to Sweden, Germany and the UK.[38] The lack of scientist and engineers is especially important for R&D heavy industries such as the wind industry.

Of significant challenges, many SME's lack access to finance and venture capital remains a challenge for Denmark ranked 39 and 41 by the ISC in these two categories.[39] The lack of venture capital was also stressed significantly by BCG in its yearly report on the Nordic countries. [40] [41] Moreover, the regulatory burden is a significant disadvantage according to the WEF. Finally, Denmark also faces a problem integrating immigrants into the workforce.[42] To run its generous welfare state, Denmark needs a labor market participation of around 80%, but the percent of immigrants within the labor market is significantly lower than for ethnic Danes.[43] Where 80% of Danish men were participating in the workforce in 2013, only 59% of non-western men participated. For women, it was 75% versus 49% in 2013. Though the numbers look better for the younger generation, this integration challenge needs to be solved in the future.[44] BCG estimates that Denmark will need 200.000 more workers to maintain its current dependency ratio so Denmark needs to learn accommodating this challenge.[45]

Context for firm strategy and rivalry

Within the business context, Denmark's highly efficient labor market is crucial. The labor market is often called the flexicurity model combining flexibility in firing and hiring with security in form of unemployment benefits of to 90% of the prior salary. The third element is an active labor market policy to offer unemployed people guidance, skills upgrade etc. resulting in Denmark having the second lowest percent of long-term unemployed in OECD after Sweden.[46] The flexicurity model is

possible due to a long-standing cooperative tradition dating back from 1899 called the Danish Model where the unions and The Confederation of Danish Employers (DA) negotiate collective agreements without government interference. This works because 70% of the workforce are union members and 24,000 companies are members of DA. The result is a very stable labor market historically well-equipped to balance the interests of companies and employees.[47] [48] Though wages are high, Denmark is very productive compared to other OECD countries (figure 5). Productivity has increased on 1.5% per year between 2009-2015, more than most peers.[49] Productivity is particularly high in the agricultural and industrial sectors such as wind.[50] Another strength is the regulatory quality and stability - particularly within green technology apart from the last few years which I will comment on later.

However, there are also challenges for the firm context. Foreign actors face significant barriers to entry in service sectors and the productivity is low.[51] [52] Moreover, the public sector is large and employs 30% of the workforce. Some argues that it crowds out the private sector, commit investment towards backward-looking entitlements over the future, and hurts productivity, while others argue it is a natural result of the welfare state which is a key factor in Denmark's success.[53] [54] There are also significant shortfalls. The regulatory burden is big and the total tax burden stands at 47% of GDP, highest in OECD.[55] This is due to high taxes on income, capital and environmentally damaging things such as owning cars - though corporate taxes are below the OECD average at 22%. This hurts the incentive to work and invest according to the ISC. When it comes to investment, the public investment in R&D is at 1% of GDP only surpassed by South Korea in OECD. On the other hand, private investment in R&D is 1.86% of BNP, only #8 in OECD and below Sweden and Finland with around 2%.[56] Moreover, inward FDI and technology transfer has decreased since 2007 where it topped at 2.26% of GDP though it has recovered some of the gap since.[57] [58] FDI is necessary as Denmark's large companies mostly invest abroad manifested in Denmark's big FDI deficit. [59]

Yet, the biggest problem is the lack of new growth companies. Denmark has not managed to produce any unicorns (technology starts-ups valued at more than 1 billion USD) compared to six in Sweden and two in Finland. Even worse, no company founded after 2000 have managed to reach 1000 employees.[60] One reason is a lack of entrepreneurial spirit, though that has changed the last few years.[61] Another reasons is that the growth of SME's are restricted by bad access to finance and lack of VC funding where Denmark trails Finland and Sweden.[62] Without that, it impossible for them to grow to

a critical scale and compete in international markets where the competition also forces them to become more productive.[63] [64] This is critical to address because the large companies only employ 15% of the workforce, mostly invest abroad, and furthermore cannot be expected to be continuously successful - though 65% of Denmark's large companies have been around since before 1964.[65]

Demand

Denmark benefits from high standards, especially environment standards, which forces the companies to produce advanced and good products. One example is within the wind industry, where the government early introduced a certification system back in 1991 and later an approval office for turbines in 2004 called EGV.[66] The ISC is a little lukewarm when it comes to buyer sophistication ranking Denmark 33. It seems a little odd as Denmark is ranked #9 by the WEF and #20 in complexity by the Atlas of Economic of Complexity which does not take Denmark's small size into account.[67] The buyer sophistication is related to the cluster development and the factor conditions in the sense, that leading companies such as Vestas and Siemens Wind Power within the wind industry, or Novo Nordisk within the life science, sets high requirements for their suppliers and the people they want to hire. This sophisticated demand then forces suppliers to perform uppermost as well as it has spill-over into universities and research.

Clusters

When it comes to cluster development, Denmark has strong clusters within life sciences, cleantech (wind industry among more), ICT technology (hearing aid), transport (shipping, logistics), the food sector (meat, dairy, enzymes) and design (architecture, industrial design, furniture) (see Figure 2). In fact, BCG calculated that the Danish MNC's have outperformed global MNC's in total shareholder return for the past 20, 10, 5 and 2 years from 1994 to 2014, on average.[68] Many of these are engaged with fairly complex products resulting in a #8 rank in the Global Innovation Index and in patents/capita well above the OECD average, for example above Germany[69] [70] Apart from these strong established clusters, Denmark is constrained by lack of scale and thus quantity of suppliers.

Summing up, the microeconomic of competiveness is strong in Denmark due to the workforce, labor market, high standards and sophisticated clusters. Yet, there are challenges when it comes to creating new MNC's when SME's are constrained by poor access to finance. Moreover, the regulatory as well the tax burden is high and the FDI has decreased the last 10 years (Figure 4 for summary).

4 The Danish Wind Cluster

I begin with the history of the cluster focused on the political support that has helped develop the cluster. I then map the cluster actors with attention towards their contribution and skills. This is essential because the cluster has emerged due to the holistic efforts of these players. The map will act as the fundament to the final analysis of the cluster's performance using Porter's diamond framework.

4.1 History and role in Denmark

In 1973, Denmark was hit by the global energy crisis. At that time, 90% of the energy consumption was covered by oil from the Middle East. The increased oil price put stress on Denmark. To limit the import of oil, efforts such as car-free Sundays, less light on the streets and decreased speed limits were introduced. However, the crisis resulted in two significant actions. Denmark started to explore the North Sea for oil and gas, which really paid off in the 1980's. But it also took a bet on renewable energy and particularly wind. Due to Denmark's geography surrounded by water and particularly the exposure to wind along Jutland's long coastline, makes Denmark a great place for wind energy (see figure 7). Both efforts were rewarded when Denmark in 1997 became an energy exporter.[71]

When it comes to wind, the first mill was connected to the grid in the 1970's. Also in the 70's, the test and certification center for turbines Risø National Laboratory opened funded by the state and operated by The Danish Technical University, (DTU). Initially the wind mills where owned by small communities lead by environmentalist who wanted to create clean energy for local needs. The government early subsidized the purchased equipment by 30%, but later implemented a feed-in-tariff. The owners of the turbines were guaranteed access to the grid and that the utilities would buy its energy at a fixed price.[72] From 1977 to 2000, 8000 wind mills were installed onshore in Denmark, and when land scarcity became a problem, developers installed the turbines offshore starting in 1991 and later with the largest offshore farm in 2002 at Horns Rev.[73] Apart from the subsidies on price, the government also supported the cluster by committing public money to R&D.[74]

Later in the 0's, the liberalization of the energy market led to the side effect of creating the modern DONG Energy. It later transformed from being only a utility company to also become the leading offshore developer in the world. Another element that helped Denmark develop wind to this level has been the Nord Pool Spot market which Denmark entered in 1999 with current members Finland, Sweden, Norway, the Baltics, and Germany. In periods with surplus electricity from wind, Denmark can sell it to its neighbors and in periods of deficit, they can buy energy (See figure 7).

[75] Yet, another key element in this process of introducing wind into the grid has been to use district heating and biomass to cover the energy consumption when the wind is not blowing.

Apart from a change in the tariff system in 2004 by the government of Anders Fogh Rasmussen (later Secretary General of NATO) which effectively stopped adding wind capacity up until 2008, there has been continuous political support to wind energy.[76] Wind's role in the green transformation has been incorporated in the government's energy plans all the way back from the 1980's. When the EU started its ambitious climate change agenda in the 0's, Denmark was already positioned to take commercial advantage of that. In 2012, Denmark became even more ambitious with a plan of cutting CO2 emissions 34% by 2020 compared to 1990. Moreover, targets were set of reaching 100% renewable electricity in 2035, using no coal after 2030 and make renewable energy become 35% of total energy consumption by 2030. Wind was set to play a key role in this plan through new onshore and offshore wind-farms[77] However on the back side, companies and consumers have for long paid a higher-price for electricity due to the feed-in-tariff that ensured support for wind.[78]

Today, Denmark has the most renewable energy per capita in the world, excluding hydro power, according to The Global Renewable Status Report. Wind plays a crucial role covering 42% of electricity consumption on average a year, and around 7.5% of total energy consumption.[79] [80] Furthermore, onshore wind is now the cheapest energy source in Denmark and the price of offshore wind continues to decrease significantly each year which I will elaborate on later.[81]

4.2 Cluster map

In order to grasp the cluster's success, it is essential to understand the players in the cluster and their contribution. The whole value-chain is present in Denmark for both onshore and offshore wind, which is significant for a product that has 8000 components (figure 9 for value-chain). In reality the onshore and offshore industries differ as the former is mature and the latter is still in development.[82] But as most key players operate in both industries, I will treat it as a whole cluster. Figure 10 shows the cluster map and its key actors within each category.

Key players: Turbine manufacturers and developers

The true anchor of the cluster is the turbine manufacturers Vestas Wind Systems and Siemens Wind Power (Now merged with Gamesa to become Siemens-Gamesa). In 2011 The Danish Association estimated, that 1/3 of the world's turbines originates from Denmark.[83] Both companies are top players

in onshore and offshore wind. Starting with onshore wind, Vestas is the leading global manufacturer and had the highest market share in 2016 with 16.5%, whereas Siemens was number 5. Yet with the merger with Spanish Gamesa they are set to enter the top 3[84] [85]

Within offshore wind, it was estimated in 2014 that Siemens and Vestas (MHI-Vestas which is Vestas offshore JV with Mitsubishi) has installed 90% of all offshore capacity in the world. [86] Siemens in particularly is leading in offshore wind, but MHI-Vestas is also present.[87] Finally, as the onshore industry matures, Vestas has grown its services business significantly through several acquisitions the last few years. This has been a logical move as margins are higher at around 17% for services, versus 7% for turbines.[88] Vestas expects the service market to grow 9% per year the next ten years.[89]

These two players have had enormous influence in the cluster not only for their sourcing from local suppliers, but also because they are leading in R&D through their facilities in Denmark. For example, Vestas has the largest mill in the world at 8 GW with a diameter of 164 meters. As size is important to lower the levelized cost of energy (LCOE), a metric to measure the cost of energy, this is a sign of their leading edge. Both are also heavily involved in the test centers, both in cooperation with universities but also through their own such as Siemens' test center for blades in Aalborg (largest in world) and in Brande for turbines.[90] The leading R&D facilities is also the reason why turbine manufacturers such as GE (# 2 in the world 2016), Goldwind (#3), Envision (#9), Suzlon (#15), and Gamesa (#4) (closed down 2010 but now merged Siemens) are present in Denmark to track or use the R&D facilities.[91]

Other key actors are the developers who develops and operates the offshore farms. Even though German E.ON and Swedish Vattenfall also are present in the cluster and have played an important role, the key actor is Danish DONG Energy. The Danish company has emerged from a utility to an energy company with a growing edge in offshore development. In 2016, DONG's IPO was the largest in Europe mainly due to its wind business.[92] DONG estimates that they have built more than 25% of windfarms in the world.[93] Particularly, DONG has been innovative with partnerships with pension funds to secure funding for its wind farms. Lately, DONG has made the first bid in the world to develop and operate an offshore windfarm in Germany without any state subsidy set to open in 2024.[94]

Research institutions and test centers

The cluster's edge in R&D has been developed through the collective efforts of turbine manufacturers along research institutions. Four Danish universities work systematically with wind and they cooperate

along two public technical research centers called GTS within the Danish Research Consortium for Wind Energy by, conduct research, share ideas, arrange conferences etc.[95] The leading university in wind is the Danish Technical University (DTU) and its department DTU Wind Energy with 240 employees. It has the world's only master in wind energy, but it also operates and collects data from three keys test centers. One is the National Laboratory at Risø which has approved and tested turbines since the 1970's. The other is Østerild Testcenter, which can test full-size turbines in real life conditions. It is the only place in the world where mills up to 250 meters can be tested. This is ideal for offshore testing where the size increase every year. They have 7 spots, where Vestas have bought three, Siemens two, and Envision and GE Alstom one.[96] The last is Høvsøre which is also a test place for large mills. The final key tester center is Lindøe Offshore Renewable Center (LROC) which is financed by Vestas, Siemens, DONG, Vattenfall, and University of Southern Denmark among others proving the strong collective commitment in the cluster.[97]

Government institutions

I have already pointed out how important the role of the Danish government have been in the development of the cluster. Key ministries are involved in developing and promoting the cluster. The Climate and Energy Ministry is responsible for Denmark's climate plans, and the Ministry of Foreign Affairs promotes wind energy in international summits, through its trade council department and business delegations. The government have just launched a strategy to double Danish exports of energy towards 2030 where wind plays a key role.[98] A few more actors should be mentioned. The municipalities have ordered and owns many onshore mills. The Danish Energy Agency has ensured safe and optimal mills through the Approval Secretary for Wind EGV, as well as they have facilitated the support schemes.[99] Finally, the transmission system operator, Energinet.dk, has ensured the integration of wind into the grid while still maintaining reliable electricity.

Institutions for Collaboration (IFC's)

Collaboration between different entities has been essential for the cluster. Hence, there are also several important institutions for collaboration (IFC's), who facilitate these relationships and networks, set standards, help exports etc. They improve the business environment, productivity, and lower transactions costs to help develop the cluster. From a commercial perspective, a key actor is the Danish Wind Association (DWIA) which facilitates networks and lobby for its 240 members across the whole value chain. Another actor is the Danish Wind Exports Association owned by DWIA which helps its 300 members to export their solutions and products. A new IFC is MissionInnovation led by

the Confederation of Danish Industry with participation from key industry players committed to ensure continued investment in the green energy cluster in Denmark.[100]

For collaboration between business and research institutions Megavind was founded in 2006 as a strategic partnership with members such as Vestas, Siemens, DONG, universities, and government agencies as observers. It works for ensuring primary production, knowledge and testing facilities, and has helped push forward the establishment of Østerild Testcenter. Megavind is committed to maintain Denmark as the leading wind hub. Another recent example is InnoVind where DTU along Vestas and Vattenfall plan to use space data to locate the optimal wind spots and help increase Danish exports.[101] Also, offshoreenergy.dk is a nonprofit organization with 230 members across offshore oil, gas and renewables. They aim to "contribute to the development and growth of the cluster members through working with innovation, cost effectiveness, knowledge sharing and internationalization."[102] Finally, when it comes to public-private partnerships, State of Green is funded by the Danish government, Confederation of Danish Industry, DWIA and the Ministry for Environment. Its mission is to brand and promote Danish green energy solutions especially wind.[103] Hence it is safely to say that IFC's both within onshore and offshore are essential in the cluster.

Supporting players: suppliers and related industries

As mentioned earlier more than 500 suppliers are present within the cluster. These expands over the whole value-chain from lightning test & blades to installment and manufacturing of foundations (Figure 9 for value-chain). Many of them are leading players within their segments. A related industry is the shipping industry. The port of Esbjerg in western Denmark for example, is the world's leader in offshore shipment.[104] Another is the general cleantech cluster consisting of energy efficiency solutions, wind and other clean energies. The government's new strategy to double export of energy includes both clusters of wind and cleantech proving the spill-overs [105] Finally, the pension sector has played an important role in offshore farms due to their large investment in these. Moreover, a niche within finance for wind has developed with Copenhagen Infrastructure Partners. [106] [107]

4.3 Cluster performance

The Danish wind cluster is overall a mature cluster. This is reflected in the relatively stable economic performance of over the last 10 years. The total revenue of the cluster was 11.9 billion EUR in 2015, and it has grown every year since 2010 with an average growth of 3.3%, though 2008 remains the top with a revenue of 13.8 billion EUR. From the revenue, 55-60% are exports. Exports topped in 2008

with 9.5 billion EUR, and has then been stable around 6.5-7 billion EUR since 2010. Moreover, the wind cluster now employees 30,000 people - 31,000 if you include the energy companies – which is less than the 35,000 in 2008 but an increase since 2010 (Figure 8 for exports and employees).[108]

Factors

From a capability perspective, the Danish wind cluster has become the leading wind cluster in the world due to key elements such as R&D/testing facilities, research institutions and the skilled labor.[109] First, Denmark has the best R&D facilities in the world according to industry experts.[110] This especially include the test centers starting with Risø back in the 70's, but also Lindøe Offshore Renewable Center and Østerild Testcenter which I mentioned under the cluster map. This is also the reason behind the fact that most key turbine players are present in Denmark. Also, a survey in 2011, showed that 25% of the industry players are foreign owned emphasizing the foreign interest in the cluster.[111] Second, four Danish universities have expertise in wind, and the world's first master in wind has been offered at the DTU since 2002.[112] Last, the workforce is highly educated. In 2011, the workforce within the sector was split between production (51%), testing and development of new products (11%), process and quality assurance (10%), sales and marketing (10%) and other (7%). Of the 30,000-employed people, they are only 11% non-skilled workers, 14% are academic and 41% have a higher education, compared with 25% in the industry in general. This also underlines how R&D-heavy the sector is.[113] [114] Still some challenges remain in finding enough mechanical and technical engineers, as well as include suppliers in research projects. Studies show that only 6% of industrial wind companies have been engaged in research projects more than once. That I will address in the later section on threats[115]

The context for firm strategy and rivalry

The context for rivalry is strong because many leading turbine manufacturers are present in Denmark through manufacturing and/or R&D activities. Yet, as Denmark is a small part of the global wind market, there is more emphasis on collaboration to help improve the cluster, than fierce competition among within the cluster. Yet, there has definitely been rivalry between the two main turbine manufacturers Vestas and Siemens, and between DONG, Vattenfall and E.On. Moreover, and as pointed out earlier, the investment climate has been stable for many years with early subsidies, secured assess to the grid and a price guarantees for developers which has helped facilitate the development of wind in Denmark. However, there has been less investment in the sector the last few years especially from public resources, which is why some players has launched MissionInnovation, mentioned under

IFCs. Still, the wind industry is a global and the leading turbine manufacturers compete globally. Hence, the local context is decreasingly important.

Demand and supporting industries

As stressed in the history section, the sophisticated demand has played a key role in the development of the cluster. The government has set ambitious plans to use wind energy, and the leading turbine manufacturers has pushed suppliers to perform. Later when local support for onshore mills decreased due to the scarcity of small Denmark, there was pressure to develop offshore farms. This has led into a Danish leadership position within offshore wind.[116] From the cluster map, we saw the importance of the + 500 suppliers present in all segments of the value chain. Other clusters such as shipping which has helped developed offshore capabilities, and the pension sector have also played key roles.

5 The future of the Danish Wind Cluster

I will end the paper by first outlining some key industry trends and discuss how they affect the Danish wind cluster. I then discuss the cluster's internal issues, before I end the paper by offering some recommendations on how the cluster can remain viable in the future.

5.1 External trends and issues

TABLE 1	TRENDS	LEVEL OF THREAT
1	Continuous growth but outside Denmark and the EU	Strong threat
2	New clusters are emerging in Hamburg, China & the US	Medium threat
3	Consolidation (Siemens-Gamesa, GE Alstom etc.)	Some threat
4	Focus to lower the levelized cost of energy (LCOE)	Opportunity
5	Continuous growth of offshore wind	Opportunity

The first trend is the rapid growth of the wind energy market which by one estimate will be 8% per year towards 2035.[117] In fact, more than half of the world's total wind capacity has been installed within the last five years, according to The Renewable Global Status Report.[118] However, most of this growth takes place outside of Europe in especially China and the US (figure 11). Asia has been the largest market for the eighth consecutive years, accounting for 53% of added capacity in 2015, followed by the European Union (20.1%) and North America (16%). [119] Whereas Vestas is really strong in US, danish turbine manufacturers still haven't succeeded in capturing significant shares in China where domestic manufacturers dominate. Moreover, the Danish suppliers are weakly present in emerging markets further complicated by an increasing demand for local content limiting the possibilities for Danish suppliers.[120]

Second, new clusters are emerging. The main competitor is Hamburg in Germany. It has turbine manufacturers, test facilities and as well as a large and growing home market. Still, it trails the research capabilities and supplier network of Denmark. Given the short distance to Denmark, it is unlikely that Siemens (offshore) and Vestas will move there. When it comes to offshore wind, which I will touch upon later, Denmark also has the leading offshore shipment port in Esbjerg. Other potential threats are in China and in the US. Though the Chinese government has significant power to enhance facilities quickly, as well as GE in the US along leading universities has the potential to challenge Denmark, they both need to upgrade their R&D and testing facilities as well as develop the whole value-chain.[121]

The third trend is the ongoing consolidation in the industry. Though the industry is already quite consolidated where a 69% market share in 2015 was held by the top 10 producers, there is still consolidation exemplified by the Siemens-Gamesa merger. As especially the onshore industry is maturing and competition increases, turbine manufacturers have also moved into other segments of the value chain. The second largest turbine manufacturer GE acquired the leading blade manufacturer Danish LM Wind, while Vestas has enhanced its service business through acquisitions of UpWind Solutions and Availon. [122] It is not clear if the ongoing M&A will result in less jobs in the Danish cluster. [123] Siemens-Gamesa, for example, will maintain its offshore activities in Denmark.[124] Moreover there is also opportunities for Danish players particularly among suppliers to consolidate.

Fourth, there is a continuous effort to lower the levelized cost of energy (LCOE) and make wind a competitive source of energy without subsidies. The price of wind has decreased 80% the last 20 years on global scale and is now the cheapest new energy source in many European countries such as Denmark, Germany and the UK when taking carbon price into account. Lazard has calculated that onshore wind is fully competitive with coal and gas in many countries.[125] Five key ways to further lower LCOE are by building larger mills, optimizing transmission, developing better foundations, lower production cost, and improve service and maintenance.[126] In almost all of these instances the Danish cluster seems well-equipped. Østerild Testcenter can test the largest mills in the world, Siemens & Vestas are leading in developing larger mills, it has leading foundation manufacturers and has been successful transmitting the energy into the grid. A backside on size though, is that as the mills get bigger, transportation gets costlier.[127] When most growth takes place outside of EU, this can be problematic for the cluster. Also, when it comes to total production cost, Danish suppliers can be

better in developing "good enough" products, more than the best products, to help lower the production cost for turbine manufacturers.[128] The high modularity among suppliers limits the ability to think holistically across components.[129]

The final trend is the increasing offshore segment which according to Bloomberg Finance (see Figure 12) is expected to double 24 times from 2012 to 2032 from its current share of 3% of total installment.[130] The big advantage of offshore is the stronger wind at sea, that few citizens live nearby, and that many big large cities are near water and will need more and more energy.[131] As pointed out earlier the onshore and offshore industries are in different phases. Whereas the onshore industry is maturing, the offshore is still in the exploration phase and have not developed the same industry standards yet.[132] [133]This is a major advantage for the Danish cluster because it is positioned to ride this new s-curve. Despite its size, Denmark was the third largest market for total installed offshore in the world in 2015,[134] Also it has two of the leading turbine manufacturers and distinct capabilities such as Esbjerg Port.

Moreover, the European offshore home market is growing more than onshore making the task of exporting larger turbines less challenging. Offshore is expected to grow from delivering 1% of electricity in the EU in 2014 to 9% in 2030.[135] Even though offshore is more expensive than onshore wind and thus not competitive yet, DONG has as mentioned earlier submitted an offer to develop a German windfarm opening in 2024 without subsidies. Likewise, cost have decreased 46% the last five years and are estimated to decrease further 26% by 2035. Yet, there are also new players moving into the offshore industry such as Norwegian Statoil, Royal Dutch Shell and Italian ENI to compete with DONG. [136] This does not limit the opportunities for turbine manufacturers and suppliers though.

5.2 Internal issues

I have already touched upon a few challenges for the Danish wind cluster, such as the lack of engineers which is a serious challenge if Denmark needs to maintain its lead in R&D. I want to emphasize six more challenges shown below in table 2.

TABLE 2	ISSUES	LEVEL
1	Shortage of certain engineers	Serious
2	High dependency of turbine manufacturers	Medium
3	Political climate	Medium
4	Lack of supplier engagement in research	Serious
5	Modularity among suppliers	Serious
6	Lack of internalization among suppliers	Serious

Secondly, the cluster is obviously dependent on the success of the turbine manufacturers Vestas and the new Siemens-Gamesa's offshore business. While Vestas is the industry leader and Siemens for offshore, there are more intense competition from low-cost Asian producers well-positioned in growth market as well as GE, which is betting big on its new renewables department. GE is already highly invested in machine learning, big data and the internet of things across its business. GE might get a lead using these for their turbines to maximize the output per wind farm through better use of software, adjusted speed, aerodynamics and by optimizing maintenance so that turbines can live up to 3 more years.[137] Still, Vestas and Siemens are also at the front-line of innovation.

Third on political stability, the current right-wing government introduced a "green realism" approach upon gaining power in 2015 resulting in less public funding to research. After massive protests from firms, universities and industry associations, the government lately changed its position to a more supporting line especially through its plan to increase energy exports by 100% towards 2030.[138] Still, there is not enough private and public R&D as the before mentioned MissionInnovation reflects.

Fourth, suppliers are not engaged in research and development which according to Megavind (the strategic partnership of leading players in cluster) is the major missing piece in the cluster. Only 16% have participated in research projects and 6% more than once.[139] As SME's they are often not geared towards participating in large scale long-term research projects or to hire PHD's. Moreover, there is limited public funding for research focused on maintenance and services which the small suppliers are more focused on. That is critical considering that operation and maintenance cost are half of the total life-time cost of a windmill.[140]

Fifth, the focus on cost arriving from intense competition and attempts to reach competitive energy prices, puts new demands on suppliers. Where turbine manufacturers before demanded flexibility and innovation, they now demand quick delivery and efficiency. The total focus on cost also requires suppliers to work more closely together across components to find the cheapest solutions. This will either require more formalized networks or consolidation by some suppliers across components.[141]

Finally, very few suppliers are present internationally. As the industry is now global and most demand comes abroad, the suppliers need to be more engaged abroad.[142]

5.3 Recommendations

I will now provide recommendations for actions to help address the external and internal threats. I start with a few recommendations on overall Danish competitiveness that are relevant for wind. Then I move to the cluster specific recommendations starting with the government level and then move onto the cluster actors (Overview in Table 3).

General recommendations for overall competiveness

For improving the general competiveness of Denmark, it is essential to educate more scientists and engineers. While a cap on educations with high unemployment rates has already been introduced to move people over to science, it might also make sense to cap some of the social sciences though the freedom to choose one's area of study should still be the standard. Campaigns should be introduced early in elementary and high schools to promote science and open the student's eyes to its vast opportunities. Moreover, it will be essential to improve the growth opportunities for small companies. The capital income tax needs to be lowered from 42% compared to 30% as in Sweden to favor more small-cap over real estate investment for citizens. Moreover, institutional investors should be encouraged to invest much more in small-cap potentially through a public catalyst fond that then invest in funds.[143] This can help some of the small suppliers attract capital and become international.

Cluster recommendations: Government level

Turning to the cluster, the government needs to take strong action. First, a council for the wind cluster's competitiveness 2030 should be made such it has been done for the life sciences. Participants should include key players across the value chain, researchers, pension sector etc. This will help map the challenges ahead and better address deficiencies.

Second, the government should help facilitate investment private investment in R&D through tax incentives such as a 100% deduction on R&D.[144] R&D and test facilities remain the backbone of the cluster and thus needs to be in place. Third and related, continuous public investment is needed for the test facilities. Likewise, more public funding needs to be committed through the Energy Research and Development Program (EUDP) to fund research and help suppliers participate in research projects.[145]

Fourth, a national research and development program should be launched to focus on lowering LCOE. Not only for CAPEX for wind turbines, but also total production cost including suppliers as

well with efforts to lower OPEX for example by experimenting with using big data and the IoT to optimize maintenance.[146]

Firth, the government need to ensure the continuous development of offshore farms or at least ensure that the planned ones are executed on as there have lately been doubt about. It will be essential for the cluster to maintain its the edge in the young and growing offshore industry. One good example is the transmission operator Energinet.dk investigations of the potential for artificial islands in the North Sea to mass-produce wind to Denmark, the Netherlands and Germany as well as make it possible to transfer energy across countries when needed.[147]

Sixth, investment in ports and roads will be valuable to help facilitate the transport of larger mills as well as help the offshore segment of the cluster.[148]

Seventh, the government needs to favor electric cars much more. Though a recent change in the support schemes have been re-introduced for a limited time, the government needs to bet big on electric cars. The potential of wind is limited by the level of electrification. Hence introducing more electric cars will make the potential for wind energy much larger. Especially as the wind at night can be used to charge the cars. This will also help Denmark with the issue below.

Finally, Denmark needs to incessantly improve and capitalize on its knowledge of smart grid. That is the more intelligent grid needed when there is high use of weather depended source such as wind and solar where supply and demands to be balanced. If the government continuously improve the smart grid and develop world leading solutions and standards, Danish companies can export solutions and consulting services. Here the integration of electric cars and even more wind is important.

Cluster recommendations: Cluster participants

Among the cluster players, the suppliers need to be more integrated in research. The research institution and particularly the leading DTU should be better integrating small players. Moreover, successful collaborations should be published to encourage more companies to participate. Moreover, research should also focus on driving down cost of operations and maintenance, which is most relevant to the small suppliers. Universities should also partner up with smaller suppliers to facilitate and sponsor student's writing their bachelor, master thesis or Ph.D. with smaller companies.

Suppliers will need to do two things. One is to participate in international markets. Some of this can be addressed by the membership in the Danish Wind Association which should facilitate workshops, conferences and business promotion trips for the suppliers. Still, the stronger suppliers need to consolidate and buy up smaller components producers to reach more scale. This is also related to the second point of supplier's need to think more holistically in the architecture of the components, more than just the single components. This is not only required by turbine manufacturers demand for "good enough" products but also essential to lower the production cost and thus LCOE. Again, these more formalized networks could be facilitated through small groups under the Danish Wind Association.

The key industry players such as Vestas, Siemens and DONG basically needs to continue being competitive as they are the engine of the cluster. This includes being better positioned in growth markets such as China and India, investing heavily in potential storage or do M&A in that segment, being at the front in the use of big data and IoT for example through collaboration with leading universities around the world, and finally position into other more profitable segments in the value chain such as Vestas has done with services when competition increased in the turbine industry.

TABLE 3A	**GOVERNMENT ACTIONS**
GENERAL COMPETIVENESS	Wind Competitive Council analyzing the cluster's challenges towards 2030. Led by the key industry players with wide participation.
PRIVAT R&D	Introduce tax deduction scheme up to 100% of R&D to foster R&D
PUBLIC R&D	Continue committing money to public research and make it easier for suppliers to participate so it's not only for the big industry players
LCOE EFFORTS	Establish a national research and development program focused on driving down LCOE both in turbines, across value-chain and for operations and maintenance.
OFFSHORE WIND	Develop more offshore farms to ensure further cluster experience in offshore
INFRASTRUCTURE	Improve roads and ports for shipping larger turbines and to service offshore
LOCAL DEMAND	Embrace electric cars through long-term subsidies to a) lower emissions, b) ensure an increasing local market and c) maintain leadership of wind in the grid
NEW GROWTH	Capitalize on smart grid solutions and knowledge

TABLE 3B	INDUSTRY PLAYER'S ACTIONS
SUPPLIERS IN R&D	Universities to facilitate more suppliers in R&D projects Universities should make catalogue of successful collaborations Universities to sponsor more master thesis' or PH. D projects with suppliers
SUPPLIER'S EXPORT	Danish Wind Association (DWIA) and its under-organization of export should make efforts promoting suppliers abroad, create workshops and networks
MODULARITY AMONG SUPPLIERS	Modularized suppliers to consolidate or work more across components to meet turbine manufacturers' demand for less expensive solutions IFC's such as the DWIA should encourage this cooperation among its members
KEY PLAYERS' COMPETIVENESS	Developers & turbine manufacturers to focus on growth markets, explore storage, invest big data & IoT and expand to other profitable segments

Conclusion

In conclusion, the Danish wind cluster has become world leading with wind due to long term political commitment to wind energy, world leading turbine manufacturers, excellent R&D facilities, presence of the whole value-chain and strong cluster collaboration. But as the industry globalize, competition is increasing among turbine manufacturers and growth takes place outside of Europe, the cluster needs adjustment.

I have argued in this paper, that the cluster needs to maintain its R&D leadership through continuous public and private investment. The latter made possible by favorable deductions on R&D. Moreover, it is essential to upgrade the suppliers by including them in research and help them compete internationally to take advantage of the growing world market. The last might require consolidation which is why the SME's access to capital in Denmark in general needs to be improved. At last, Denmark should continue its ambitious plans for the use wind energy in the smart grid, develop offshore farms to cement its leadership in that growing industry and increase the wind energy in grid by embracing electric cars.

Exhibits

Figure 1 - Danish GDP/Capita over time

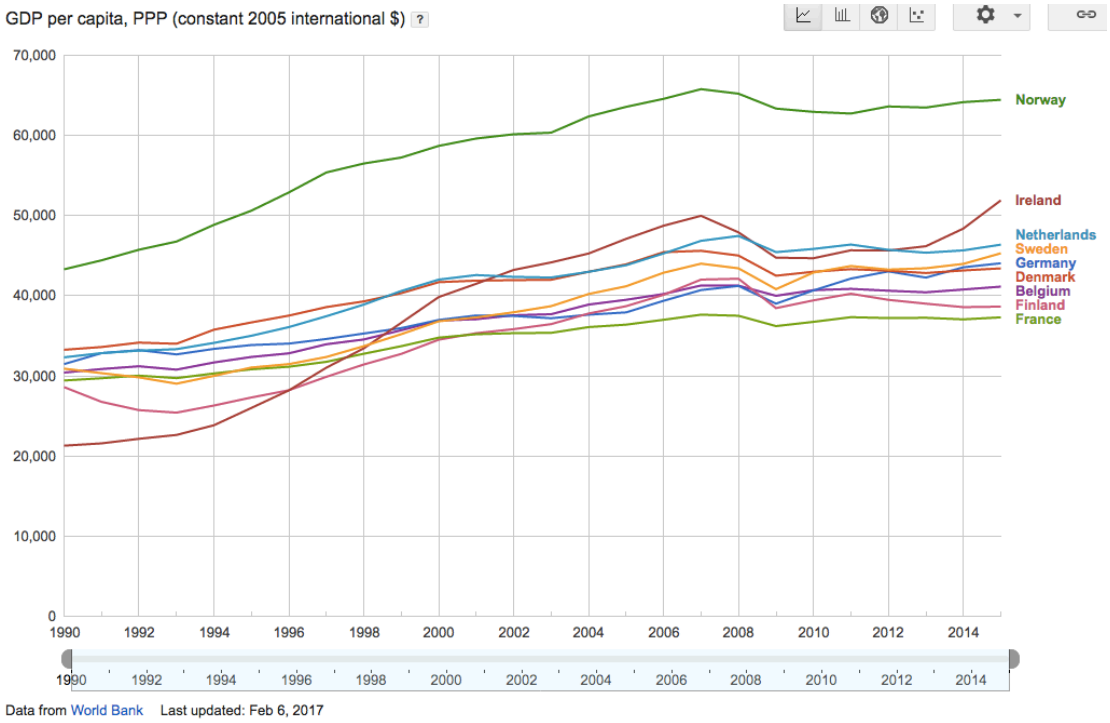


Figure 2 - Danish exports and companies[149]

Figure 3 - Institute of Strategy & Competiveness Ranking of Denmark

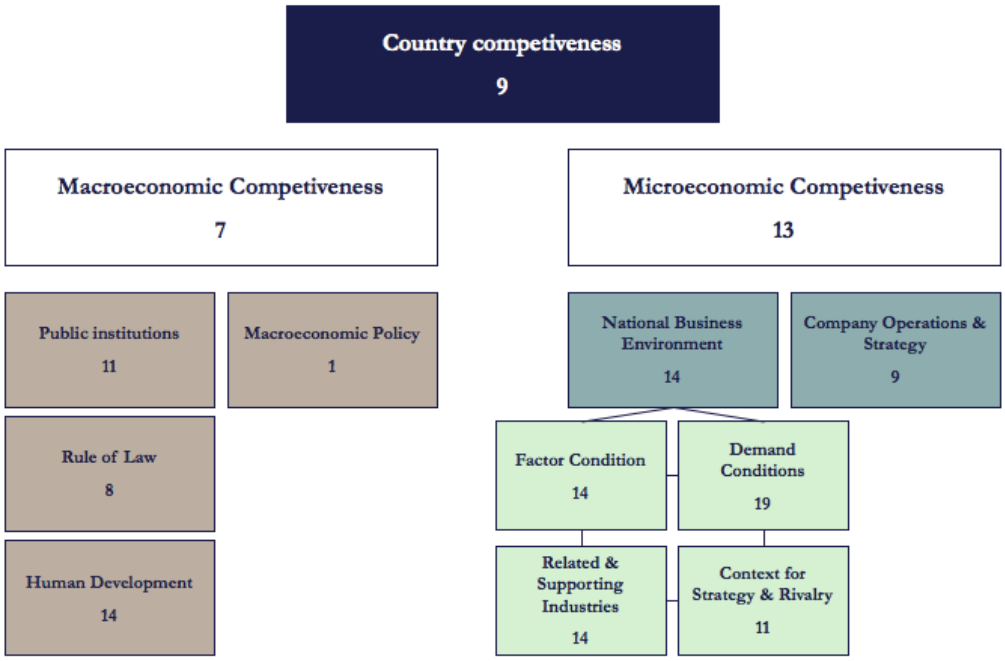


Figure 4 - The National Diamond

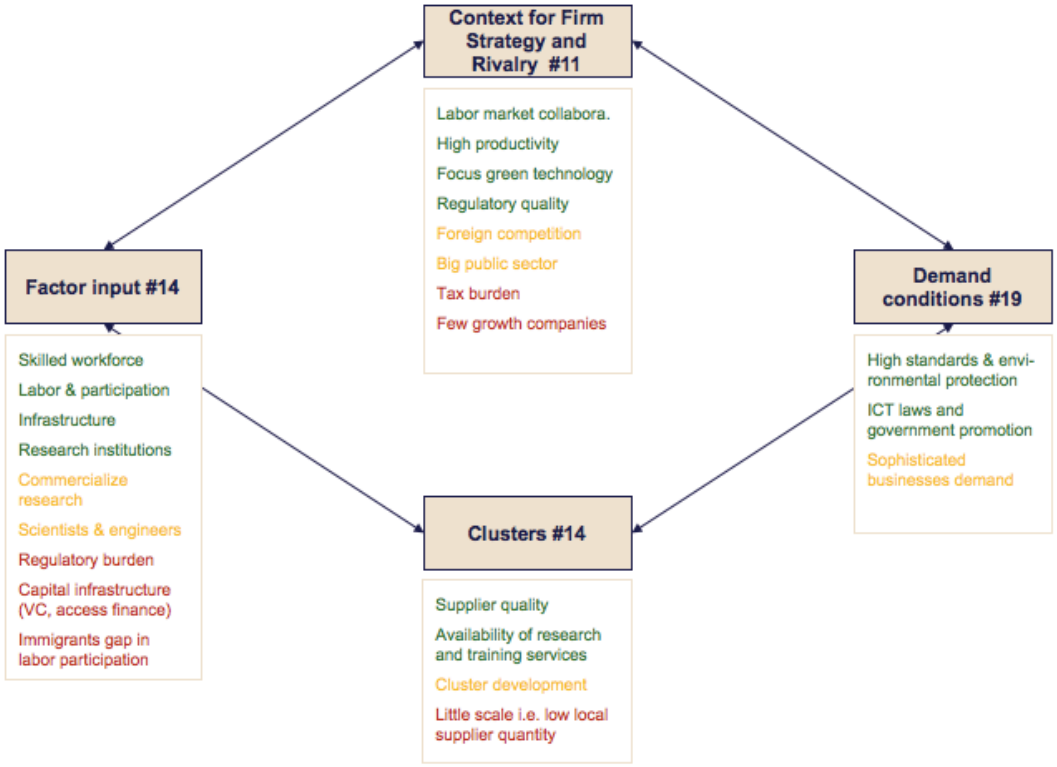


Figure 5 – Danish Productivity 2015

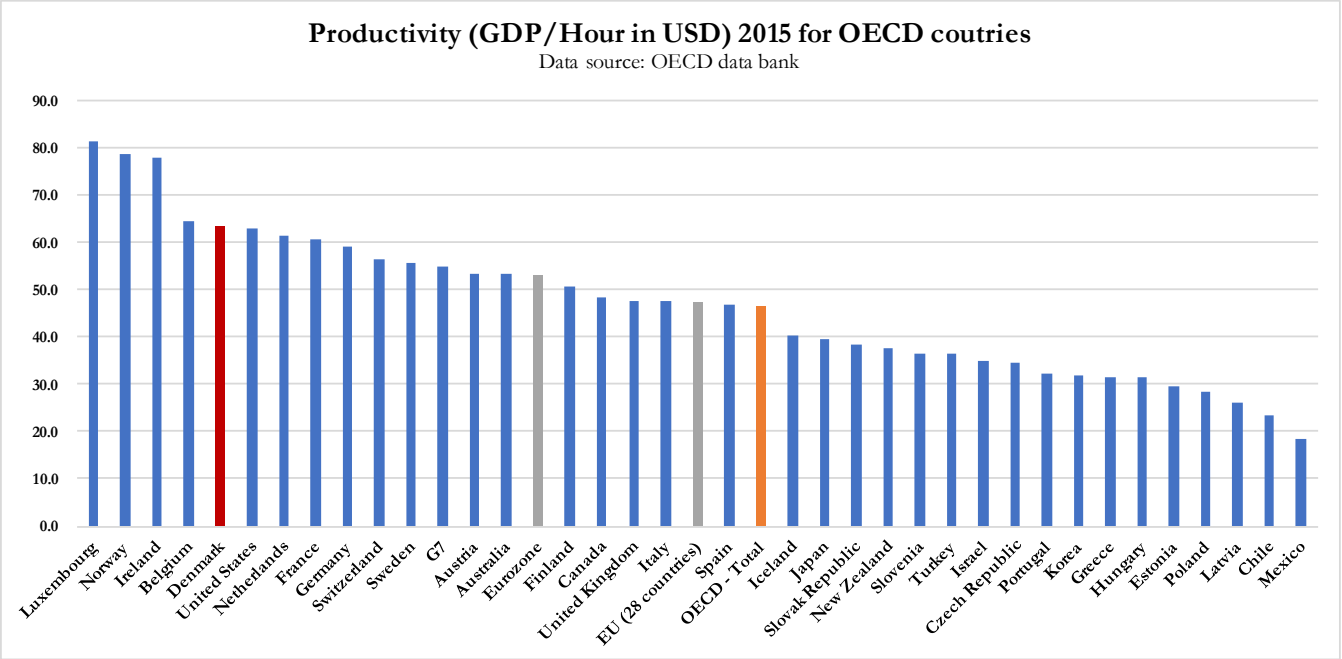
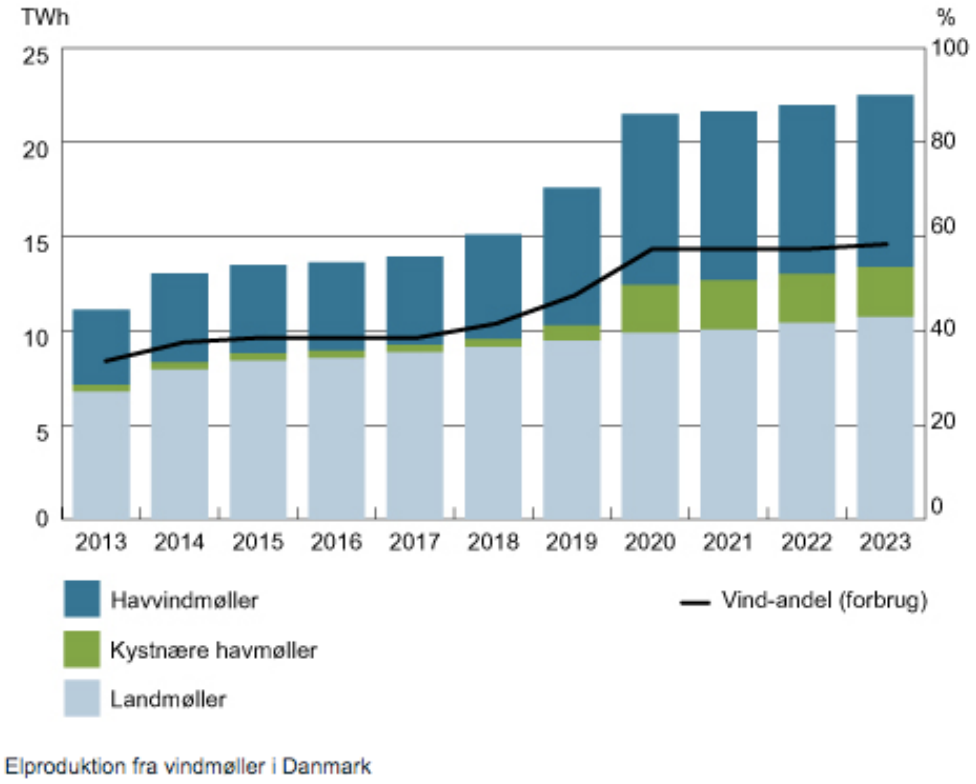


Figure 6 - Wind energy in Danish electricity consumption 2013-2023[150]



*** Havvindmøller (offshore), kystnære havvindmøller (near coast offshore), landmøller (onshore)*

Figure 7 - Danish Wind farms and the Nord Pool Spot[151]

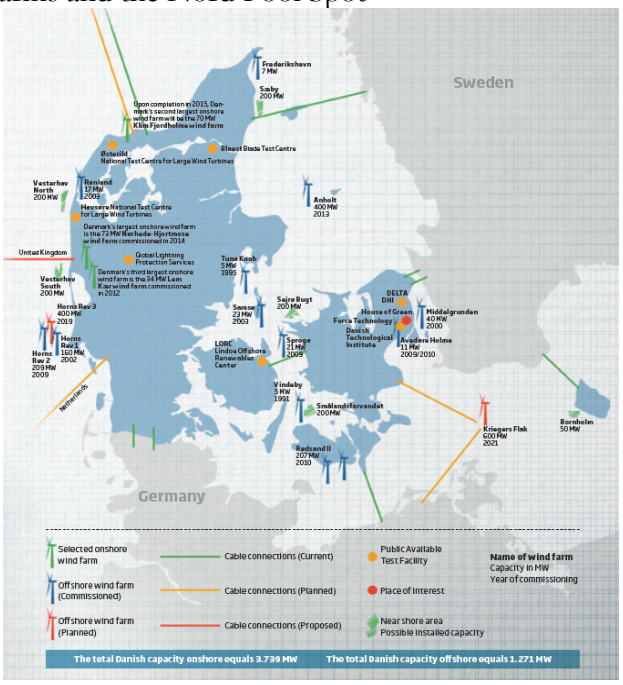


Figure 8 - Exports and total employees in the Danish Wind Cluster

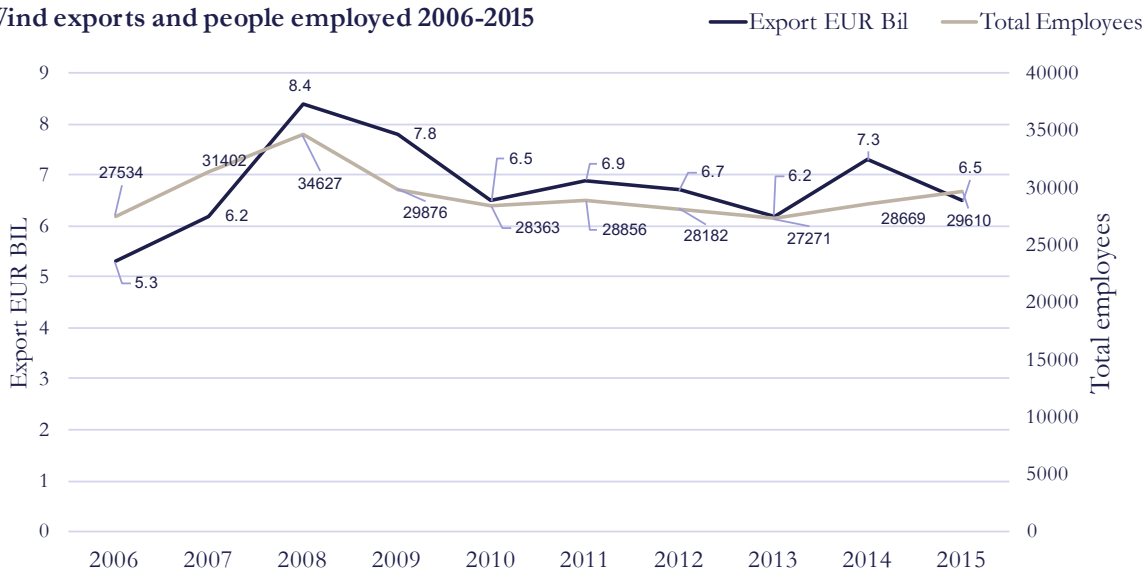


Figure 9 – The value chain[152]

Integration wind power (power companies)	Project development (developers, turbine manufacturers, energy providers, consultant)	Turbine design (manufacturers, design houses)	Components design (Suppliers, manufacturers, design houses)	Manufacturing (Manufacturers, suppliers, other suppliers)	Logistics (Shipping agents, contractors, suppliers, shipping firms, energy providers)	Construction & cable-laying (Energy providers, contractors/construction, insurance, cable layers)	Operation & maintenance (Wind turbine manufacturers, service companies, third party supplier)

Figure 10 - Cluster Map

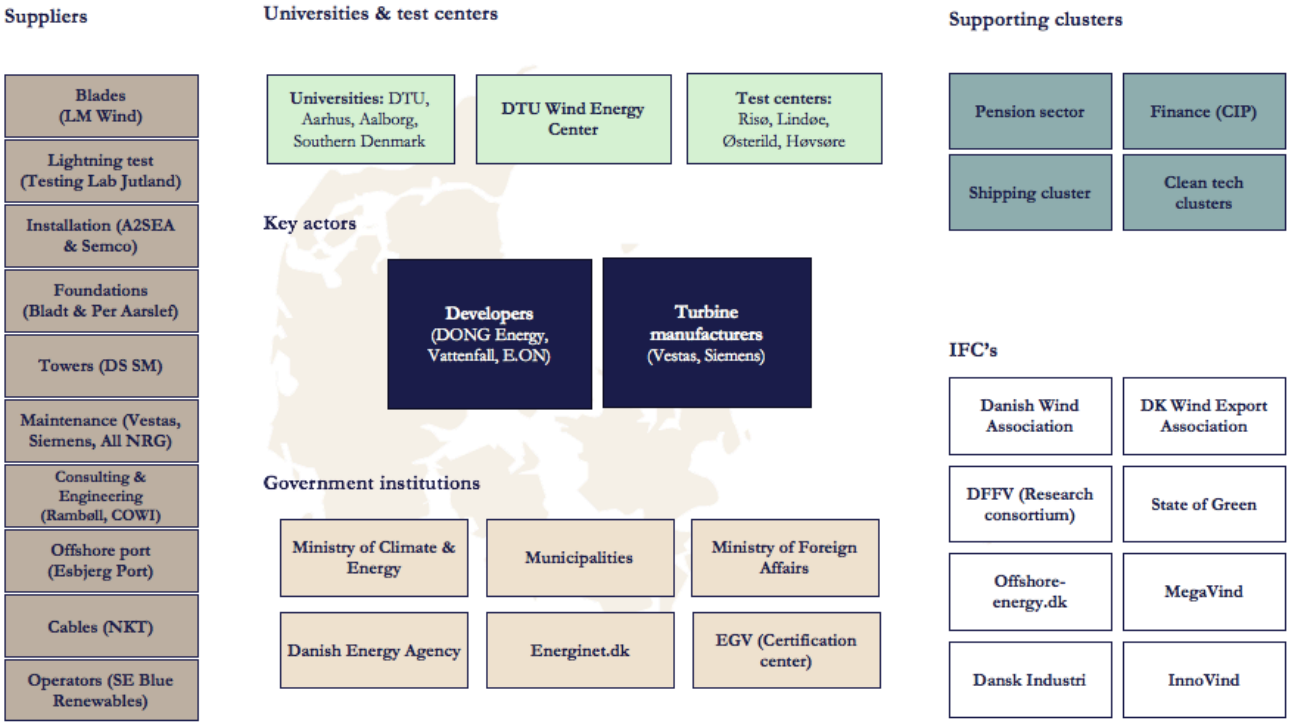
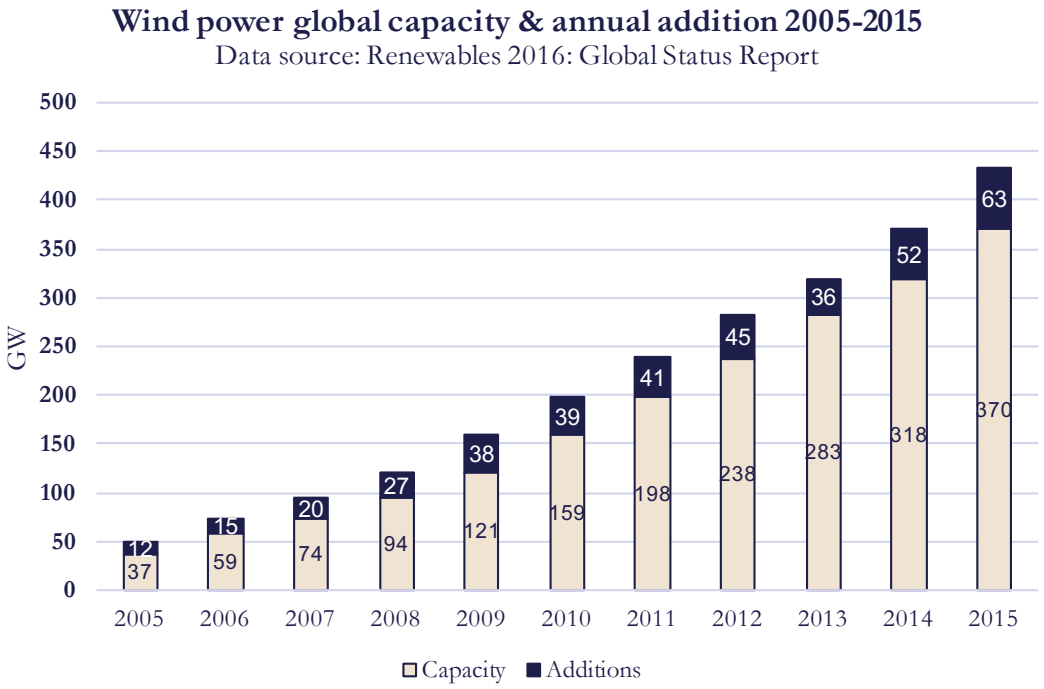


Figure 11 - Global Wind Installment total 2005-2015 and split on regions 2015[153]



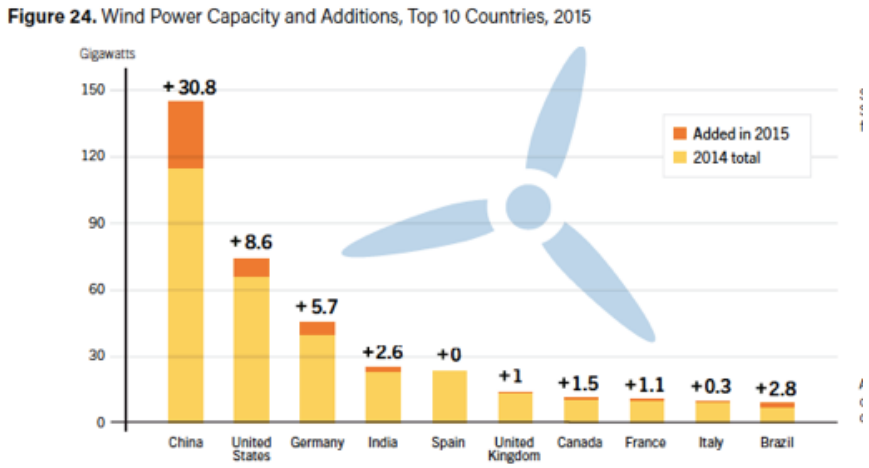


Figure 12 - Offshore Wind 2012-2032[154]

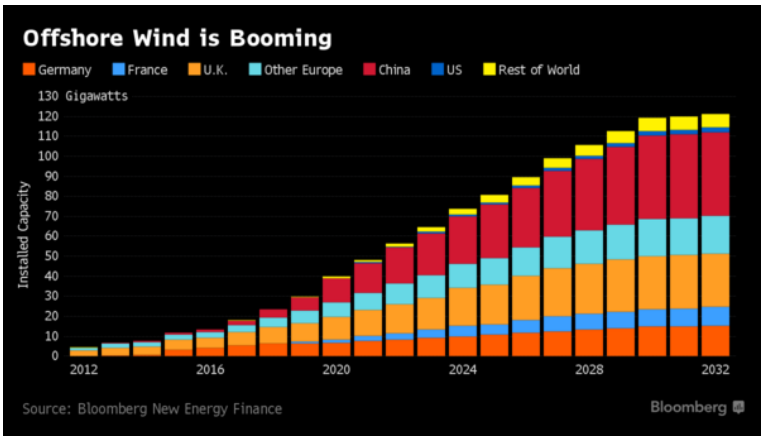
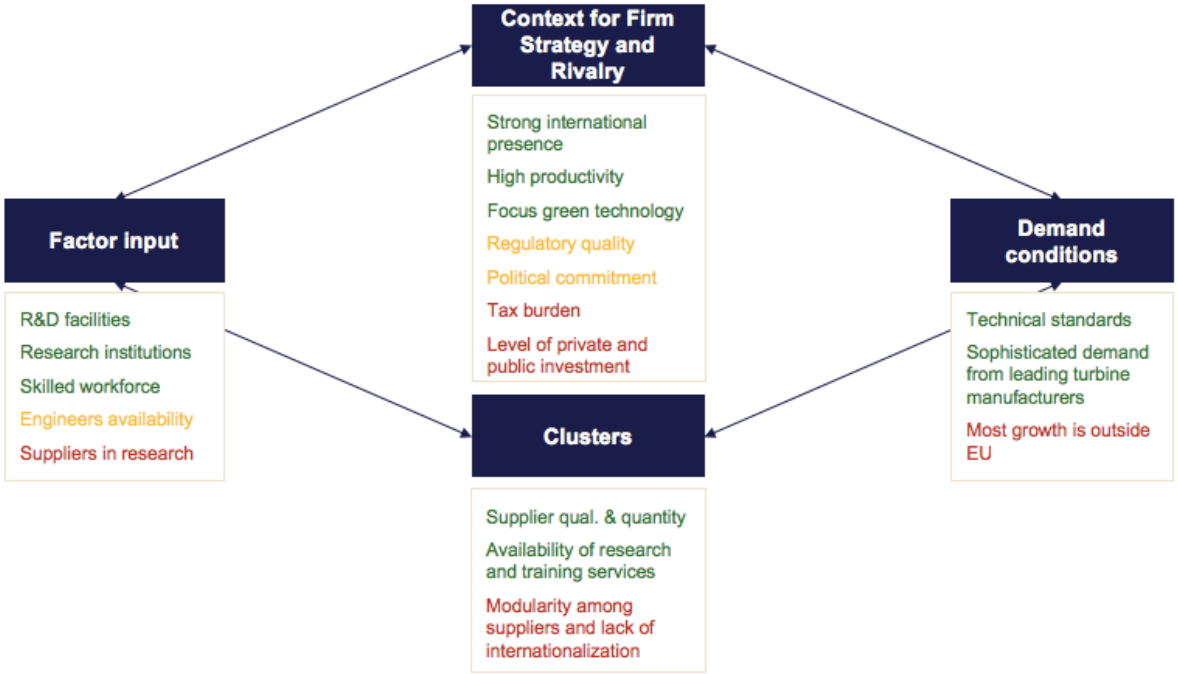


Figure 13 - Diamond Wind Cluster



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