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Authors: Leire Gorroño Albizu, Daniele Pagani and Tonny Brink / Nordic Folkecenter for Renewable Energy

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1. Remuneration System

The first public policies for the promotion of wind power in Denmark date back to the 1970s. At that time the Danish energy system was almost 100% dependent on oil for all energy uses (electricity, heating and transport) and approximately 90% of the oil was imported (Danish Energy Agency, 2012). The oil crisis in 1973-1974 brought the risks of such high energy dependency and the urgent need for alternatives to light. This historical event marks the beginning of the Danish green energy transition and the development of wind power that is relevant for this study.

The first two official Danish energy plans (1976 and 1981) were prepared in response to the oil crisis and therefore they focused mostly on security of supply. This was to be achieved by means of diversification of energy sources –mainly coal, natural gas and nuclear power– and energy savings through energy efficiency measures. Nuclear power was finally eliminated from Danish energy plans in 1985 and renewable energy first got relevance in the energy plan of 1990, which included specific targets for wind power (1,300 MW by the year 2000). The targets were increased in the energy plan of 1996 to 1,500 MW onshore by 2005 and 4,000 MW offshore by 2030. Support to renewable energy and wind power in Denmark was reduced in late 1990s and early 2000s –this coincides with the liberalisation of the EU energy market and the entering of a new Government in 2001. It was not until 2008 that wind power recovered the momentum. (Meyer, 2010) Later, in March 2012, the Danish Energy Agreement was signed almost unanimously by the parties in Parliament. The agreement sets 100% renewable energy as the long term goal for 2050 and includes covering 50% of the electricity demand with wind power by 2020. Figure 1 shows the main events in the promotion of wind power in Denmark as presented by (Meyer, 2010), with additions for the period after 2010.

Along with the different levels of technology development and governmental support, many different policy measures have been implemented to promote wind power in Denmark. These comprehend among others research and development subsidies, investment subsidies, price subsidies and tax deductions. (Neij, et al., 2003) Tables 1-5 collects the information about investment subsidies and price subsidies, including compensation for grid balancing (i.e. for stopping the wind turbines) and bonuses for investors with repowering certificates. Graph 1 shows the annual average spot market prices for electricity prices since the year 2000.

Repowering policies were meant to (1) make the most of the country's wind resources by replacing old and small wind turbines with new, bigger and more efficient turbines (Miles & Jensen, 2004) and (2) correct what many saw as "chaotic" siting of wind turbines across the country (Kruse, 2013 (a)) with improved planning practices (Miles & Jensen, 2004). The repowering schemes, together with changes in onshore wind planning and ownership regulation, had significant impacts in the ownership of wind turbines (Maegaard, 2014) as later explained in section 4.

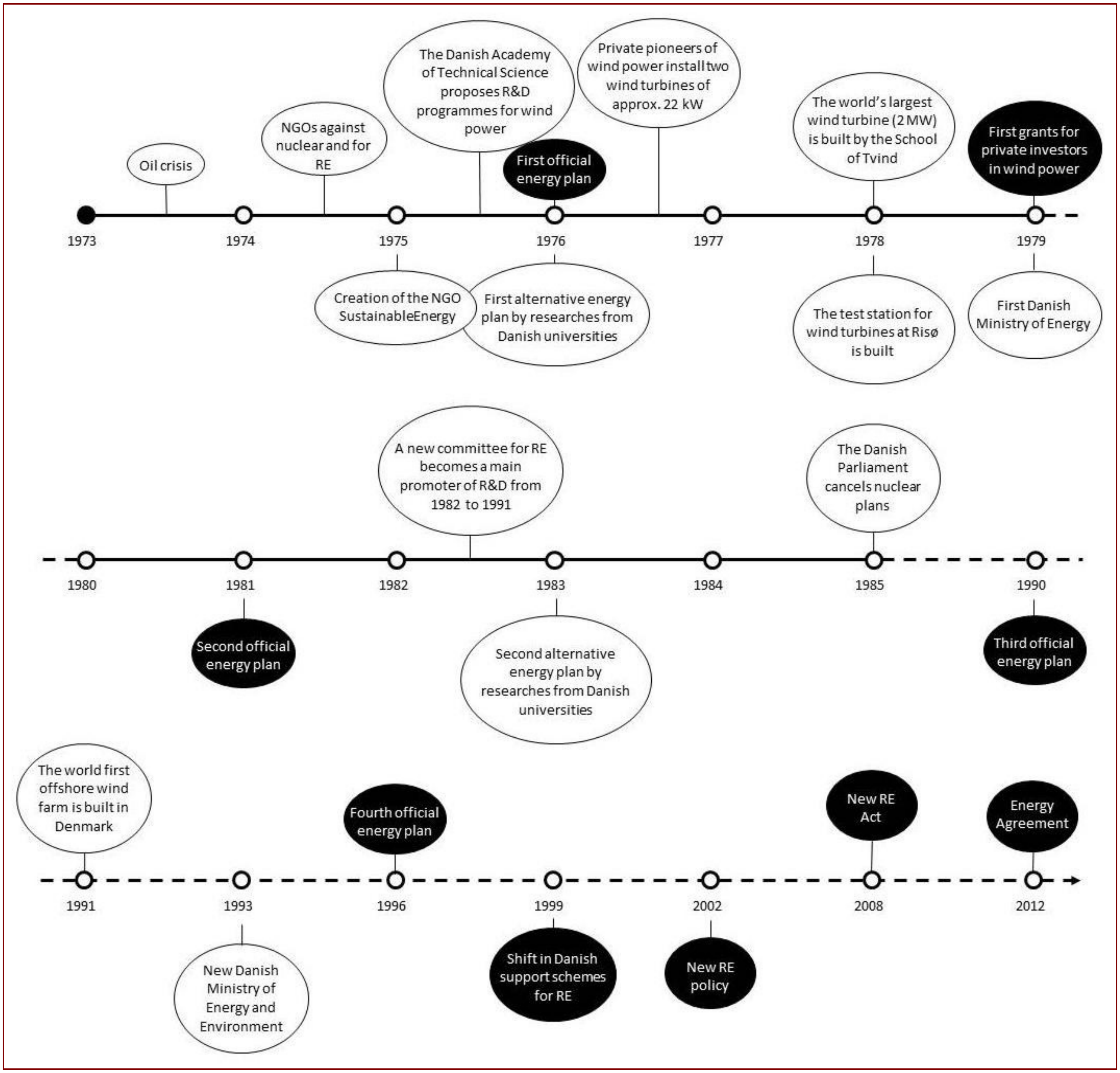


Figure 1: Main events in the promotion of wind power in Denmark as presented by (Meyer, 2010), with additions for the period after 2010.

Two repowering schemes have been implemented in Denmark. The first one for wind turbines with capacities up to 150 kW decommissioned during the period from 3 March 1999 to 31 December 2003. The second for wind turbines with capacities up to 450 kW decommissioned during the period from 15 December 2004 to 15 December 2011. Wind turbine owners with repowering certificates had the right to receive a price supplement (see tables 2 and 3). (Danish Ministry of Energy, Utilities and Climate, 2017)

Within the first repowering scheme, the wind turbine owner was entitled to receive the price supplement for the triple of the decommissioned capacity if decommissioned wind turbines had an installed capacity of less than 100 kW. If decommissioned wind turbines had an installed capacity of between 100 kW and 150 kW (both power values inclusive) and if it was located 2.5 km from a wind turbine that had an installed capacity of less than 100 kW and that had obtained a repowering certificate, the wind turbine owner was entitled to receive the price supplement for the double of the decommissioned capacity. (Danish Ministry of Energy, Utilities and Climate, 2017) Within the second repowering scheme, the wind turbine owner was entitled to receive the price supplement for the double of the decommissioned capacity. (Sperling, et al., 2009)

Legislation and regulation related to wind power in Denmark is very vast. The main related laws are the Electricity Supply Act and the Promotion of Renewable Energy Act. Besides those, it is worth mentioning the Act on Energinet.dk, the Act on the Carbon Duty Tax on Certain Energy Products, the Electricity Tax Act, the VAT Act and the Planning Act. A detailed analysis of these laws and their amendments would require a separate study on its own. Instead, the most recent rules related to subsidy schemes collected in tables 1-5 are listed below (Danish Energy Agency, 2014). The impacts these changes in legislation and regulation had in the social aspects of wind power, are described in section 4.

- *Act no. 1330 of 25 November 2013 of the Promotion of Renewable Energy Act.*
- *Act no. 1329 of 25 November 2013 of the Electricity Supply Act.*
- *Law no. 903 of 4 July 2013 amending the waste and raw materials tax Act, the carbon dioxide tax on certain energy products, the tax on electricity, the VAT act and the difference just other laws.*
- *Law no. 1390 of 23 December 2012 amending the law on the promotion of renewable energy, the law on electricity supply, the law on natural gas supply and the law on energinet.dk.*
- *Law no. 576 of 18 June 2012 amending the law on the promotion of renewable energy law on electricity supply, the Electricity Tax Act and the Equity Act.*

Table 1: Investment and price subsidies for wind power in the early days.

WIND TURBINES BOUGHT BEFORE THE END OF 1999
The first support scheme for wind turbine owners was introduced in 1979. This was a combination of investment subsidies and price subsidies in form of guaranteed prices. (Neij, et al., 2003) In 1979 the investment subsidy covered 30% of the turbine purchase price (Meyer, 2010). Later the percentage was

gradually lowered (25% in 1983, 15% in 1984 and 10% in 1989) until it was totally removed in 1990 (Neij, et al., 2003).

Regarding price subsidies, the last one of this period had the following characteristics: (1) guaranteed price of 0.60 DKK/kWh until the end of the full-load hours, (2) 0.43 DKK/kWh until the turbine was 10 years old and (3) a premium FIT of 0.10 DKK/kWh with a ceiling of 0.36 DKK/kWh until the turbine was 20 years old. The balancing subsidy of 0.02 DKK/kWh was to be added to the former values. (Meyer, 2010)

Table 2: Support scheme for wind power during the liberalisation process of the Danish electricity sector (2000-2002). (Energinet.dk, 2016 (a)) (Danish Energy Agency, 2014)

	Fixed-price FIT (DKK/kWh)	**Premium FIT** (DKK/kWh)	**Guaranteed price** (DKK/kWh)	**Balancing subsidy**[1] (DKK/kWh)	**Repowering subsidy** (DKK/kWh)	**Regulation / expiration of grants**
WIND TURBINES CONNECTED TO THE GRID 2000-2002						
Onshore wind turbines						
Up to 22,000 full-load hours			0.43	0.023	0.17 (fixed)	The guaranteed price, for the first 22,000 full-load hours. The repowering subsidy for the first 12,000 full-load hours.
After 22,000 full-load hours		Supplement: 0.10 Ceiling: 0.36		0.023		After the first 22,000 full-load hours and until 20 years from the grid connection.
Offshore wind turbines						
Up to 10 years			0.43	0.023	0.17 (fixed)	The guaranteed price, for the first 10 years from the grid connection. The repowering subsidy, for the first 12,000 full-load hours.
After 10 years		Supplement: 0.10 Ceiling: 0.36		0.023		After the first 10 years from the grid connection and until 20 years.
Utility wind turbines						
Onshore wind turbines	0.10	Supplement: 0.10 Ceiling: 0.36	0.33			For the first 10 years from grid connection, guaranteed price and fixed-price FIT. After the first 10 years from grid connection and until 20 years, premium

[1] The balancing subsidy is for the entire life of the wind turbine. [2] Utility turbines are of special agreements. The bill ended with the issue of appropriations on 4 June 2002 and includes all utility wind turbines connected before this date and the offshore wind farms at Horns Rev 1 and Nysted.

						FIT.
Offshore wind turbines (connected after 1 July 2000, i.e. Horns Rev 1 and Nysted)	0.10		0.353			For the first 42,000 full-load hours.

Table 3: Support schemes for wind power after the liberalisation of the electricity sector and up to the Energy Agreement of March 2012. (Danish Energy Agency, 2014)

	Fixed-price FIT (DKK/kWh)	**Premium FIT** (DKK/kWh)	**Balancing subsidy**[2] (DKK/kWh)	**Repowering subsidy** (DKK/kWh)	**Regulation / expiration of grants**
WIND TURBINES CONNECTED TO THE GRID 2003-2004		Supplement: 0.10 Ceiling: 0.36	0.023	0.17 (fixed)	The premium FIT, for 20 years from grid connection. The repowering subsidy, for the first 12,000 full-load hours.
WIND TURBINES CONNECTED TO THE GRID 2005-FEB. 2008	0.1		0.023	0.12 (premium)	The fixed-price FIT, for 20 years from grid connection. The repowering subsidy for the first 12,000 full-load hours. (only for onshore wind turbines) Ceiling: 0.48 DKK/kWh (fixed-price FIT + repowering subsidy + market price)
WIND TURBINES CONNECTED TO THE GRID FEB. 2008-2013					
Onshore wind turbines	0.25		0.023	0.08 (fixed) **OR** 0.12 (premium) with a ceiling of 0.38	The fixed-price FIT, for the first 22,000 full-load hours. The repowering subsidy for the first 12,000 full-load hours.
Offshore wind turbines (where an application for pre-authorization has been submitted before 15 June 2013)	0.25		0.023		For the first 22,000 full-load hours.

[2] The balancing subsidy is for the entire life of the wind turbine.

Table 4: Support schemes for wind power after the Energy Agreement of March 2012. (Danish Ministry of Energy, Utilities and Climate, 2012) (Gorroño Albizu & Scupovs, 2014)

	Premium FIT (DKK/kWh)	**Balancing subsidy**[3] (DKK/kWh)	**Regulation/expiration of grants**
WIND TURBINES CONNECTED TO THE GRID 2014-FEB. 2018			
Onshore wind turbines and offshore wind turbines under the open-door procedure (where an application for pre-authorization has been submitted after 15 June 2013).	Supplement: 0.25 ceiling: 0.58	0.023	Full-load hours are calculated with the formula 1.1.

(1.1) $$\text{Hours} = \frac{0.3\ (22{,}000 \cdot \text{turbine's capacity})}{\text{turbine's capacity}} + \frac{0.7\ (\text{production per m}^2 \cdot \text{swept area})}{\text{turbine's capacity}}$$

The Danish Energy Agreement of 2012 specified the new capacity to be installed from the year 2014 to 2020 in order to meet the wind power goal set for that year. Initially this was 1,800 MW onshore (in replacement of existing 1,300 MW), 500 MW nearshore and 1,000 MW offshore (Danish Ministry of Energy, Utilities and Climate, 2012).

- Onshore: in average 300 MW were to be installed annually from 2014 to 2020. Only 105 MW were installed in 2014, 234 MW in 2015 and 220 MW in 2016 (Danish Energy Agency, 2017). One of the issues that is posing relevant challenges for onshore wind power development in Denmark is the local opposition to new projects, as explained in section 4. The target of new 1,800 MW is not expected to be reached anymore, but intended to be balanced with lower decommissioning of existing wind turbines.
- Nearshore: Subsidies for nearshore projects were to be defined through tendering processes and should not exceed 0.77 DKK/kWh for the first 50,000 full-load hours. In 2015 the target for nearshore capacity was reduced to 400 MW, out of which 50 MW were reserved for testing purposes (Danish Energy Agency and Energinet.dk, n.d.). Finally, nearshore targets were cancelled based on cost arguments. Up to the moment,

[3] The balancing subsidy is for the entire life of the wind turbine.

only one testing project consisting of 4 wind turbines with capacities of 7 MW has been approved. (Danish Energy Agency, n.d. (a))

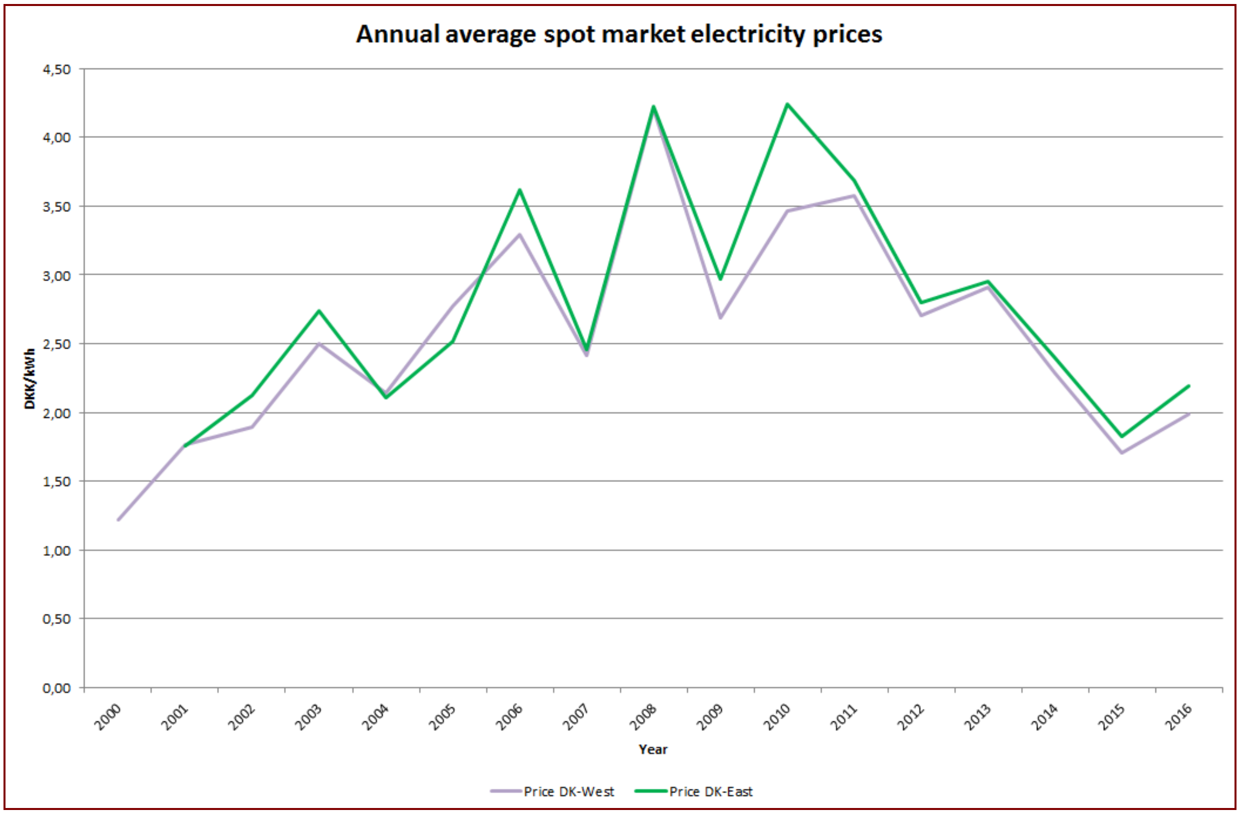
- Offshore: The new 1,000 MW offshore capacity were decided to be built in two wind farms – Horns Rev 3 (400 MW) and Kriegers Flak (600 MW). Subsidies for this two wind farms were granted through tendering processes, as it is common practice for offshore wind farms to be built as an initiative of national authorities. Results of all tenders for offshore wind farms are collected in table 5. It is important to note that the given values do not include the cost of connecting the wind farm to the national grid onshore. This cost is covered by Energinet.dk (Lindegaard, n.d.), the Danish TSO and public company. The connection to the grid is an additional subsidy given to offshore wind farms only –in onshore wind projects is the owner who has to pay for the cables up to the grid connection point (Neij, et al., 2003). The Danish Ministry of Energy, Utilities and Climate also requested Energinet.dk to carry out the environmental impact assessments, to conduct the geotechnical and geophysical surveys and to acquire information about wind, wave patterns, and currents, etc. for the two offshore wind farms planned as result of the Energy Agreement of 2012 (Lindegaard, n.d.). Again, in onshore wind projects, it is usually the future project owner who has to cover the expenses related to the environmental impact assessment.

Table 5: Subsidies for offshore wind farms awarded as result of tendering processes. (Danish Energy Agency, n.d. (a)) (Danish Energy Agency, n.d. (b)) (Energinet.dk, 2016 (a)) (Danish Energy Agency and Energinet.dk, n.d.)

	Guaranteed price (DKK/kWh)	**Expiration of grants**
Rødsand 2 (2010, 207 MW)	0.629	For the first 10 TWh or a maximum of 20 years from grid connection.
Horns Rev 2 (2009, 209 MW)	0.518	For the first 10 TWh or a maximum of 20 years from grid connection.
Anholt (2013, 400 MW)	1.051	For the first 20 TWh or a maximum of 20 years from grid connection. Note: no guaranteed price is granted when market prices are negative.
Horns Rev 3 (2020, 400 MW)	0.770	For the first 20 TWh or a maximum of 20 years from grid connection.
Kriegers Flak	0.372	For 13 years.

(2021, 600 MW)		

Regarding tax deductions it is worth mentioning tax exemptions on wind power gains for citizens who invest in wind power and obtain revenues below 7,000 DKK per year (Danish Wind Turbine Owners' Association, 2013). This is sufficient to allow citizens to buy wind shares that will make it possible for them to cover their electricity demands and bills.



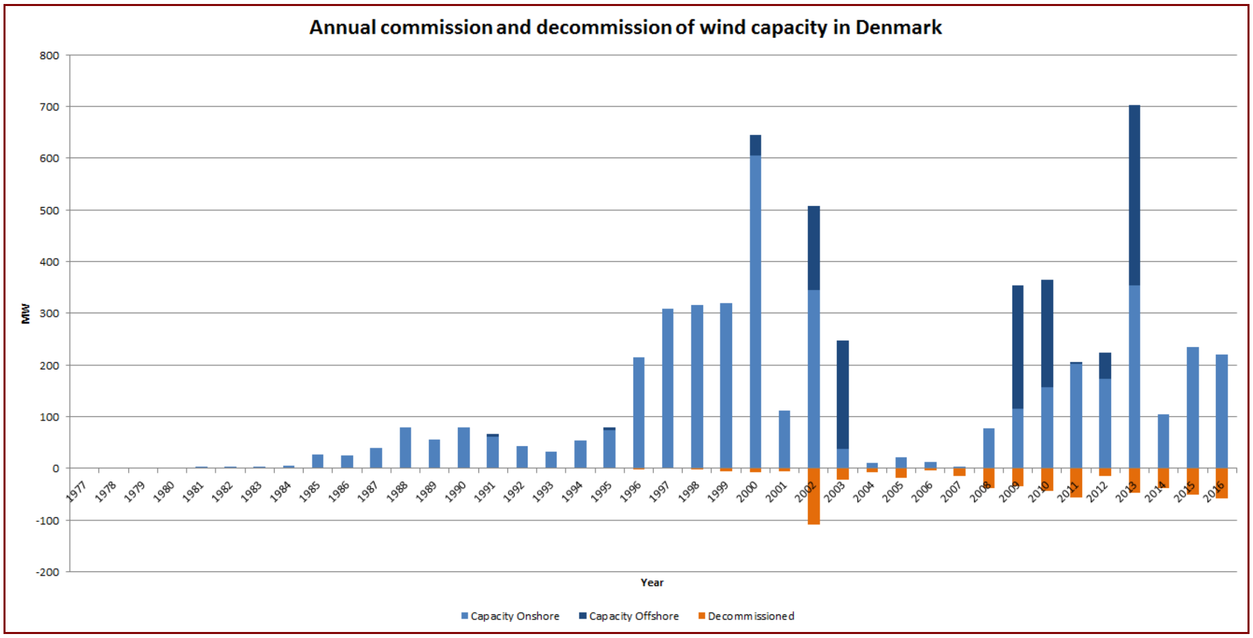
Graph 1: Annual average spot market electricity prices in Denmark since the year 2000. (Energinet.dk, 2017)

Danish policy schemes have put Denmark at the forefront of wind power development and deployment in the global context. In fact, in 2016, with 5,226 MW[4] (Danish Energy Agency, 2017), Denmark had the highest installed wind capacity per capita of the world (REN21, 2016). In the same year, onshore wind capacity accounted for approx. 75% of the total installed capacity. In 2015 42% of the final electricity demand of the country was supplied by wind power (Energinet.dk, 2016 (b)).

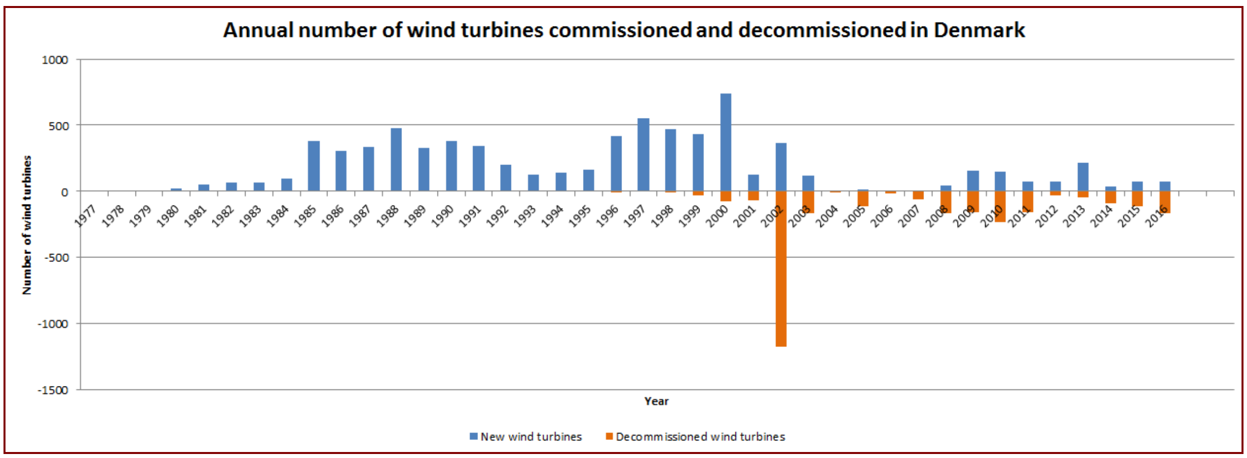
Graph 2 presents the annual installation of new wind power capacity in the country from 1977 to 2016. The annual installed capacity is influenced not only by supportive or non-supportive wind power policies, but also by the size of wind turbines and by social aspects, such as local opposition. As shown in graph 3, the number of wind turbines installed in Denmark is the highest in the 1980s and in the second half of the 1990s. In contrast, the peak of new installed capacity per year happened from the year 2000 on. It is important to note that almost no new capacity was installed in the period 2004-2008 due to unsupportive energy policies. According

[4] Excl. household wind turbines, i.e. wind turbines with capacities less or equal to 25 kW

to (Meyer, 2010) after 2002 “*feed-in tariffs are reduced and end up as the lowest ones in the EU*”.



Graph 2: Annual commission and decommission of wind power capacity in Denmark for the period 1977-2016. (Danish Energy Agency, 2017) Numbers exclude household wind turbines, i.e. wind turbines with capacities less or equal to 25 kW.



Graph 3: Annual number of wind turbines commissioned and decommissioned in Denmark in the period 1977-2016. (Danish Energy Agency, 2017) Numbers exclude household wind turbines, i.e. wind turbines with capacities less or equal to 25 kW.

2. Grid Connection Regulations

It was in 1976 when, without any permission, the wind power pioneer Christian Riisager connected his home-made wind turbine to the grid, realizing that his electricity meter started to run backwards; that was the beginning of a process which made, 30 years later, wind turbines become integrated part of the grid.

During the 1990s, the grid faced some serious pressure due to the introduction of local CHP (Combined Heat and Power) plants, which also had the priority on the electricity supply; seeing that this problem might become a common issue also for other member states, the EU adopted a directive on electricity market liberalisation which allowed all the end users to have access to the grid and, therefore, being able to choose their own electricity supplier. Furthermore, the directive required also the separation of production and transmission: in Denmark, this separation lead to the creation of Energinet.dk, which is a merging of two TSOs, Eltra and Elkraft. Energinet.dk is now in charge of the entire Danish power system (Bulow, 2010) and is, therefore, responsible for developing the necessary regulations to keep the network stable and efficient. Among these regulations, Energinet.dk can also force the stopping of wind turbines, to avoid the risk of overloading the grid in cases of excessive surplus power; the policy is that the electricity that cannot be traded with neighbouring countries (through the Nord Pool Spot Market) or stored, should be eliminated from the system. In such cases, Energinet.dk will need to compensate the turbine owner for the lost revue in the period of the stop.

Although this situation happened only few times, the risk of having a higher stopping frequency in the future is much higher, due to the plans of increasing the wind power capacity (Rasmussen, s.d.). Therefore, in Denmark the development of grid codes follows the development of wind turbines, both technologically and in terms of quantity installed. The regulations before 1997 dealt only with safe operation of the distribution network, putting very little requirements on the wind turbines, but things changed already in 1999, where the first grid code for wind turbines in the world was established.

The code required: (1) Control of active and reactive power production from wind turbines; (2) Fault ride through capability of the wind turbines; (3) Power quality; (4) Remote monitoring and control capability. In 2003, grid codes were revised, taking into account the recent technological developments of wind turbines (Havsager, 2010).

The key aspects of the current code are reported in table 6, the reference to be considered is the Technical Regulation 3.2.5 for Wind Power Plants above 11 kW, revision 4 (22.07.2017), available on Energinet.dk.

Table 6: Current code for grid connection in Denmark. (Energinet.dk, n.d.)

Tolerance of frequency and voltage deviations	• *A wind power plant must be able to withstand frequency and voltage deviations in the Point of Connection under normal and abnormal operating conditions while reducing active power as little as possible;* • *For the sake of planning and grid expansion the electricity supply undertaking has the right to reject grid connection for non-three phase plants;* • *The electricity supply undertaking must ensure that the maximum voltage stated in the reference tables is never exceeded;* • *If normal operating voltage range Uc ±10% is lower than the minimum voltage* *indicated in the reference tables, the requirements for production in the event of frequency/voltage variations must be adjusted so as not to overload the wind power plant;* • *The wind power plant must be able to briefly withstand voltages exceeding the maximum voltages within the required protective settings stated in the code;* • *Within the normal production range, the normal operating voltage is Uc ±10%, and the frequency range is 49.50 to 50.20 Hz;* • *Automatic connection of a wind power plant can take place no earlier than three minutes after the voltage and frequency have come within the normal production range;* • *Frequency limit settings are determined by the transmission system operator;* • *The wind power plant must be designed to withstand transitory (80-100 ms) phase jumps of up to 20° in the Point of Connection (POC) without disrupting or reducing its output;*
Power quality	• *For all plant categories, the DC content of the supplied AC current in the plant's Point of Connection (POC) may not exceed 0.5% of the nominal current;* • *For all plant categories, asymmetry between phases at normal operation or in the event of faults in the electricity-generating unit may not exceed 16A;* • *The flicker emission must be documented for continuous operation and for connections. The flicker level is documented using data*

	from type tests or emission models; • *Emission of harmonic distortions and interharmonic distortions as well as Ddstortion emission in the 2-9 kHz frequency range must be documented for the entire wind power plant;*
Control and regulation	• *In order to ensure the security of supply, the transmission system operator must be able to activate or deactivate the specified control functions and, by further agreement with the plant owner, be able to change current function settings via for example set points and activation commands;* • *All setting values for frequency parameters are determined by the transmission system operator;* • *For all active power and reactive power control functions, the accuracy of a completed control operation over a period of 1 minute may not deviate by more than 2% of Pn and Qn, respectively;*
Protection	*The wind turbine power plant should:* • *Be protected against damage due to faults and incidents in the public electricity supply grid;* • *Be protected against damage due to out-of-phase reclosing;* • *Be protected against disconnections in non-critical situations for the wind power plant;*
Exchange of signals and data communication	• *To ensure the operation of the public electricity supply grid, the plant must be prepared for data communication between the wind turbine operator and the transmission system operator as well as the electricity supply undertaking in the plant's communication interface in line with this regulation;*
Verification and documentation	• *The plant owner is responsible for ensuring that the wind power plant complies with this technical regulation and for documenting that the requirements are met;*
Electrical simulation model	• *From the design phase to the verification phase, the plant owner must keep the transmission system operator informed if the preliminary data can no longer be regarded as being indicative of the finally commissioned wind power plant;*

3. Permission Procedures

In the Early Years of Wind Power Development

In the 70’s there was no special legislation for a wind turbine project implementation. No permission, but only notification was needed if a wind turbine was to be built in a farm in a rural area. For other wind turbines installed in rural area, permits were given as long as there was no conflict with nature and preservation fields. Municipality permits were required for wind turbines that were planned to be constructed in urban areas. Those permissions were issued if safety and noise standards of installations were met. However, visual impact was not taken into consideration. (Miles & Jensen, 2004)

After 1999 there was a decline in installations of onshore wind energy due to two reasons: changes in administrative procedures of the spatial planning of wind power and redesign of the economic support schemes, as already explained in Section 1. The method of setting out the prescriptive location for future wind turbine installations ruled out most locations from onshore wind energy development due to broader categories of restrictions considered by municipality planning such as wind resources, size and amount of wind turbines and landscape considerations (Bowyer, et al., 2009).

Permission Procedures for Onshore Wind Turbines

Danish Municipalities are responsible for onshore wind planning for wind turbines of up to 150 m height to the tip. Above that height, the responsible authority is the Ministry of Environment. (Danish Energy Agency, 2015)

Municipal onshore wind planning is divided into two phases: the overall municipal plan and the concrete project plan. For the former, Municipalities have to clarify their aspirations and ambitions for the future expansion of wind turbines in the municipality and the planning process starts by examining the potential areas in the municipality taking into account people, nature and environment. When the Municipality's proposal for a municipal plan and the environmental analysis are finished, they are both published in a report, which includes the areas chosen by the Municipality for wind turbines and the description of possible impacts on nature, environment and people. Citizens have the chance to participate by giving their opinion and comments before and after the plan is published. (Danish Ministry of Environment, n.d.)

Regarding the concrete project planning, it starts when an application for a wind turbine project is submitted. At this phase the Municipality analyses the application, defines the changes to be done if necessary and makes a proposal determining how many, where and how wind turbines can be placed for the specific wind turbine project. This proposal must include an environmental impact assessment carried out as provisioned by the Environmental Impact Assessment Directive of the EU. Citizens’ involvement is once again encouraged before and after the report is published. After the final proposal is presented and citizens’ response has been analysed, it is Municipality's responsibility to accept or deny the concrete project. When a project obtains the approval from the Municipality, the project developer has to hold a meeting in order to inform neighbours about their right to buy shares and to apply for an economic compensation for their properties' value losses. (Danish Ministry of Environment, n.d.)

Even if the overall municipal planning points the areas for the development of wind turbine projects, it does not mean that there is no option to develop a project for a land outside those areas, but it has to be taken into account that obtaining the permission for the implementation of the project might be more complicated. (Olive, 2013)

Table 7 provides additional information about renewable energy project development and permission, key actions and interaction among stakeholders.

Permission Procedures for Offshore Wind Turbines

There are two possible procedures for the establishment of offshore wind turbines: "*a tender procedure run by the Danish Energy Agency or an open-door-procedure*" (Danish Energy Agency, n.d. (c)). In the following both are described along with the related Danish legislation. All the information under section 3.3 is provided by (Danish Energy Agency, n.d. (c)).

Legislation

The conditions for offshore wind farms are defined in the Promotion of Renewable Energy Act. In chapter 3 it is stated that the right to exploit energy from water and wind within the territorial waters and the exclusive economic zone (up to 200 nautical miles) around Denmark belongs to the Danish State.

Thus, three licenses are required to establish an offshore wind farm in Denmark. The three licenses are granted by the Danish Energy Agency, which serves as a "one-stop-shop" for the project developer. The three licenses are stated below:

1. License to carry out preliminary investigations
2. License to establish the offshore wind turbines (only given if preliminary investigations show that the project is compatible with the relevant interests at sea)
3. License to exploit wind power for a certain number of years, and an approval for electricity production (given if conditions in license to establish project are kept).

The three licenses are given successively for a specific project. Furthermore, it is necessary to perform an Environmental Impact Assessment (EIA) if the project is expected to have an environmental impact. So far, it has been necessary to perform an EIA for all of the existing Danish offshore wind farms.

Table 7: Phases for renewable energy project development and permission, key actions and interaction among stakeholders as identified and described by (DCEA, DTU Wind Energy and Nordic Folkecenter for Renewable Energy, 2017)

Phase	**Key actions**
1 Exploring the options	The developer makes preparations, including initial surveys of potential areas, negotiations with landowners. Initial dialogue with the municipality may happen at this stage however this is not always the case.
2 EIA screening	The developer submits the project for screening by the municipality, to determine if an EIA is mandatory. The screening decision is publicly announced (may be merged with step 3)
3 Idea phase *Duration: at least 14 days*	The municipality will publicly announce the intended project and the EIA process, and will call for ideas and inputs.
4 Scoping	The scope of the EIA is explored & agreed between the developer/consultant and the municipality. The municipality draws up a statement about the scope.
5 & 6 Administrative and political process (white paper not mandatory)	The received inputs are processed by the municipality's administration; this work is reviewed and endorsed at the political level. The municipality may produce a white paper including a summary of the received inputs and the municipality's remarks.
7 EIA development	The consultant conducts the EIA.
8 Draft EIA report	The consultant delivers the draft Environmental Impact Assessment report.
9+10 Administrative and political process followed by a public hearing (based on the EIA report, local plan proposal & municipal plan addendum) *Duration: 8 weeks*	Local government officials review the EIA report and may require changes / additions. The report is then sent for approval by the municipality's politicians. Politicians can also demand changes. Once the report is approved by the administration and the politicians, the municipality will send it out in public consultation. The consultation phase includes a public meeting.
11 Public hearing white paper *(not mandatory)*	Before the politicians make a final decision, the municipality may choose to produce a white paper with a summary of the consultation responses and the municipality's treatment of these.
12 Authorization *Followed by a 4-week formal*	The municipality authorizes the developer to move ahead with the project, and announces this in public.

Phase	Key actions
complaint period	
13 Monitoring	The planned monitoring is carried out and reported.

The specific procedure for the EIA regarding offshore wind farms is described in Executive Order no. 68 of January 26th 2012. Furthermore, the Danish Energy Agency has guidelines developed for the elaboration of EIA for offshore wind proposals. The guidelines only cover issues related to the environment at sea.

As previously mentioned, the establishment of offshore wind turbines can follow a tender procedure or an open-door procedure. For both procedures, the project developer must obtain all three licenses.

Government Call for Tenders

Most new offshore wind farms in Denmark are established after a tendering procedure to realise new offshore wind farms at the lowest possible cost. All tenders are decided in political energy agreements.

The Danish Energy Agency announces a site specific tender for an offshore wind farm of a specific size, e.g. 200 MW. The offshore wind farm has to be established within a geographical area which is defined in the tender.

The Danish Energy Agency have e.g. invited applicants to quote a kWh price in the form of a fixed price at which the bidders are willing to produce a certain amount of electricity corresponding to a certain number of full-load hours. The owner of the wind farm will have to sell the electricity at the market, and get a subsidy to cover the difference from the market price to the fixed bid price.

The winning price will differ from project to project, as shown in table 5 under section 1. Thus, the result of a tender depends on the project location, the wind conditions at the site, the competitive situation in the market at the time, etc.

In tenders for large scale offshore wind farms, Energinet.dk constructs, owns and maintains both the transformer station and the underwater cable that carries the electricity to land from the offshore wind farm. Energinet.dk is responsible for the electricity infrastructure in Denmark and act as an independent system operator (TSO).

Open Door Procedure

In the open-door procedure, the project developer takes the initiative to establish an offshore wind farm. The project developer must submit an unsolicited application for a license to carry out preliminary investigations in the given area. The application must as a minimum include a description of the project, the anticipated scope of the preliminary investigations, the size and number of turbines, and the limits of the project's geographical siting. In an open-door project, the developer pays for the grid connection to land.

An open-door-project cannot expect to obtain approval in the areas that are designated for offshore wind farms in the update of the report Future Offshore Wind Power Sites from 2011.

As part of the one-stop shop concept, Danish Energy Agency initiates a hearing of other government bodies to clarify whether there are other major public interests that could block the implementation of the project before the Danish Energy Agency actually begins processing an application. Based on the result of the hearing, the Danish Energy Agency decides whether the area in the application can be developed, and in the event of a positive decision it issues an approval for the applicant to carry out preliminary investigations, including an EIA.

If the results of the preliminary investigations show that the suggested project can be approved, the project developer can obtain a license to establish the project.

After the Energy Agreement of 2012, electricity produced by wind farms under the open-door-procedure will receive a price premium at the same level as onshore wind turbines, see table 5 under section 1.

4. Social Aspects

"*There are no longer technological or economic barriers for the quantum leap to 100% renewable energy*" (Gorroño Albizu, et al., 2015). This means that the transformation of energy systems into renewables depends on political will and social aspects. (Gorroño Albizu, et al., 2015) presents four major social aspects for successful development of wind power: energy democracy, local acceptance and support to new installations, community development and affordable energy prices. These four points are the ones taken into account for the analysis and description done in this section.

As already explained in section 1, Denmark aims to cover 50% of its final electricity consumption with wind power by 2020. In order to fulfil this goal a net increase of 2,000 MW was estimated to be needed for the period 2014-2020. Onshore, 1,300 MW were planned to be replaced by new 1,800 MW. This would require an annual deployment average of 300 MW for the given the period. In contrast, only 105 MW were installed in 2014, 234 MW in 2015 and 220 MW in 2016 (Danish Energy Agency, 2017). This indicates there are important barriers to project implementation.

Local opposition to large onshore wind turbines is one of the main obstacles for the fulfilment of wind targets. Thisted Kommune, a municipality with excellent wind conditions in north-west Denmark, perfectly exemplifies the severity of the issue –6 out of 7 project applications presented in 2011 were rejected due to strong protests and no large wind turbines have been installed since 2007 (Kruse, 2013 (b)). The objections presented during the public hearing process of the municipal wind planning for new 75 MW took up about 500 pages of the environmental impact assessment report (Hvelplund, 2014). Like Thisted, many other municipalities have cancelled entire municipal plans as well as specific projects.

Besides the environmental implications of hampering the commission of onshore wind turbines, it is also important to consider its negative effects on the cost of transition to renewable energies, electricity prices and rural economies. Local authorities and project initiators use resources for projects and plans that are finally cancelled, alternatives to the cheap onshore wind power –which is currently the most economical technology for electricity supply in Denmark (Maegaard, 2013)– are needed, and rural areas may not make the most of their abundant wind resources.

The problem of local opposition to onshore wind power is not new, it was already perceived in the late 1990s as results of changes in ownership patterns (Hvelplund, 2014) led by changes in legislation (Maegaard, 2014). Initially, investments in wind power were restricted to local residents living within a certain distance to the wind turbine (Bowyer, et al., 2009), who were only allowed to buy a small amount of shares –just sufficient to cover their electricity demand (Kruse, 2013 (a)). Project implementation was this way dependent on other local residents' involvement and promotors would call for a public meeting where the initial idea would be presented and those interested in the project would join it.

Later, restrictions in distance and amount of shares were loosened. The ownership was opened to the entire municipality and also to neighbouring municipalities. Finally, in 1998 the obligation for local ownership was removed (Maegaard, 2014). In the same way, there was no longer a limitation on the amount of shares one can buy. It is estimated that by the end of the 1990s local ownership policies had resulted in more than 3,000 wind cooperatives and 150,000 shareholders (Bowyer, et al., 2009) (Maegaard, 2014).

The bottom-up approach that had characterized the Danish wind power development in the early years turned into a centralized and business oriented approach in the second half of the 1990s and early 2000s. Not only the obligation of local ownership was abolished, but the repowering schemes resulted in the closure of many wind cooperatives, which could not see themselves involved in bigger wind projects as required by the new planning rules. Together with the local cooperatives, the local advocates for wind power also disappeared, leading to local opposition problems. (Hvelplund, 2014) (Maegaard, 2014)

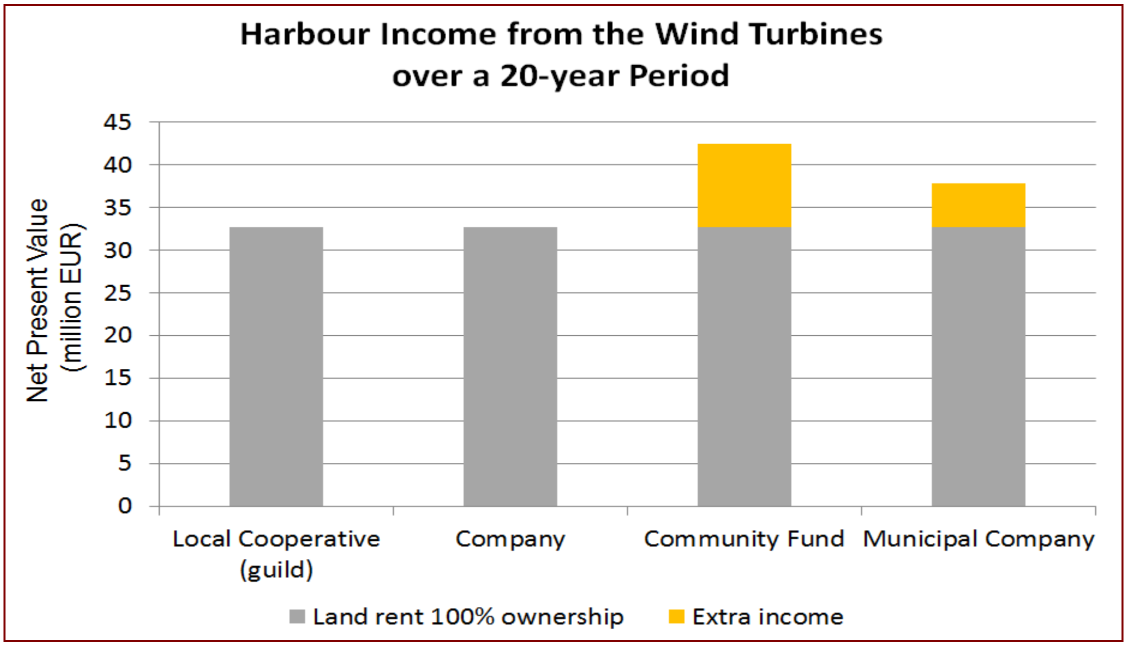
The Promotion of Renewable Energy Act of 2008 tried to address the problem by including four measures: (1) economic compensation for loss of property value, (2) the Green Scheme to develop activities to increase local acceptance of wind turbines, (3) a fund to help local entrepreneurs with the initial costs of wind projects and (4) the obligation to offer 20% of the shares of every wind turbine higher than 25 m to local residents. In spite of the innovative character of some of those provisions, they have not been sufficient to mitigate the problem. Studies show that even if 80% of the Danish society has a positive opinion about wind power, the same percentage is against having wind turbines nearby their living places (Rambøll, 2013). Furthermore, according to the Danish National Association of Neighbours against Giant Wind Turbines, in 2016 there were about 120 protest groups in the country.

In the early years of wind power development, the local cooperatives, with their democratic and inclusive character, ensured that benefits and inconveniences of new wind turbines were equally distributed among community members. Low payments for land rent or purchase and limited revenues prevented the generation of any imbalances between land owners, wind investors and the rest of the local residents. In contrast, the currently prevailing model is based on a top-down approach and aims for maximisation of private profits. In this model there is no democratic decision-making (communities are informed and consulted when the important decisions have already been made) and the needs of communities' are left apart. In the best case scenario, revenues of wind turbines go to a few local investors; in the worst case, they fly away from the local communities to the pockets of investors sitting in other areas of the country or even abroad. High land rents and exclusive ownerships create imbalances in the distribution of benefits and inconveniences, i.e. they create clear winners and losers, which results in local opposition to the current model. (Gorroño Albizu & Scupovs, 2014)

The necessary local acceptance is only achievable by means of democratic and inclusive organisational models where the purpose is the common good in form of local development. In this way, the entire community may perceive the new wind turbines as a positive thing for the local area. (Maegaard, 2014) (Gorroño Albizu, et al., 2015) Several examples proof the support of local communities to this model (Rambøll, 2013), also referred to as community power (Maegaard, 2014 and Gorroño Albizu, et al., 2015).

The example of the wind turbine project in Hanstholm Harbour confirms that it is the model local residents oppose to or support. Here in 2006 a wind turbine project consisting of 6 wind turbines and initiated by one of the big utilities was cancelled after receiving approx. 1,200 complaints in the public hearing of the environmental impact assessment –the population in Hanstholm is approx. 2,300. In contrast, in 2013 local residents were supportive of a wind turbine project consisting of 9 bigger wind turbines to be built close to the place where the former 6 had been planned. The main difference between the two projects lied in the ownership and final purpose –the second was to be owned by a community foundation (80%) and by local residents (20%) and meant to partly finance the expansion of the harbour, which is the main economic activity of the area and is directly or indirectly linked to the household income of all local residents. (Pozzi, et al., 2013)

(Pozzi, et al., 2013) analyses the capacity of wind turbine projects in combination with different ownership models to promote local development. The analysis is done based on the wind turbine project of Hanstholm Harbour and main results are presented in graph 4. The main conclusions from the economic study are (1) that all ownership models would contribute with the same amount to the financing of the harbour expansion with the land rent because the wind turbines were to be placed in an area owned by the harbour and (2) that only the community foundation and the municipal company would provide additional income for the harbour project. The harbour is operated by a municipal company. Therefore, one could also think that municipal taxes generated by the local cooperative or a company could be used to support the harbour expansion project. However, the tax generation is insignificant in comparison to the profit generation of the wind turbine project.



Graph 4: Capacity of different ownership models for wind turbines to support the financing of the expansion of Hanstholm Harbour. (Pozzi, et al., 2013)

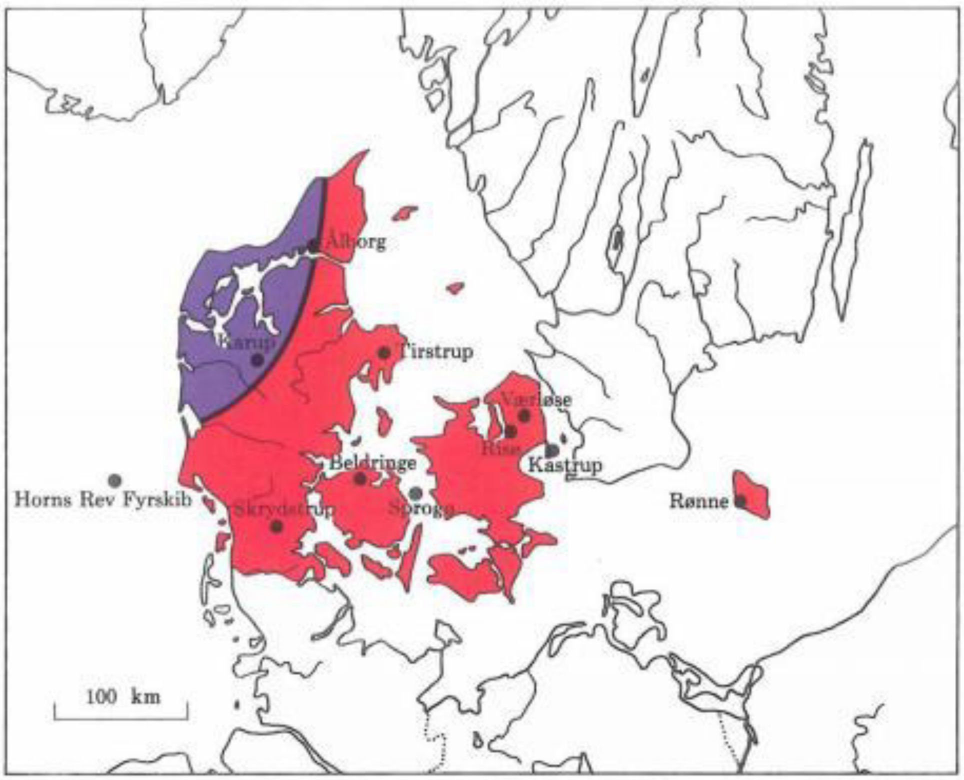
To sum up, community ownership models can better support local development since their final purpose is the common good and are fully accepted by local citizens. With community ownership models, the profits of wind power can be reinvested to satisfy the main needs of the local community; e.g. improvement of infrastructure, creation of new jobs, finance for local schools in rural areas, to provide support for local organisations, for environmental projects, local public e-transport, etc. This will be strategic for the revitalisation of Danish rural areas.

In spite of the several benefits of bottom-up approaches and community power, Danish energy policy promotes investment from big players. This is especially obvious in the design of the tendering for offshore and nearshore wind projects. The conditions to be pre-qualified make it impossible for municipal companies, citizen groups and non-profit organisation to be allowed to participate (Jensen & Sperling, 2016). According to recent research conducted by the Department of Development and Planning of Aalborg University for the European project MOBGis, only about 13% of the total existing installed capacity is owned by cooperatives nowadays and the share of municipal companies and community foundations is negligible.

From the above explanation, it is evident that Danish energy policies will need to be revised in order to ensure wind and renewable energy targets to be met.

5. Available Wind Data

The annual average wind speed in Denmark is 5.8 m/s, with a wind direction mainly coming from West (25% of the time); although the country is small and does not present relevant orographic obstacles, there is a considerable variation in wind resources based on which location the analysis is performed: as an example, the number of days with strong winds (10.8-13.8 m/s) ranges from approximately 30 in inland regions to about 170 in Skagen (the northernmost location in Denmark). Storms (>24.5 m/s) are mostly present on coastal areas and appear in winter approximately every third or fourth year (The Danish Meteorological Institute, n.d.).



Wind resources at 50 metres above ground level for five different topographic conditions*										
	Sheltered terrain		Open plain		At a sea coast		Open sea		Hills and ridges	
	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400
o	Regions where local concentration effects may occur						* see Fig. 2.3 for full explanation			

Figure 2: Wind map for Denmark (Troen & Lundtang Petersen, 1989, p. 41)

The country has a considerable amount of reliable wind data, which were collected for decades –the European Wind Atlas was published by Risø research center already in 1989- and which allow performing precise analysis on wind farms potential location and production. shows the wind map for Denmark, published on the European Wind Atlas of 1989; the black dots in the picture represent the meteorological stations which have collected all the data used for the simulations; although the map shows the speed values only for a height of 50 m, it is possible to obtain data also for 10, 25, 100 and 200 m, when a specific location is selected.

All the values are then inserted in simulation software, like WaSP - also developed by Risø research center, now DTU wind -, which produce resource maps for the selected area; these maps can subsequently be used for defining the annual energy production of the wind turbine or wind farm, as well as for selecting which would be the best spots for the installation of wind turbines.

The European Wind atlas is now under update: the goal of the NEWA (New European Wind Atlas) is to use satellites to increase the precision of the atlas and deliver better data for the industry (CORDIS, n.d.).

6. Domestic Industrial Capacities

Historical Background

The wind energy path in Denmark has ancient roots: although the modern industry developed in the last 30-40 years, researches on wind for electricity production were already carried out in the 1890s. A special merit should be given to Poul la Cour, a Danish physicist and teacher**,** who, with his work at the Askov Folk High School in Jutland, set the base for what would become one of the leading industries of the country. More than a century ago, he developed and built a 22 m-diameter wind turbine for electricity production and, in addition to that and further studies on wind and wind turbine components, he also thought about energy storage by producing hydrogen through electrolysis, a practice which is currently under consideration in the country.

The wind electrification in the early 1900s was based on the concepts developed by la Cour, which resulted in 120 turbines being installed all over the country by 1918, for a total of 3 MW (3% of the national electricity demand).

The following 40 years saw a general development in the technology (both in Denmark and abroad) which led to the development of the Gedser windmill, the base for modern wind turbines. Although successful, the technology was abandoned by electricity utilities in the 1960s, when oil and coal prices became excessively cheap for wind to compete.

The situation changed after the oil crises (1970s), when Denmark, highly relying on oil imports, started to look at wind again as an alternative to free itself from the fluctuations of oil prices; the Gedser concept was taken again in consideration and was considered as the starting point for further developments. Unlikely in other countries, in fact, the Danish wind development relied heavily on early innovators and inventors, who took a large portion of risk, by exposing themselves directly on the financial level. Reliability was, therefore, very important and set the base for the entire Danish wind industry (Meyer, 2013).

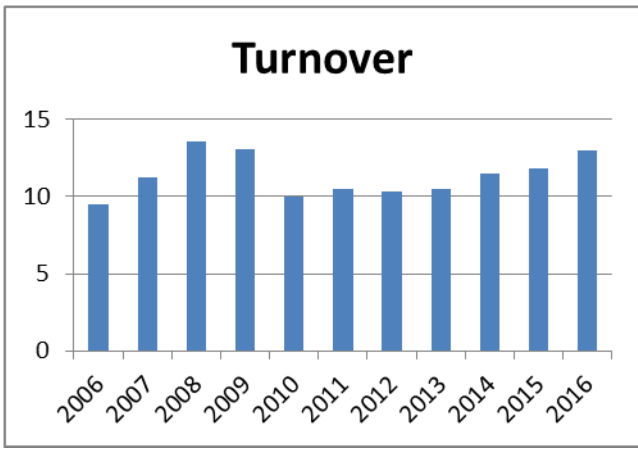
Denmark is now one to the countries in which the wind industry has the largest impact on the national economy (Shahan, 2013) and where the ratio wind turbine/citizens is the highest – 899 W/capita- (SolarSuperState, 2017). The current situation and the quick development of the industry from the 1970s were possible due to the "open source" approach that characterized the early stages of wind industry. During the year, several open meetings were called, where turbine owners, small manufactures and potential stakeholders came together to discuss what were the best solutions adopted, what did not work and, in general, to take advantage of the developed best practices and hence speed up the development of wind energy.

In the late 1970s, NIVE was established. The purpose of the association was to be a working group carrying out research and development and subsequently develop detailed construction manuals and drawings, which could afterwards be used by SMEs to enter the wind market: by having a ready-made solution SMEs could start producing small wind turbines, improve them and sell them under their brand, therefore enlarging their market potential. Since physical properties of wind were not yet so well-known as today, high safety factors were used, resulting in over-designed, but long-lasting machines. Reliability was the main focus of the SMEs, since breakdowns would compromise their image on the market. The approach turned out to be successful, allowing SMEs to grow and become, in some cases, world leaders of the industry.

The worked carried out by NIVE was later continued by the Folkecenter for Renewable Energy, which was established in 1983 and took the development to a higher level: now, the design of wind turbines was intensified and professionalized, taking into account also that the different components (blades, gearboxes, etc.) became available from specialized sub-suppliers. The availability of standard and reliable components made it even easier -and cheaper- for SMEs to enter the wind business. The work of Folkecenter for wind was subsequently expanded also to other renewable energy fields (Mægaard, 2013).

Industrial Capacity

Wind industry is an important sector for Danish economy, accounting for just below 2.8% of the country's GDP (2016). The impact on employment is considerable and in 2016 accounted for 31,194 people directly employed in the wind industry and 85,000 employed in sectors in some way related to wind. The turnover directly related to the wind business in Denmark accounted for 13 billion Euro in 2016**,** to which a similar turnover related to consumption generated from the employee's incomes should be added. Both the impact on the GDP, the number of employees and the industry's turnover increased between 2015 and 2016 (Danish Wind Industry Association, 2017). Historical figures for the turnover and the number of employees in the wind industry can be found in graph 5.



With a total installed capacity of 5.22 GW (3.95 Onshore and 1.27 Offshore), wind production accounted for an average of 27.17% of electricity consumption in the period 2005-2016, with a record value of 42% in 2015. (Danish Wind Industry Association, 2017).

Danish wind industry is leader in the sector and some of the companies are even world-record holders: just to provide some examples, Vestas produces the largest commercial turbine in the world (V164-9.5 MW), which reached a record production of 216 MWh in a 24-hour period (MHI Vestas Offshore Wind, 2017). Another Danish record holder is the blade manufacturer LM, which produced the longest blade in the world (88.4 m) (LM Wind Power, 2017).

In addition to record holders, Denmark has also a large variety of industries related to the wind sector, which cover practically the entire supply chain. From components manufactures to financial and legal services related with wind industry, every aspect of wind is covered in Denmark.

During the early stages of development of the industry, many small and medium size companies were present on the market. The majority of these companies were subsequently merged, giving birth to some industrial giants. Figure 3 provides some examples of merging and absorption of Danish wind industries.

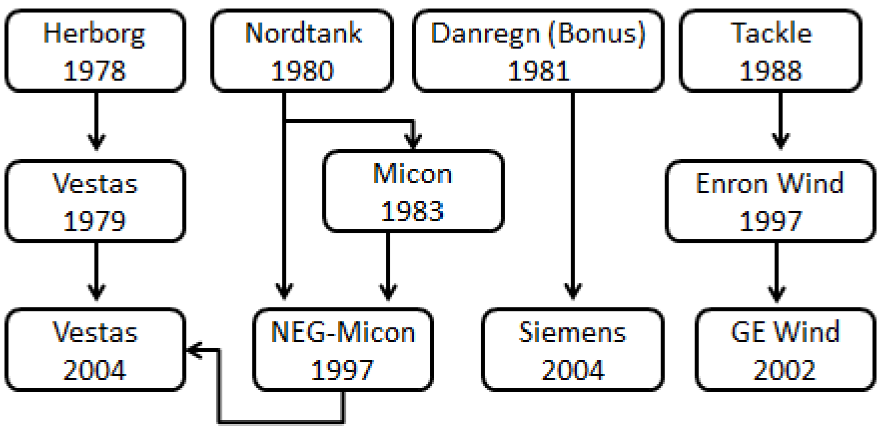


Figure 3: Danish wind power evolution (Dykes, 2013, p. 147)

Table 8 presents an overview of the wind turbine manufactures present in Denmark, together with some key factors about their business. Please, note that the selection was carried out based on the companies having an address in Denmark and not on those that are presently Danish: it is a fact that some Danish industries were financially purchased by foreign players, but the main facilities are still kept in Denmark. An overview with only the pure Danish companies would provide a different picture of the country, which would become outdated in short time, due to the quick changes due to financial issues, in which companies might incur.

Table 8: Overview of wind turbine manufacturers in Denmark (Envision Energy, 2017) (Energy Business Review, 2017) (Statista, 2017) (Nordex GmbH, 2017) (Siemens Gamesa Renewable Energy, 2017) (Vestas A/S, 2017)

Company	**Headquarters**	**Number of Employees (Globally)**	**Revenue**

Envision Energy ApS	Shanghai, China	1000 (2014)	11 M€[5] (2013)
Goldwind Energy ApS	Beijing,China	6,526 (2017)	3.77 billion USD (2016)
Nordex Energy GmbH	Rostock, Germany	4645 (2016)	3.40 billion Euro (2016)
Siemens Gamesa Renewable Energy A/S	Zamudio, Spain	27,000 (2016)	11 bn Euro (2016)
Vestas Wind Systems A/S	Aarhus, Denmark	21,625 (2016)	10.24 billion euro (2016)

Testing Facilities

Being the wind industry very developed in Denmark, a wide range of option for testing components and entire wind turbines are available. From materials and welding testing to blades and nacelles, every key component can be tested in the country, factor which provides a competitive advantage over other countries: access to testing facilities means, in fact, a quicker development of more reliable and innovative prototypes, which, after being certified, can become standard components for the wind industry, therefore increasing the total revenue of the sector.

The following list of testing facilities is not meant to be exhaustive, but tries to give an overview of the most important facilities available in the country.

5 The values refers to the Danish seat only

National Test Center for Large Wind Turbines – Østerild

Located in the Northern part of Jutland, the test field was established in 2012 and it is managed by the wind department of the Danish Technical University (DTU). Originally planned with place for seven wind turbines with a maximum size of 16 MW (Megavind, 2016) and a maximum height of 250 m, in 2017 the test center got permission to increase the height to 330 m and to add two extra places for wind turbines.

Current installed turbines can be found in table 9.

Table 9: Wind turbines in the national test center of Østerild (DTU Wind Energy, 2017 (a))

Place #	Company	Model	Power (MW)	Rotor Diameter (m)	Hub Height (m)	Tip Height (m)
1	EDF GE–Alstom	150-6 MW	6.0	150	117	192
2	Vestas	V164-9.5 MW	9.5	164	140	222
3	Vestas	V136-3,45 MW	3.45	130	116	184
4	Vestas	V126-3,45 MW	3.45	126	137	200
5	Envision Energy	EN-120/3.0 MW	3.0	120	90	150
6	Siemens Wind Power	SWT-8.0	8.0	154	120	197
7	Siemens Wind Power	SWT-7,0	7.0	154	120	197

National Test Center for Large Wind Turbines - Høvsøre

Located in the **central western** part of Jutland, the Høvsøre test center is also managed by DTU and has place for five wind turbines, with a maximum height allowed of 165 m (Megavind, 2016). At the location, it is possible to test wind turbine safety, performance and noise levels. From 2017, the test filed got approval to increase its places from five to seven, bringing the national testing capabilities for large wind turbines to 16 places (Offshore Wind, 2017).

The turbines currently installed in Høvsøre can be found in table 10.

Table 10: Wind turbines in the national test field of Høvsøre (DTU Wind Energy, 2017 (b))

Place #	Company	Model	Power (MW)	Rotor Diameter (m)	Hub Height (m)	Tip Height (m)
1	Siemens Wind Power	SWT-2,5/120	2.5	120	92	152
2	Vestas	Vestas V100-2.2MW	2.2	100	80	130
3	Siemens Wind Power	SWT 4,0/130	4.0	130	95	160
4	Nordex Energy GmbH	Nordex N100-3300	3.3	100	75	125
5	Siemens Wind Power	Siemens SWT-3,6 130	3.6	130	99.5	164.5

Aalborg University

Located in the Northern part of Jutland, Aalborg University is equipped with testing facilities for determine the lifetime and toughness of power electronics components and systems used in wind turbines. The department responsible for these tests is the Center of Reliable Power Electronics (CORPE). More information about the center can be found on http://www.corpe.et.aau.dk/.

Blaest - Blade Test Center

Established in 2005, the Blæst test center is also located in Aalborg and focuses on structural tests for blades: stiffness and fatigue tests, thermographic and acoustic noise emission analysis are just some of the services offered by the test center, which can accommodate blades of a length up to 85 m. Plans are present to develop testing facilities capable of handling blades up to 100 m length. More information about Blæst can be found at http://www.blaest.com/.

Global Lightning Protection Services A/S (GLPS)

GLPS is located in Herning (central part of Jutland) and provide lightning tests, both on small and large wind components. In the specific, the testing facilities can accommodate indoor blade sections and full blades up to a length of 75 m. Materials can also be tested in, among others, their conductivity and electrical breakdown strength. The test center, which has 2,100 m^2 indoor testing facilitie, performs also striking simulations, with exposure risk assessment, current and voltage distribution simulation. The facilities can produce:

- High voltage and impulse voltage of 3 MV;

- Continuous HVDC voltage of 700 kV;
- High current of 250 kA (10/350 µs) and 1,500 C (DC current);

DTU Wind energy

The wind department of the Danish Technical University also provides a series of testing facilities: in addition to Østerild and Høvsøre (see section 6.3.1 and 2), DTU Wind also is responsible for the Risø National Laboratory, former nuclear test facility. The three test centers combined can provide full-scale wind turbine testing, as well as static blade test (up to 25 m, 45 m planned), drivetrain test (1 MW) and tests in a wind tunnel. More information about the testing facilities can be found at http://www.vindenergi.dtu.dk/english.

DNV GL

Among many other fields of operation, DNV GL also performs tests on materials, their resistance and their corrosion properties. In addition to that, also high-power, high-voltage and ultra-high voltage tests for transmission and distribuition equipment are carried out. Full-scale tests for static and dynamic loads, as well as extreme pressures and temperatures are part of the company's testing portfolio. More information on the institution can be found on https://www.dnvgl.dk/.

Force Technology & DELTA

Force Technology and Delta have recently merged: together, they provide material testing as well as a wide range of climatic tests; in their facilities, wind equipment can be tested to the hardest conditions that a wind turbine can found: extremely cold temperature, dust, and salted fog are just some of the examples of tests carried out at the faculties. More information can be found at https://forcetechnology.com/en

DHI

DHI performs tests of foundation structures, pipelines and cables both in shallow and deep water basins. The tests include wave impact on structural components, wave and wind interaction studies and CFD modelling. More information can be found on https://dhigroup.com.

Danish Technological Institute

The Danish Technological Institute (DTI) performs tests of joints, both standardized and customer specific, including friction testing. The facilities are equipped to test hardness and corrosion of welds and base materials and can accommodate components up to 40 m long on a reinforced concrete floor. High-temperature tests (up to 300°C) can also be performed for components up to 3 m long. More information can be found on https://www.dti.dk/.

Lindoe Offshore Renewable Center

The Lindoe Offshore Renewable Center (LORC) performs mechanical nacelle tests on a 10 MW test bench, but also climatic, corrosion and HALT (Highly Accelerated Lifetime Testing) tests. More information about the facilities can be found on http://www.lorc.dk/.

Nordic Folkecenter for Renewable Energy

Located in the North-West part of Jutland, the center is the ideal area for testing wind turbines, due to the particular wind conditions of the area. As part of its activities, Folkecenter perfoms test and provide certifications for both components and small wind turbines. More information about the facilities can be found on http://www.folkecenter.net/.

Despite the large numbers of testing facilities present in the country, a recent study (MEGAVIND) pointed out the need of increasing this testing capacity, so that the country would continue being the leader in the sector, despite the increasing foreign competition.

7. Institutions in the Area of R&F, Training and Education

Universities

Aalborg University

Located in the Northern part of Jutland, Aalborg University offers a wide range of courses related to wind and sustainable energy in general. The university is divided in three cities around the country (Aalborg, Esbjerg and Copenhagen). In 2016, the engineering faculty signed more than 450 agreements with external partners, proving that there is a close cooperation between the university and the industrial world. The university is very active in research and is also equipped with some testing facilities for the wind industry (see section 6.3.3). More information about the university can be found on http://www.aau.dk/.

Ingeniørhøjskolen Aarhus Universitet

The engineering school in Aarhus is part of the Aarhus University and aims to form high-quality engineers. All the research and development activities are carried out in cooperation with industries and research centers, meaning that the education is based on the newest knowledge and technologies available. The engineering school has approximately 2,500 students. More information about the institution can be found on www.ase.au.dk.

DTU Wind Energy

DTU Wind Energy is the department of the Danish Technical University (DTU) focusing specifically on wind. The department provides education (on campus and online masters), high-level research and manages the two national test-field for large wind turbines (see sections 6.3.1 and 6.3.2). Furthermore, the department is also in charge of the testing facilities of Risø (Roskilde), where a 4-rotor concept turbine can be found. More information about the department can be found on http://www.vindenergi.dtu.dk/.

University of Southern Denmark

The University of Southern Denmark (SDU) does not directly offer courses on wind energy, but it provides educations which can be related to the wind and energy fields. The university is divided in five campuses (Odense, Esbjerg, Kolding, Slagelse and Sønderborg) and has 32,000 students. More information about the university and its research activities can be found on http://www.sdu.dk/.

Other Training Institutions

EUC Vest / KursusCenter Vest

The EUC Vest center does not have a specific education on wind turbines, but provides a wide range of technical courses that can be used by already trained technicians to increase their knowledge about working environment both on and offshore. More information about the institution can be found on http://rybnerskursuscenter.dk/.

Falck Safety Services A/S

Located on the Western part of Denmark (Esbjerg), Falk Safety Services provides courses on safety on the workplace. They collaborate with many industries, with which they develop tailored programmes for specific fields. The institution has also an education regarding safety for wind turbine operators, which consists of four modules: manual handling, first aid, working at heights and fire awareness. For operators working on offshore wind turbines there is also the possibility to attend a fifth module on sea survival. All the courses are in accordance to the GWO (Global Wind Organization) parameters. More information about the institution can be found on http://www.falck.dk/da/safetyservices/kurser/vindkurser/.

International Wind Academy Lolland A/S

The Internation Wind Academyn (IWAL) provides safety training for wind turbines operators (first aid, manual handling, fire awareness, working at heights, sea survival) approved by the GWO. In addition to that, they provide also a basic technical training, consisting of 35 hours training on mechanical, electrical and hydraulic components. Furthermore, IWAL offers also a wind turbine technician course of a length of six weeks. More information about the institution can be found on http://iwal.dk/en/1050-2/.

Maersk Training

Mærsk Training provides courses mainly for the offshore industry. The courses offered for wind turbine operators are: GWO-approved safety courses (both for onshore and offshore), basic technical training, hub rescue and rope access. Furthermore, they also provide turbine-specific courses (e.g. for Siemens wind turbines). More information about the institution can be found on https://www.maersktraining.com/courses/category-list/wind.

Nordjyllands beredskab Uddannelsescenter

The Nordjyllands beredskab Uddannelsescenter provides safety education approved by the GWO. The modules offered are manual handling, first aid, fire awareness and working at heights. More information about the institution can be found on www.nordjyllandsberedskab.dk.

RESC - Center for Rescue and Safety

The institution provides GWO-approved safety courses. The modules offered are: first aid, manual handling, fire awareness, working at heights and sea survival. More information about the institution can be found on http://resc.dk/kurser/gwo/.

Nordic Folkecenter for Renewable Energy

Located in the North-West part of Jutland, Folkecenter offers, since 30 years, a training course on different renewable energy technologies, among which wind. Trainees can either carry out a theoretical research or focus more on practical aspects. The center has an availability of small wind turbines and components which can be used during the training process. More information about the institution can be found on http://www.folkecenter.net/.

8. Export Promotion Policies

There are no particular promotion policies for export in specifically tailored for the wind industry. An exception could be the MEGAVIND project (see section 6.3), which, by proposing improvements in the testing capabilities, makes the industry stronger and more competitive in an international scenario.

The major promotional activities regarding export are carried out by the Danish Wind Export Association, which was established in 2013 as a joint effort of the Danish Wind Industry Association and the Danish Export Association. The association helps the members to enter the international markets by organizing promotion campaigns, like exhibitions, visits of delegations, seminars and other event which can promote the "Danish Wind" brand. Furthermore, the members are also invited to meeting and seminars held in Denmark.

More information about the association and its activities can be found on https://www.dwea.dk/.

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DUBROVNIK CONFERENCE ON SUSTAINABLE DEVELOPMENT OF ENERGY WATER AND ENVIRONMENT SYSTEMS University of Zagreb.

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WWEA
World Wind Energy Association

World Wind Energy Association e.V.

Charles-de-Gaulle-Str. 5
53113 Bonn
Germany

Tel: +49-228-36940-80
Fax: +49-228-36940-84

wwindea.org
community.wind
small-wind.org