Energy Policy Toolkit on

Physical Planning of Wind Power

Experiences from Denmark

DANISH ENERGY AGENCY

The toolkits are drafted by the Danish Energy Agency (DEA) under the Danish Ministry of Climate, Energy and Building. DEA will publish a series of toolkits providing specific, technical and concrete information on Danish experiences and lessons learned on tools and measures in promoting renewable energy and energy efficiency, targeting practitioners, governmental energy experts and policy makers in growth economies and developing countries. The aim is to give qualified guidance to countries in their implementation of Green House Gas (GHG) reduction measures and Low Emission Development Strategies (LEDS).

Comments to this policy toolkit as well as queries on the Danish Energy Agency's Global Assistance are most welcome. The idea is to further refine recommendations according to identified needs in growth economies and developing countries. For comments and queries please contact: Mr. Kristian Havskov Sørensen, Chief Advisor, e-mail: khs@ens.dk, phone +45 3392 6738. For more information on DEA's Global Assistance and its policy toolkits please visit www.ens.dk/en/Global-assistance.

Abbreviations

CHP	Combined Heat and Power production
DC	Direct Current
DEA	Danish Energy Agency
EIA	Environmental Impact Assessments
GHG	Greenhouse Gas
GW	Giga Watt
kV	Kilo Volt
kW	Kilo Watt
LEDS	Low Emission Development Strategies
MW	Mega Watt
Power	Electricity
PSO	Public Service Obligation
R&D	Research and development
R, D & D	Research, development and demonstration
RE	Renewable Energy
TSO	Transmission System Operator

Contents

Introduction

Countries around the world face challenging energy choices today that may have significant implications for many years to come.

Economic growth and future prosperity is confronted by rapidly increasing energy needs worldwide. The bulk of today's global energy production is based on unsustainable fossil fuels such as coal, oil and gas. This poses a serious climate threat as well as a threat to the livelihood of future generations and people living in adversely affected regions and countries.

Concrete actions by countries as well as international efforts to find solutions to mitigate global warming are needed. Strong national strategies to phase out fossil fuels and in parallel increase the production of renewable energy and use that energy much more efficiently than we do today are needed.

Denmark has years of experience in sustainable energy transition promoting energy efficiency and renewable energy that could be relevant to countries wishing to make their energy systems more sustainable and less dependent on fossil fuels.

Wind power today amounts to approximately 30% of Danish electricity consumption. This achievement can be traced back to the energy crisis of the 1970s and has fostered a unique cluster of experiences and expertise that may prove valuable to other countries.

Firmly rooted in measures adopted by a broad parliamentary majority Denmark will by 2020 have:

- 35% renewable energy in final energy consumption.
- 50% of electricity consumption supplied by wind power.
- 7.5% reduction in gross energy consumption in relation to 2010.
- 35% reduction in greenhouse gas emissions in relation to 1990[1].

This is in line with Denmark's long-term target of 100% renewable energy by 2050.

Energy choices revolve around choosing appropriate policies and measures, on decisions with regard to the energy mix and on the timing and scope of investments in energy production and grids etc. Making bad choices today may lock-in polluting and/or expensive energy infrastructure for several decades. Therefore energy choices should be based on the best available guidance and experiences.

This policy toolkit presents and discusses Danish lessons learned on the physical planning of wind turbines and is the second of three Danish toolkits in the area wind energy. The three wind policy toolkits all focus on key aspects and challenges and barriers with regard to increasing the share of energy from wind power. The first wind power toolkit addresses the challenge of integrating increasing shares of fluctuating wind power into the power grid. The Danish case proves that this challenge is manageable by applying the right set of policy tools and measures, notably with regard to system operation and market instruments[2]. The third wind toolkit will present and discuss Danish lessons learned on financing and support schemes for wind power.

Denmark has over the years developed and improved the regulation on physical planning of wind power reflecting the early and high deployment of wind power. In looking for the best sites for wind turbines the concrete wind resources should always be an important driver as it improves the efficiency of wind power. However, involvement and addressing possible concerns of local stakeholders might be less important in some countries with less deployment of wind power compared to the Danish case. Hence, the detailed description of the various regulations in Denmark on physical planning will not be equally important across different countries, but hopefully some of the described regulation will be of relevance either now or in a not so distant future.

The toolkits are drafted by the Danish Energy Agency (DEA) under the Danish Ministry of Climate, Energy and Building. DEA will publish a series of toolkits providing specific, technical and concrete information on Danish experiences and lessons learned on tools and measures in promoting renewable energy and energy efficiency, targeting practitioners, governmental energy experts and policy makers in growth economies and developing countries. The aim is to give qualified guidance to countries in their implementation of Green House Gas (GHG) reduction measures and Low Emission Development Strategies (LEDS).

1. All numbers represent the current assessment of the effects of the Danish Energy Agreement of March 2012. All numbers are subject to uncertainty.
2. See www.ens.dk/en/toolkits

Comments to this policy toolkit as well as queries on the Danish Energy Agency's Global Assistance are most welcome. The idea is to further refine recommendations according to identified needs in growth economies and developing countries. For comments and queries please contact: Steffen Nielsen, Special Advisor, srn@ens.dk, phone +45 3392 6696 or Kristian Havskov Sørensen, Chief Advisor, khs@ens.dk, phone +45 3392 6738. For more information on DEA's Global Assistance and its policy toolkits please visit www.ens.dk/en/Global-assistance.

Policies, targets and framework conditions

Long term planning and a stable and supportive policy framework in Denmark have been fundamental to the successful large scale integration of wind power.

Denmark has a tradition of implementing vigorous energy policies with broad political support and involving a broad range of actors: national authorities, municipalities, power utilities, energy companies, industry, research institutions, NGOs and consumers. Setting targets for renewables has been a central planning tool. Targets signal long-term government commitment and thus reduce perceived investment risk. Outlined in the annex is a historical overview of Danish energy policy on promoting wind power in Denmark.

This chapter gives a status on wind power deployment in Denmark and outlines the policy target towards 2020. An introduction is given to the general planning and regulation framework for wind power and its grid connection. Lastly – before turning into the detailed physical planning regime for onshore and offshore wind respectively in the next chapters' Danish experience on public acceptance is discussed.

Status on wind power deployment in Denmark

At the end of the 1970s support given to installations and advantageous feed-in tariffs for electricity produced by wind turbines led to the creation of a bottom-up market for small kW-wind turbines while power utilities focused on developing MW-wind turbines. In the early 1980s, a number of small machine manufacturers (primarily those of traditional agricultural machinery) started producing the first small kW-wind turbines. From the beginning there was a competitive environment between the manufactures and a high level of transparency between the customers regarding the best products and solutions for wind turbines. The synergy that emerged is an essential background to the Danish success in manufacturing wind turbines.

Another characteristic of the Danish wind energy sector is the cooperatives. Many of the wind turbines in the 1980s and early 1990s were owned by local cooperatives. Since then, single-person ownership has superseded the importance of the cooperatives,

Wind power's share of domestic electricity consumption, %								
Statistics							Frozen policy scenario	
1990	1995	2000	2005	2010	2011	2012	2015	2020
1.9%	3.5%	12.1%	18.5%	21.9%	28.2%	30.0%	35.7%	50.1%

Table 1.
Source: Danish Energy Agency's statistics (1990-2011) and frozen policy scenarios to 2015 and 2020.[3]

3. The 2020 frozen policy scenario is based on the 22 March 2012 Danish parliamentary energy agreement including policies and measures arriving at 50% of electricity supply from wind power in 2020 and a decrease in gross energy consumption by more than 12% in 2020 compared to 2006. The parties behind the agreement represent 171 seats out of 179 in the parliament. The agreement establishes a framework for the policy on climate and energy up to 2020 and outlines the direction Denmark will take until 2050, where the target is full conversion to renewable energy.

and now utilities and large energy companies play an increasing role in the establishment and ownership of wind turbines in Denmark, especially when it comes to large offshore wind farms. The change happened partly on account of change in regulation and incentive structures.

Danish wind power deployment as percentages of national electricity consumption has increased significantly since 1990. An assessment is given of how wind deployment is expected to evolve towards 2020 based on already agreed policies as projections based on a baseline scenario – a so-called "frozen policy" projection.

In Denmark wind power covered around 30% of the electricity consumed in 2012. That was delivered by around 5,000 wind turbines with an installed capacity of more than 4,150 MW. Approx. 1/3 of the electricity generated by wind turbines came from offshore turbines, and 2/3 from onshore turbines.

Denmark has a long history of offshore wind – the first park was installed as early as 1991. Mid 2013 Denmark had installed 516 offshore wind turbines with a total capacity of 1270 MW.

The map pictures the existing on- and offshore wind turbines and their geographical distribution between east and west as well as designated areas for future offshore and near coast wind power.

Wind Power in Denmark

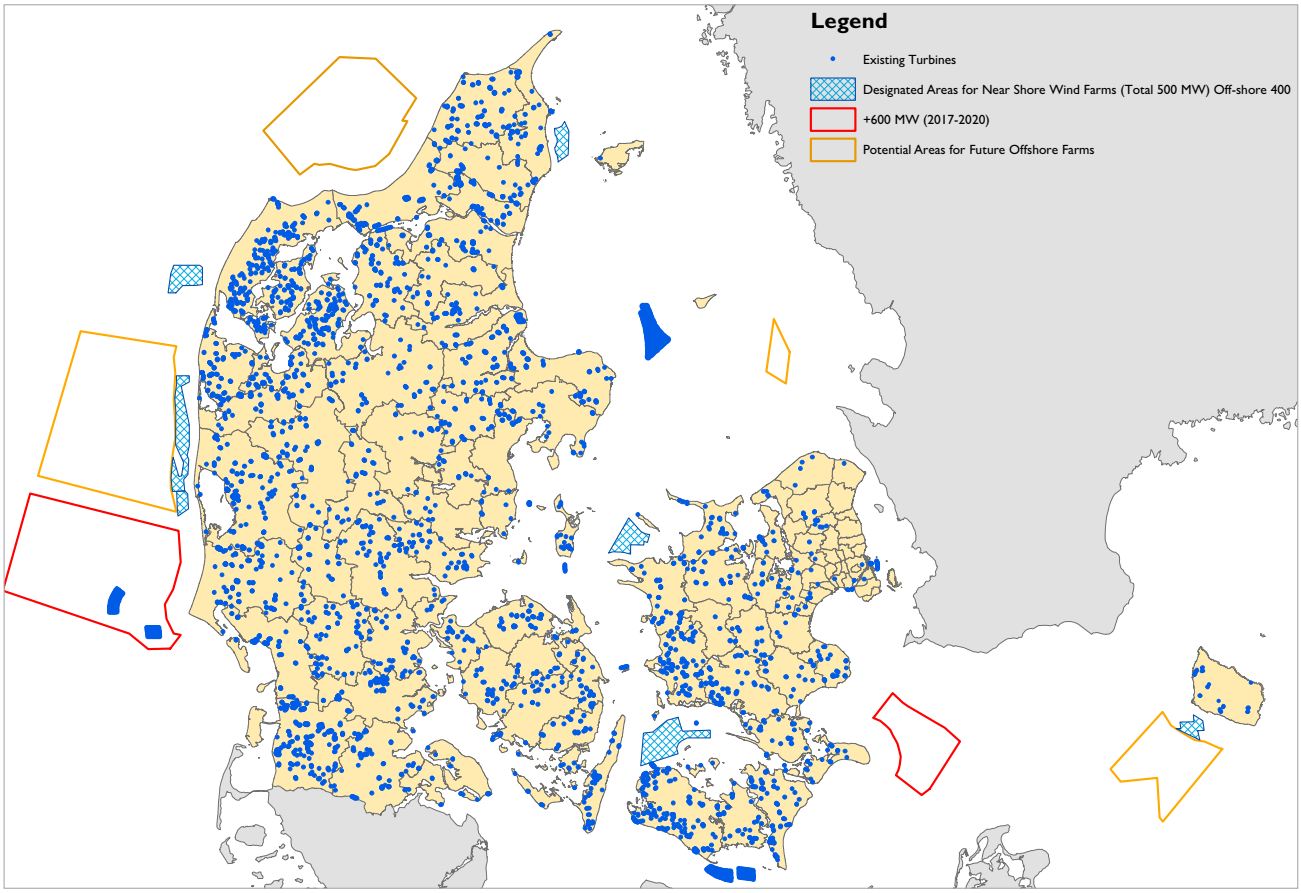


Figure 1.

Further development of wind power towards 2020

The most recent energy agreement from 2012 includes policy measures that will realise additional 2 GW wind power before 2020.

Included in the agreement is an additional 500 MW onshore wind (1,800 MW new capacity while 1,300 MW is expected to be decommissioned), 2 additional large offshore wind farms with a total capacity of 1,000 MW, 450 MW near shore wind power and 50 MW designated R&D-near shore wind power.

The 2 large offshore wind farms will be put to tender in 2013-2015 with an expected commissioning in 2017-2019 while onshore and near-shore projects will be successively commissioned. In total 2 GW of new capacity is scheduled to become operational before 2020.

KEY

Key points and recommendations from the Danish case:

› Set long-term policy targets on promotion and expansion of wind power to establish stability and security for investors, developers and producers.

General framework conditions for wind power

Wind power in Danish electricity supply has evolved continuously since the 1970s. From a physical planning perspective the regulation has gradually adapted to the technological deployment and development characterised by an increase of wind turbines both in numbers and size.

In the 1980s the location of new wind turbines was carried out with no overall plan. By the 1990s the wind turbine technology leapfrogged in size and efficiency almost on a yearly basis.

Following several repowering programmes the much larger turbines of today are more systematically included in the general planning framework. Thus a more organised approach for integrating wind power into the physical planning has been developed. The repowering programmes have also resulted in a significant reduction in numbers of turbines whilst the installed capacity has been increasing.

It should be noted that integrating wind power into the power grid and support schemes are both important aspects for wind power deployment, apart from physical planning. Those topics are addressed in separate energy policy toolkits.

Location of wind power and the physical wind turbine planning today is regulated by different authorities depending on whether it is on- or offshore.

The location of new wind turbines is carried out on the basis of an overall balancing of various factors such as wind speed, distance to nearest neighbours, noise and shadow effects, other technical installations, cultural heritage, agricultural interests, sailing, fishing and regard for the landscape and nature. All new wind turbines must comply with the Danish Wind Turbine Certification Scheme[4] in order to make sure that they are safe and can be incorporated without further ado into the power system.

4. In order to ensure that new wind turbines are safe and can be incorporated into the power system, a Secretariat for the Danish Wind Turbine Certification Scheme has been set up and located at the Danish National Laboratory for Sustainable Energy at the Technical University of Denmark – DTU-Wind Energy – (formerly known as RISØ). The specific regulations are described in Danish Energy Agency's Order no. 73 of 25 January 2013 on the technical certification scheme for the design, manufacture, installation, maintenance and servicing of wind turbines. The technical prescriptions for the connection of wind turbines to the electricity grid are available online www.energinet.dk/EN/El/Forskrifter/Technical-regulations/Sider/Regulations-for-grid-connection.aspx.

Wind resources mapping

Since the 1980s wind resource mapping has been developed and included in wind power planning both at national and municipal level. The development of a refined wind atlas for Denmark identifying national wind resources was published in 1999.[5] The wind atlas is used in the planning process when assessing the wind resource potential in a given area and to assess identification of potential wind development zones in line with the strategic environmental framework or assessments studies. Also it provides wind speeds prediction with known and traceable accuracy for developers and allows them to calculate the potential yield of the wind energy resources. In addition it gives the TSO ability to handle variable wind resources and it gives input to long-term grid planning.

Natural Environment

Regarding nature and environment it should be underscored that wind power is a clean way to produce electricity as there are no fuel emissions during operation.

Calculations show that a modern MW turbine in less than one year will produce the same amount of energy used for its manufacturing, location, operation and decommissioning[6]. Nevertheless, like other infrastructural activity attention has to be taken not to locate wind power within or close to vulnerable natural environments[7].

Large and uniform landscapes will also usually be suitable for large wind turbines. Such landscapes can match the large dimensions of the turbines because it is often characterised by flat or evenly sloping terrain with large and open spaces.

Small-scale landscapes will often be less suitable for large wind turbines. These landscapes are characterised by small hills or gentle slopes with smaller and more confined spaces, where large wind turbines would dominate and change the character of the landscape more.

Regardless the type of landscape – experience from Denmark show that any location requires customized planning including tailored wind farm patterns.

Onshore Wind Atlas for Denmark

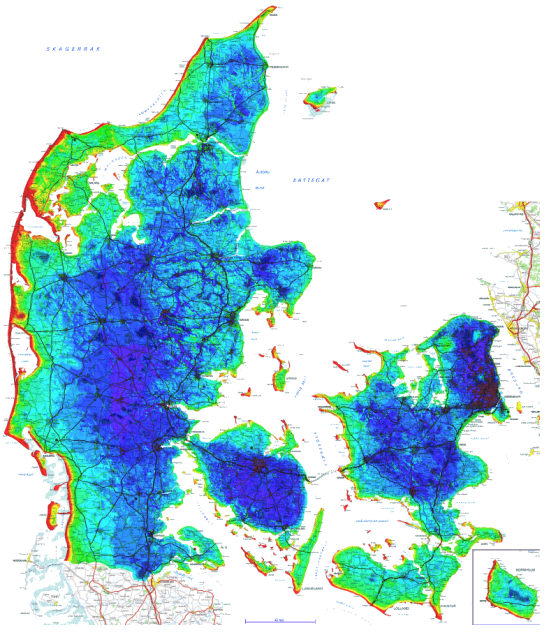


Figure 2. The figure illustrates onshore the wind power density in Wm2 at a height of 45 m above ground level. The range of mean wind speed is approx. 5.5 m/s (the dark blue) to approx. 7.5 m/s (the dark red).

Mean Wind Speed at 100 meter AMSL

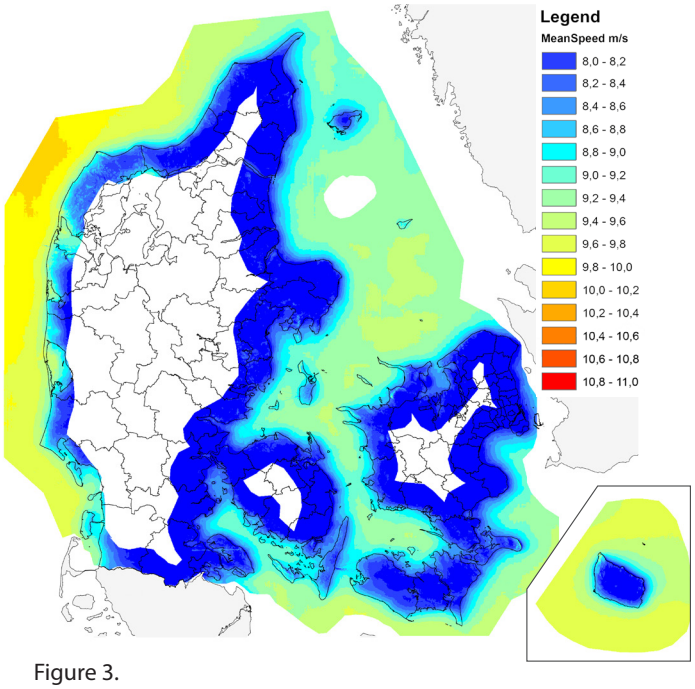


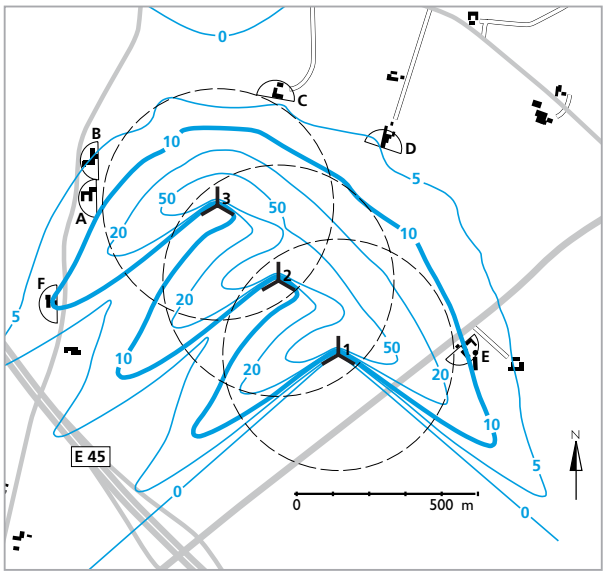
Figure 3.

5. A matrix with 200m squares has been calculated for different heights (25, 45, 70 and 100 m) for the whole country. For further information see www.emd.dk/wind-energy-consultancy/wind-resource-mapping/. Even though the mapping gives a close estimate, a concrete assessment – a so called wind-atlas calculation – has to be undertaken when assessing the exact potential from a specific location.
6. www.dkvind.dk/html/teknik/energibalance.html and www.vestas.com/en/about/sustainability#!energy-payback
7. See factsheet on the environmental impacts of offshore wind farms on page 26.

Noise and shadow effects

Generally, the location of new wind turbines must respect a distance from the nearest neighbours at a minimum of 4 times the total height of the wind turbine. This minimum distance reflects the visual impact of the wind turbines. Often this distance is also sufficient to comply with the noise limits as well as recommendations on shadows and flicker effects.

As shown in figure 4 the isolines for shadow effect for 0, 5, 10, 20 and 50 hours a year for a group of 3 wind turbines is indicated. The critical times for shadow cast occurs in Denmark either early in the morning or late in the evening and only in conditions where the sun is shining and the wind is blowing at the same time. The recommendation is that there should be no more than 10 hours with shadow effects on a yearly basis on average towards neighbours.



Figur 4. Isolines for shadow periods in hours per year. Lines for 0.5. 10, 20 and 50 hours.
Source: www.dkvind.dk/fakta/P8.pdf

FACT

Factsheet

Noice

Wind turbines must comply with noise limits, which are part of a statutory order. The noise level must not exceed 44 dB (A) at any dwelling at 8 m/s wind velocity and 42 dB (A) at 6 m/s. These noise limits are to be kept out doors at a maximum distance of 15 m. from the dwelling. In housing areas and noise sensitive recreational areas such as e.g. camping sites – more restrictive levels are required of 39 and 37 dB (A) at 8 and 6 m/s respectively. In 2012 an additional limit for the low frequency noise indoors was added of 20 dB at 6 and 8 m/s. The developer must demonstrate that these limits are met before the wind turbines can be set up, and after they are established the owner covers the cost to undertake noise measurements and calculations if demanded by the authorities i.e. before measurements are demanded they need to be justified by authorities. The noise levels are calculated based on the measured noise emission from the wind turbine and the distance to the dwellings and to the recreational areas; the measurement procedure and the calculation method are part of the statutory order as well.

Other infrastructure and land use interests

A general restriction excludes wind turbines within; conservation areas, nature protection areas, forests, national heritage, gravel mining sites and airport safety zones. General minimum distances are defined for certain land use interests including; Churches (300m), radio corridors (200m), main roads, highways and railroads (1-1.7 times total height) overhead transmission lines (1 times total height plus 15m to nearest phase), underground electricity cables (50 meters) gas pipelines (2 times total height). In addition a variety of other land use interests may pose restrictions on how close a wind turbine may be in the vicinity.

Aviation is a special concern. All significant obstacles to aviation should be visible at an appropriate distance, so the pilot can perform the necessary operational measures in due time.

Wind turbines are by virtue of their design difficult to mark on their highest point. Denmark is engaged internationally to develop new appropriate international standards and recommendations for marking and lighting wind turbines[8]. The existing provision has been developed over time in close cooperation between the wind power industry, planning authorities and aviation authorities, i.e. both civil and military. The provision is still being refined.

FACT

Factsheet

Marking and lighting

When marking and lighting wind turbines exceeding 150 meters the owner can chose between two different options:

1) The rotor blades, nacelle and upper 2/3 of the supporting tower of the wind turbine must be painted white (RAL 7035). Furthermore, the turbine must be equipped with two high medium intensity flashing lights placed at the nacelle visible 360^0 horizontally both during night and day. Finally, the distance between the light and the highest point (tip of the blade) must not exceed more than 120m.

2) The wind turbine can be marked with alternative options: Options are evaluated by the Danish Transport Authority on the basic of an individual risk assessment produced by the wind turbine owner.

Most onshore wind turbines between 100m to 150m should be equipped with low-intensity fixed red obstruction lights on the nacelle visible 360^0 horizontally both during night and day. In a few cases medium intensive flashing light might be necessary if special flight safety conditions apply. In this case, a specific assessment of the need for light marking of wind turbines between 100 and 150 meters is made. The assessment includes remarks from military authorities regarding military flights in the area. For offshore turbines it might be necessary to install red medium intensity lights on the nacelle due to search and rescue missions as well as military operations.

Wind turbines outside the obstacle limitation surface below 100m will under normal circumstances not need any light marking.

For wind farms, specific assessments are made. The general rule (applicable to turbines exceeding 150 meters) establish that where the distance between turbines does not exceed 900m it is sufficient to have significant light marking only on turbines placed in the outer perimeter as well as in corners, while the rest only needs low-intensity fixed red obstruction lights.

Large wind farms may have an effect on radars e.g. for aviation. Radars are typically designed to show only moving objects and filter out anything stationary. The spinning blades of the wind turbines may therefore appear on the radar screen. To avoid this in areas where radar surveillance is of importance, flight safety technology designed for detection and separation of small air targets and large surface targets like wind turbines may be applied.

The provisions and guidelines are expected to be refined further along the technological development in e.g. radar and other electronic devices for aviation etc.

8. The provisions in force are laid down in Regulations for Civil Aviation BL 3-11 of 21 March 2013.

General framework for grid planning

Integrating wind power into the distribution and transmission grids involves planning that combine grid analyses on connection of wind power with specific locations of wind farms. The aim is to transmit power most efficiently and with least associated transportation costs.

Connecting wind turbines to the grid was one of the first major challenges in the development of the wind sector in the late 1980s. The distribution grid had to accommodate for private owned small scale kW size turbines scattered more or less randomly around the countryside. Learning by doing was the dominating planning tool among municipalities and electricity grid companies to this new development.

Already before the development of the wind turbine industry the Danish transmission grid was rather strong and in general able to cope with the power generation delivered from wind turbines. Grid reinforcements were, however, necessary in the local 10 kV grid. And as size of turbines increased, reinforcements became in some cases also necessary in the 50/60 kV grid.

Early in the development – in 1986 – a fixed procedure for cost sharing had to be established by law. The grid company finances grid extension, and the wind turbine owner finances the transformer and local grid to a connection point – the principles remain today. See factsheet on cost sharing on page 13.

When wind power expanded in the early 1990s it became apparent that a more coordinated effort was needed. Subsequently the municipalities were requested to decide in their municipal plan where and to what extent wind turbines could be installed. In parallel, grid companies were required to appropriately extend and reinforce the electricity grid to the identified designated wind areas.

Wind turbines were in the 1990s generally connected to the power system through distribution grids of less than 100 kV. This was the case for both individual wind turbines and wind farms. But in 1998, it was decided to connect large wind farms (primarily offshore) directly to the transmission grid over 100 kV. The reasoning behind was that it is not possible to convey large power volumes in the existing, low- and medium voltage grid. The new challenge was to connect large wind farms in remote sites to the transmission grid, originally built to transport power in the opposite direction, from centralised power plants to consumers. It was possible to grid connect the first offshore wind farms of app. 160 MW without major investments in grid reinforcement of the existing transmission grid. Subsequently to avoid bottlenecks – reinforcements were made for some of the more recent large offshore wind farms.

Expansion of renewable energy – in particular with the Danish 50% wind power target in 2020 – spawns the need for expanding the transmission grid further.

The transmission grid above 100 kV is entirely owned by the TSO. The TSO prepared in 2009 – based on a political decision – a grid action plan for undergrounding of the entire 132 and 150 kV transmission grid. The plan outlines the possibilities of going from an overhead line network to a completely underground 132-150 kV electricity transmission grid. A grid that has been prepared to cope with the increasing volumes of wind power in Denmark taking into consideration system stability and minimum visual impact. The plan describes the decommissioning of the existing approx. 3,200 system km of 132-150 kV overhead lines and the construction of around 2,900 km of new 132-150 kV underground cables. The upgrading of the entire high voltage grid during the next 20 years will support wind integration due to redesign of the grid topology.

The grid action plan is revised every 2nd year and most recently in 2013. The process has 2 major objectives; to underground the 132-150 kV electricity transmission grid and to integrate more decentralised renewable energy power production in particular wind. For each new investment according to the plan a detailed business case forms the basis for the specific investment decision.

Together with Statnett – the TSO in Norway – the Danish TSO has also decided to expand the interconnection between Denmark and Norway with a new submarine cable, "Skagerrak 4", enabling the integration of more wind power into the Danish power system while enhancing the efficiency and competitiveness of the Nordic electricity market.

The Dutch and Danish TSO have further decided to investigate the possibilities of establishing an interconnection by the so called "COBRA" cable between Denmark and the Netherlands. The purpose is to

incorporate more renewable energy into both the Dutch and the Danish power systems and to enhance the security of supply. Moreover, such a cable would increase competition on the northwest European electricity markets. A regional business case for the project covering Denmark, the Netherlands and Germany is being developed, and this will clarify the socioeconomic benefits for the region, the optimal capacity of the cable, the size of the investment required and when the cable can be expected to be in operation. A final investment decision is planned for in December 2014. Commissioning of the cable connection can follow 3-4 years later.

FACT

Factsheet

Cost sharing

The local grid company or the TSO is required to connect onshore wind turbines to the grid. The connecting point to the grid and voltage level is assigned by the grid company. The grid company or the TSO bears the costs for the expansion and strengthening of the grid.

The grid company or the TSO are required to establish grid connections up to a connection point on the boundary of specifically designated wind area laid out in the municipality plan, when there is sufficient certainty for the provision of wind turbines with a total installed capacity of at least 1.5 MW. The developer has to provide adequate security such as a bank guarantee or equivalent collateral. The local grid company or the TSO specifies the voltage level. The developer on his part pays the connection costs. Connection costs include only the cost of the wind turbine installation, low-voltage connection, low-voltage socket, the establishment of a local wind turbine transformer, incl. meter, power cord to the power grid, grid connection including power factor correction, and the costs of the collective electricity supply company processing the request for grid connection. Costs for power factor correction for uncompensated reactive power consumption are financed by the Grid Company or TSO and eventually paid by electricity consumers via their general tariff (the PSO).

In a government offshore tender in the designated offshore areas, the Danish TSO builds and operates the technical installation that brings electricity from the wind turbines to the overall electricity grid, i.e. transformer substations, cabling as well as all necessary reinforcement onshore. Consent is given by the authority of the DEA. Costs incurred by the TSO for substation, the export cable and onshore cabling will be paid by the electricity consumers directly through the public service obligation tariff and will thus not be imposed on the owner of the concession. The owner of the concession will be responsible for the internal grid in the wind farm from the individual turbines to a specified connection point on the transformer substation.

In offshore open door concessions and near shore concessions the developer finances the grid connection up to the nearest shore. From there the responsibility is placed on the grid company, and costs will be paid by electricity consumers via their general tariff or PSO tariff if it is less than 100 kV.

When the optimal connection point has been identified, negotiations with land owners can begin and contracts sealed. If agreements cannot be reached possibility for expropriation may be the last resort for a solution. Regarding larger infrastructural activities e.g. when connecting large wind farms – EIA procedures including public consultation has to be aligned with the process for consent to the wind turbine installations itself.

Public acceptance

The Danish population has been and still is at large positive towards the increasing use of wind power.

Denmark has had a long tradition for local ownership of wind turbines. During the 1980s and 1990s many small investors were financially engaged in wind power. That engagement ensured local buy-in and a high degree of public acceptance.

Public acceptance has also been achieved through the planning process involving coordination between stakeholders such as national and local planning authorities, energy regulators, developers, grid operators and NGOs.

Public participation in the decision making process through public consultation procedures and meetings has led to a better public appreciation and higher accept rate. Having administrative appeal procedures available additionally gives the civil society a tool to test a case in front of an appeal board prior to the normal judicial possibilities through the courts.

As part of the Danish environmental monitoring programme for offshore wind farms , a willingness to pay study was undertaken in 2003 based on three samples; – a survey of 700 households in a national sample and 350 households in each of two sub-samples in targeted regions (Horns Rev and Nysted areas, respectively).

Across the three samples, less than 15% of the respondents indicated a negative attitude towards existing onshore wind turbines. Less than 10% of the respondents across the three samples had a negative attitude towards existing offshore wind farms. The same goes for an expansion of offshore wind power generation.

The willingness to pay for increasing the distance to wind farms was elicited based on the respondents choices between alternative offshore wind farm locations – and the associated increase in the electricity bill. A significant willingness to pay was found for wind farms located at distances where the visual disamenities would be significantly limited, i.e. up to 18 km from the shore. There were not equally strong preferences for having wind farms moved further out to a distance of 50 km, where they would be virtually invisible from the shore.

In 2009 another survey[10] sustained these findings. This time 91% of the Danish population was in favour of increased use of wind power in Denmark and 85% were in favour of an increase in wind power in their local area. This trend was also the case in an analysis from 2012 "The perception of wind turbines as experienced by their neighbours".[11] Nevertheless "not in my back yard" attitudes have sometime been the case due to the perceived negative effects on the landscape, potential noise including that of low frequency and potentially negative effects on private property. Construction of new high voltage transmission lines and the general enhancement of the entire power grid necessary to increase its flexibility have also been of some concern to local communities.

In order to sustain public support 4 new schemes were introduced in 2009:

- Local citizens' option to purchase wind turbine shares.
- Guarantee fund to support financing of preliminary investigations by local wind turbine cooperatives.
- Compensation for loss of value to neighbouring real estate.
- Green scheme to enhance local scenic and recreational values.

The schemes are further addressed in the onshore chapter.

KEY

Key points and recommendations from the Danish case:

- Ensure that all new wind turbines are safe and can be incorporated in the power system by applying internationally recognised technical certification guidelines.
- Map wind resources and place data in the public domain in order to:
  - Save cost and time for developers.
  - Assist in calculating the potential yield of the wind energy resources and in identifying potential wind development zones.
  - Handle variable wind resources.
  - Give input to long-term grid planning.
- Consider providing investors with a long-term investment horizon by identifying designated areas for future expansion of wind farms and in parallel require grid companies to make all necessary grid investments and grid extensions.
- Define clear noise limits that provide clear guidance for manufactures and developers of wind power projects.
- Develop in close cooperation with international standardisation initiatives a regime for light marking of wind turbines where this would be assessed unavoidable i.e. nearby airports etc.

Grid connection and planning:

- Consider timely planning of necessary investments in grid reinforcement of the existing distribution and transmission grids and alignment to the planning process of wind power.
- Take necessary grid investments of possible new sites for on- or offshore turbines into account in the planning process, especially when considering sites far from the location of the power consumption.
- Consider a fair and balanced cost-sharing framework for grid connection of wind turbines.

Public acceptance:

- Consider incentives for local communities to increase and sustain local acceptance and buy-in.
- Provide a transparent and embracing framework for public participation in decision making process e.g. through public consultation procedures and consultation meetings.

Onshore wind turbines

Around 4,600 onshore wind turbines are installed in Denmark. They are scattered across the Danish territory, although concentrations of turbines are higher in the western part of the country and in coastal regions where wind is ample.

The planning regulation in general ensures that citizens, associations, authorities and other stakeholders are continuously involved in the process through public consultations.

The Ministry of Environment through the Danish Nature Agency approves onshore turbines larger than 150 meters due to mere size e.g. assessment towards aviation and their potential visual impact on the surroundings.[12]

For onshore wind turbines[13] up to 150 metres the planning authority is the municipalities.

Siting

Wind turbines in the 1970s and 1980s were often spread out in the landscape, which meant that they impacted a very large area with a quite limited installed electrical output. Since 2001 several repowering programmes have been introduced with the aim to incentivise the scrapping of old outdated turbines and have them replaced with new more effective ones placed in a more structured manner and integrated into the overall planning framework.

Wind turbines[14] typically are placed in areas designated through reservations and following guidelines in the municipal plan. The municipalities are obligated to actively take into account planning of wind turbine locations – hence consider access and designate areas suitable for wind turbines through municipal planning.

The balancing of different land use interests when siting wind power onshore is brought about through the municipal wind turbine planning, which enables involvement of citizens, organisations, authorities, etc.[15]

In the context of planning, the landscape is divided into urban-zones and land-zones. Any developments in the land-zone including wind turbines need a special land-zone permission.

The municipality must in its planning ensure that it gives full consideration to neighbouring residences, nature, the landscape, culture-historical values etc., and – of course – the possibility of harvesting the wind resource. All these considerations must be implemented into a municipal plan.[16]

New municipal plans must also satisfy the requirements for environmental assessment, which include consultation with the relevant authorities, including neighbouring municipalities, the region (county) and national bodies that have to grant environmental approvals to allow implementation of the physical planning, as well as any local and regional supply companies whose installations may be affected by the project.

Special consideration must be given to the coastal zone, which is defined in the Danish Planning Act as a three-kilometre zone from the coastline. If a municipality wants wind turbines onshore in the coastal zone, this requires special planning and functional justification, for example that there is especially favourable wind conditions along the municipality's coastline.

In order to be able to assist the municipalities in its work a Wind Turbines and Planning Task Force has been set up within the Danish Nature Agency, under the Ministry of Environment. The Task Force provides municipalities with guidance and practical assistance in wind turbine planning, e.g. in identifying the sites that are most suitable in respect of neighbours and nature protection interests, share relevant information and lessons, interpret relevant national legislation and participate in citizen and stakeholder meetings, etc. In public meetings, the task force can help answer questions about national legislation and political targets, with which the local authorities have to comply in

12. The Ministry of Environment is the authority that handles applications for infrastructural activities with potential substantial environmental impact. The procedures are similar to projects approved by the municipalities (turbines below 150 m) including public consultation and Environmental Impact Assessments (EIA). These types of approvals have been particularly relevant in relation to the need for test sites of new prototypes for manufactures.
13. Wind turbines below 25 kW only have to notify municipalities that the project complies with the law of construction. Small turbines also have to be certified in accordance with the technical approval scheme and comply with noise regulation like large turbines. If the project is in the land-zone then a land-zone approval needs to be given in addition.
14. Excluding the smallest turbines below 25 kW.
15. The regulations for siting are set out in the Danish Planning Act and implemented in Wind Turbine Circular no. 9295 of 22 May 2009.
16. Municipalities may decide that a local plan has to be undertaken for new infrastructure projects such as wind turbines. A local plan must include decisions on the exact location, numbers and height and visual appearance of wind turbines.

the planning process. Most of Denmark's municipalities are in dialogue with the Task Force, either to get answers to specific queries or to obtain assistance with the planning process. The Wind Turbines and Planning Task Force have a Danish website[17] that contains answers to frequently asked questions as well as tools for use in municipal wind turbine planning. This also includes a summary on key siting considerations, i.e. restrictions and possibilities, information on the planning process and a timeframe as well as links to all relevant legislation.

A working group has looked at a number of challenges in municipal planning for new onshore wind turbines with the objective to review the existing plan paradigm in order to assess the opportunities and constraints found in the current framework. The task was also to look at whether municipalities have the right planning tools to help to ensure the Government's objectives for the continued expansion of wind turbines. Recommendations from this work included that municipalities should promote conditions that could expand designated wind turbine sites through voluntary acquisition and expropriation as well as potential wind turbine sites in wetlands. It was also recommended to continuously expand and digitise information on relevant protection issues relating to nature and landscape interest. In line with the recommendations a joint initiative by the Danish Energy Agency, the Environmental Protection Agency, the Nature Agency, national TSO, Energinet.dk, and the Transport Authority has produced a web platform – Wind-Info[18]. The platform was introduced in 2013 and compiles information on wind turbines from all the relevant national authorities' websites to citizens, municipalities and wind turbine developers.

A new guideline to provide an overview of the process that lead to identification of new areas for wind turbines and a new draft decree on planning for wind turbines have been drafted by the Danish Nature Agency with a consultation deadline 28 October 2013. The guideline is targeted municipal planners, but also interested citizens will be able to get help to understand how the authorities are working with wind turbine planning.[19]

KEY

Key points and recommendations from the Danish case:

- Consider designating areas to wind turbines through a local planning process with due consideration to optimal wind conditions, distance to neighbours and visual impacts etc.
- Cluster wind turbines in the landscape by placing them in wind farms. Generally it is socioeconomically better to cluster wind turbines. Among the many advantages to cluster wind turbines in larger groups should be highlighted; that a few large projects rather than many small ones make it easier for grid companies to connect the turbines; it is easier to plan for project developers; there are less administrative planning burdens for municipalities; fewer neighbours are affected; potential environmental impacts including visual impacts are lumped together in fewer areas.
- Consider to establish an entity, e.g. a national wind turbines and planning task force that can support local authorities in the planning process.
- Consider a web based hub linking different authorities in play regarding onshore wind.

17. www.naturstyrelsen.dk/Planlaegning/Planlaegning_i_det_aabne_land/Vindmoeller.
18. www.vindinfo.dk/ – in Danish only.
19. www.naturstyrelsen.dk/Planlaegning/Planlaegning_i_det_aabne_land/Vindmoeller/Cirkulaere_og_vejledning_om_vindmoeller/

Process line for concrete project proposals

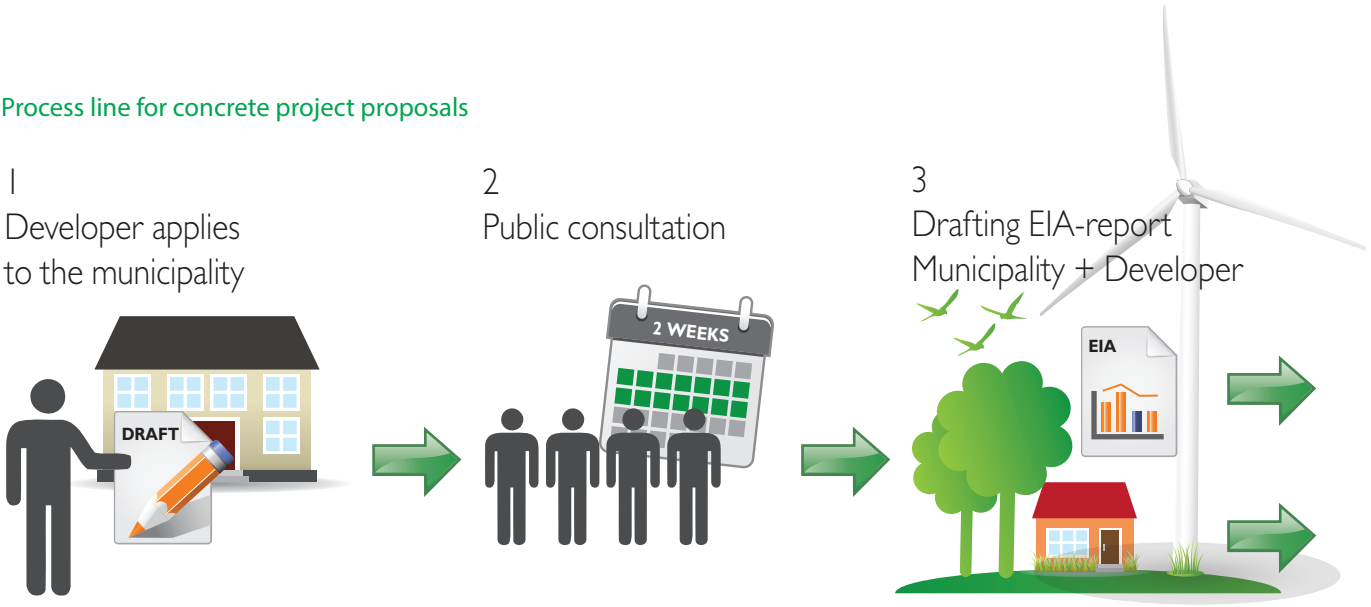


Figure 5

Consent procedure

The approval procedure for onshore wind turbines is an open door process which means that a potential developer in principal can apply for a project at any time. Commonly the municipalities identify sites for potential wind turbines in their municipal plan.

Process for the Environmental Impact Assessment

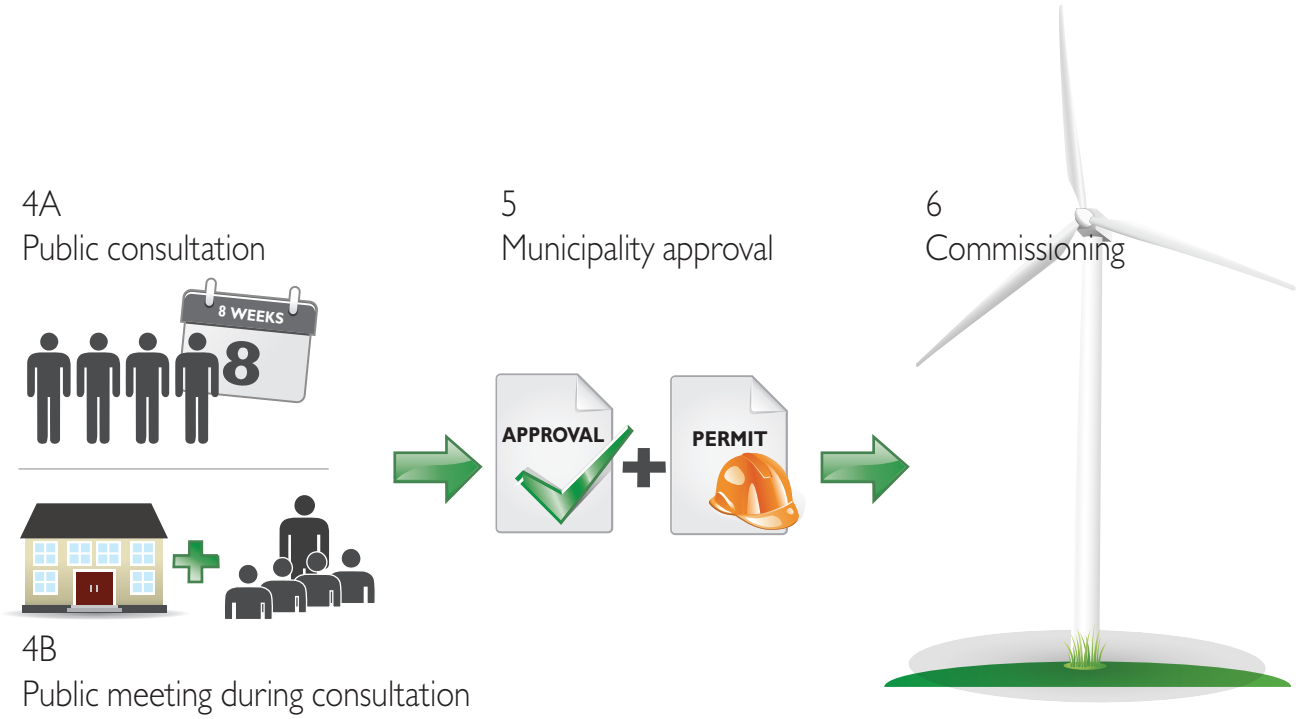
Generally the concrete planning of specific projects is initiated by a project developer who wishes to use a designated area for wind turbines – after having identified a good spot based on verified wind resource estimates. A project developer wishing to establish a wind turbine project must apply the project to the municipality.

Projects involving turbines with a total height of more than 80 metre or a group of more than three turbines must be accompanied by an Environmental Impact Assessment (EIA) assessing the consequences of the project for the environment. An EIA is often required in approval processes as most projects involve groups of turbines or turbines above 80 metre. The objective of the EIA regulation is to assess relevant environmental aspects and suggest relevant measures to eliminate or minimise these, prior to any construction permit.

The EIA must include a description of how the wind turbine project will affect neighbouring residences in terms of noise and shadow, nature, the landscape, cultural-historical values, agricultural interests etc. The EIA must also provide data and information on local wind conditions and calculate the expected reduction in CO_2 emissions.

The planning process for projects requiring an EIA begins with a design phase in which the municipality drafts a discussion paper inviting comments, concerns and proposals from the public. This design phase, which is also called the pre-public phase, must last at least two weeks.

The planning process for projects requiring an EIA also involves consultation with the relevant authorities to identify potential restrictions or interests that may require modifications of the project to gain their permit. Based on the feedback that it receives from the consultation, the municipality draws up guidelines on the further local planning and determines the scope of the EIA, adjusts the project accordingly and decides on the necessary mitigation measures to gain the EIA approval. This material is sent for public consultation lasting at least eight weeks. In this public phase, property owners, neighbours, associations, authorities, etc., may submit objections, comments and alternative proposals.



After an EIA procedure including public consultation, the municipality can finally, after any revisions deemed appropriate following the consultation and hearing phase, adopt the wind turbine project and give the project developer an EIA approval if not rejected.

If a local plan also has to be drawn up for the project, the local council in the municipality draws this up in parallel. The local plan for a wind turbine area must include regulations on the turbines' exact location, number, minimum and maximum total height and appearance.

After the process proposal has been published, the project can only be changed, if the changes are not significant, i.e. do not significantly change the environmental impact described in the EIA in size and numbers. However, the project may only be limited and not expanded neither taller nor more turbines. Otherwise a new EIA has to be sent out in a new public consultation procedure.

Drafting various materials, public involvement etc., both the municipal designation of wind turbine areas and the municipality's subsequent processing of a specific project takes time. In order for the developer to obtain a building permit on average (on- and offshore) takes 34 months in Denmark compared to the EU average of 42 months.[20] Complaints on decisions concerning wind turbine projects may be appealed to the Environmental Board of Appeal.

20. See www.windbarriers.eu

Figure 5 illustrates the process line for concrete project proposals:

1. The developer applies to the municipality by sending a draft plan.

2. The municipality undertakes a public consultation of the draft plan for at least 2 weeks.

3. The municipality is responsible for the EIA-process and EIA-report. In practice the drafting of the EIA is, however, often carried out in close cooperation the project developer.

4A. The EIA is sent in public consultation for at least 8 weeks.

4B. The municipality in parallel consults the local plan. Typically a public hearing meeting is arranged during that period – e.g. the developer is required to visualise the project and prepare other material with the view to inform concerned citizens at a public meeting – see factsheet on special schemes regarding confidence building on page 20-21.

5. Approval or rejection by the municipality. If the project is approved, the wind turbines must be registered at the municipalities with documentation that the noise regulation is kept. Simultaneously a construction permit is applied for.

6. Commissioning

Appearance

The EIA includes photorealistic computer visualisations of the project to allow citizens to get a realistic impression of the visual and aesthetic implications of the wind turbine project on the landscape from key points and at varying distances.

It is recommended that turbines onshore as a general rule should be grouped. The wind turbines in a group should be uniform and placed in an "easy to recognise" geometric pattern in relation to the landscape, e.g. a single straight line with an even distance between the individual turbines, and keep a distance of minimum 28 times the height of turbines in between groups. In order for groups of turbines to be placed closer than this, an assessment should first document an acceptable combined visual impact by the two groups. As a starting point, the aim is to site new wind turbines in groups wherever possible so as to achieve a high wind power production with impact on a relatively small area.

It is also important that wind turbines in a group should appear harmonious and uniform in size and design, preferably of the same make. A wind turbine is regarded as harmonious if there is a balance between tower height and rotor diameter. As a rule of thumb the relation between the height of the tower and the rotor diameter should be equal in order to arrive at a harmonic appearance. This is applicable for turbines up to 90 metres total height. Due to the more slender design of larger turbines and especially their rotor blades, the ratio of these can allow for comparatively larger rotors and still appear harmonic. Generally, experience recommends that the most harmonious tower/rotor ratio for larger wind turbines is 1:0.9–1.35, depending on the total height. As an example, a wind turbine with a tower height of 80 metres and a rotor diameter of 100 metres, giving a total height of 130 metres, has a tower/rotor ratio of 1:1.25.

The guidelines above reflects the particular Danish circumstances – where wind turbines and their design has undergone a significant change during the past 30 years – from small kW turbines to large MW sizes in a prevalent cultural landscape.

FACT

Factsheet

Special schemes regarding confidence building[21]

4 schemes were introduced in 2009 aimed at promoting the local population's acceptance of and involvement in the development of onshore wind turbines. All the schemes are administered by the Danish TSO. All wind turbines above 25 kW both onshore and offshore – are covered by the four schemes:

The first scheme concerns local citizens' option to purchase wind turbine shares:

- The option-to purchase scheme allows the local citizens to purchase a minimum of 20 % of the wind project. The developer must advertise locally shares equal to the minimum 20 % of project value (cost price). Any citizen who is at least 18 years old and live up to 4.5 km. from new turbines is eligible and has priority entitlement to buy into local projects. A shareholder share revenue, risk and costs on an equal footing with the developer. Remaining shares not bought by citizens within the 4.5 km radius are offered to permanent residents in the rest of the municipality.

21. It has to be noted that the schemes has been developed in a Danish context. To safeguard tangible incentives for the further deployment of wind power schemes should take country specific circumstances into account if sought applied.

The second scheme concerns a guarantee to support financing of preliminary investigations by local wind turbine cooperatives:

- The guarantee scheme support local wind turbine cooperatives with preliminary investigations for new wind power projects by giving loan guaranties, i.e. if the project fails the loan is reimbursed.
- The fund provides a guarantee up to DKK 500,000 (approx. 65,000 euro) for each project to undertake preliminary investigations, i.e. feasibility studies on technical and economic assessment of wind turbine locations and preparation of applications for authorities and EIAs.
- Eligible projects must consist of at least 10 participants, where the majority must have a permanent residence within a radius of 4.5 km from the planned wind or being permanent residents in the municipality.
- The fund is financed as a public service obligation (PSO).

The third scheme concerns compensation for loss of value to neighbouring real estate due to new wind turbines:

- The loss-of-value scheme gives neighbours of new wind turbines – if found eligible – compensation for value loss on their property. If a property is assessed to lose more than 1 % of its real estate value as a result of the introduction of new wind turbines, the developer is obliged to pay for such loss of value. The loss of value is determined by a valuation authority. A voluntary agreement on payment of depreciated value is optional.
- The developer is required to visualise the project and prepare other material with the view to inform concerned citizens at a public consultation meeting no later than 4 weeks before the municipal planning process ends. The TSO approves the announcement material to be used in conjunction with the meeting and explains at the meeting about the scheme.
- The owner of the property must notify his claim of loss of value on his property. For those having real estate further away than 6 times the total height of the turbine a DKK 4,000 fee (approx. 500 euro) must be paid – subject to be refunded if the claim is found eligible.
- In the period from 2009 to 2012 around half of the claims made were found eligible to receive compensation while the other half were rejected or lapsed.

The fourth scheme (green scheme) concerns enhancing local scenic and recreational values:

- With the green scheme municipalities can improve areas for new wind turbines. Municipalities may apply for reimbursement for projects that enhance the landscape and recreational opportunities in the municipality such as establishment of a new nature trail or educational materials on climate and energy.
- The size of the total envelope corresponds to approx. DKK 88,000/MW
- The scheme is financed by the TSO as a PSO.

KEY

Key points and recommendations from the Danish case:

- Make clear requirements on Environmental Impact Assessments in terms of definitions of administrative requirements, procedures and deadlines.
- Consider to have public consultation at an early stage of a project proposal.
- Consider incentives and measures to sustain or increase public acceptance.

Offshore wind turbines

The main driver for Denmark to move offshore is the scarcity of land for onshore sites, and the abundance of shallow waters with ample wind resources.

Since 1991 offshore wind has purposely been placed in large wind farms evenly distributed between east and west with due consideration to the power output and build-up of experience.

In 1985 the 2 large vertically integrated power utilities (i.e. having ownership of production and transmission/ distribution) were given an obligation to engage in large scale offshore wind power in order to gain experience. The power utilities' obligation to move offshore was realised by 2 pilot projects in eastern and western Denmark respectively. In 1991 Denmark became the first country in the world to place a wind farm at sea – the Vindeby offshore wind farm, followed by another – Tunø, in 1995. Meantime the planning of the first two large demonstration offshore wind farms in the North Sea (Horns Rev) and the Baltic Sea (Nysted) had begun.

The geographically different locations in the North Sea and Baltic Sea also gave opportunity to obtain experience in the western and eastern transmission grids both in relation to handling grid connection from offshore transformer platforms and in relation to system operation, i.e. managing the variable power.

Large offshore wind farms are usually located far from major centres of consumption and are connected to the transmission grid in sparsely populated areas. The transmission grid must therefore also be able to transport the power from the offshore wind farms over long distances. Spatial planning has subsequently been used to identify potential locations for offshore wind farms – taking into account grid connection routes and other areas of interests.

Finally the objective was to undertake an environmental monitoring programme with due respect to different offshore conditions i.e. different salinity, currents and tides, and different locations providing for different species, habitats and impact on migratory patterns etc. All this in order to ensure that future offshore wind farms could be established in suitable areas and in a way that would avoid or diminish substantial adverse environmental impacts.

Some offshore wind farms have been built because power utilities prior to the liberalisation had the obligation to do so – i.e. Horns Rev 1 and Nysted. Others are wholly or partly owned by local wind turbine cooperatives or other public or private entities. Most new large scale as well as the so called new near coast wind farms are being tendered – both are placed in designated areas identified on the basis of a Strategic Environmental Assessment.

Existing offshore wind farms			
Name (commissioning year)	Numbers, Capacity	Ownership	Scheme
Vindeby (1991)	11 turbines, 5 MW	Power utility	Obligation
Tunø Knob (1995)	10 turbines, 5 MW	Power utility	Obligation
Middelgrunden (2000)	20 turbines, 40 MW	Power utilities/ Cooperative	Obligation/General scheme
Horns Rev I (2002)	80 turbines, 160 MW	Power utilities	Obligation / Demonstration
Rønland (2003)	8 turbines, 17 MW	Private/Cooperative	General scheme
Nysted (2003)	72 turbines, 165 MW	Power utilities	Obligation / Demonstration
Samsø (2003)	10 turbines, 23 MW	Cooperative/Municipality	General scheme
Frederikshavn (2003)	3 turbines, 7 MW	Power utility/University	R&D
Horns Rev II (2009)	91 turbines, 209 MW	Power utility	Tender
Avedøre Holme (2009/10)	3 turbines, 11 MW	Power utilities/ Cooperative	General scheme
Sprogø (2009)	7 turbines, 21 MW	Public enterprise	General scheme
Rødsand II (2010)	90 turbines, 207 MW	Power utility	Tender
Anholt (2013)	400 MW	Power utility	Tender
Offshore wind farms in planning process			
Name	Numbers, Capacity	Ownership	Scheme
Frederikshavn (2011-2015)	6 turbines (height max 200 m)	Power utility	Open-door / R,D & D
Offshore wind farms planned for tender			
Name	Numbers, Capacity	Ownership	Scheme
Horns Rev 3	400 MW		Tender
Kriegers Flak	600 MW		Tender
Near-shore wind farms[22] including projects in the pipeline having received licence to do pre-investigations*			
Name	Numbers, Capacity	Ownership	Scheme
Meil Flak*	20 turbines (60-120 MW)	Cooperative	General scheme/Tender
Nissum Bredning*	11-14 turbines (66-84 MW)	Grid company/ Cooperative	R,D &D/Tender
North Sea (south)	t.b.d.	-	Tender
North Sea (north)	t.b.d.	-	Tender
Sæby	t.b.d.	-	Tender
Sejerøbugten	t.b.d.	-	Tender
Smålandsfarvandet	t.b.d.	-	Tender
Bornholm	t.b.d.	-	Tender

Table 2.

22. A total of 450 MW + 50 MW R&D turbines are scheduled to come on-line by 2020.

Siting

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. The Danish Energy Agency (DEA) has been given the mandate to plan for and issue licenses and production approvals to offshore wind turbines and is thus the responsible authority for planning and commissioning. DEA also approves new grid connections.

Designated offshore wind power locations have been identified through a screening process – which took off already around 1990 realising that the availability of onshore sites for wind farms became increasingly limited in the relatively small and fairly densely populated Danish territory.

In 1995 the Danish Government formed a committee to define the main areas in Danish waters suitable for establishing large offshore wind farms. The possibilities for utilising shallow waters for offshore turbines in Denmark were evaluated in collaboration between the power utilities and the Danish Energy Agency. An action plan for offshore wind farms from 1997 recommended to concentrate large offshore development within a few areas and to carry out a large-scale demonstration programme.

In the action plan five areas were identified as suitable for future offshore wind farms. The selection was based on experiences from the first two small pilot projects (Vindeby and Tunø) and the recommendations from the work of the governmental committee, which included

Designated areas, 1997

Figure 6.

wind speed measurements, mapping of water depths, visual impact on the coastal landscapes and an assessment of other interests in Danish waters. The objective of the program was to investigate economic, technical and environmental issues and speed up offshore development to open up the selected areas for future wind farms.

3 of the identified areas (Læsø, Omø, and Gedser) was subsequently ruled out as being less attractive due to other areal interests such as concerns of sailing routes and having a potentially environmental unacceptable impact on certain species etc.

For the remaining 2 areas – Horns Rev and Rødsand (Nysted) a comprehensive environmental measurement and monitoring programme was initiated to investigate the effects on the environment before, during and after the completion of the wind farms. The purpose was to ensure that offshore wind power does not have damaging effects on the natural ecosystems and to provide a solid basis for decisions about further development of offshore wind power. The measurement and monitoring programme has been considered important for both the extension of the offshore wind farms at the specific sites, and for the establishment of additional large scale offshore wind farms not only in Denmark but also in neighbouring countries. All information has been published in English and placed in the public domain[23].

Subsequently in the late 1990s an emerging public interest to form cooperatives in offshore wind also leveraged private investments for part of the projects Middelgrunden and Samsø.

23. www.ens.dk/en/supply/renewable-energy/wind-power/offshore-wind-power/environmental-impacts

FACT

Factsheet

The environmental impact of offshore wind farms

As an integral part of the projects for the first two large demonstration offshore wind farms in the North and Baltic seas, (Horns Rev and Nysted), an Environmental Monitoring Programme was carried out between 1999 – 2006 to document the impact of the projects on the marine environment reflecting 2 different types of habitat.

The effect studies took the point of departure in the classical BACI design (Before After Control Impact).

The analyses in the environmental monitoring programme have dealt with:

Benthic fauna and vegetation: Studies of bottom fauna and vegetation, including the food basis for fish, with particular focus on the introduction of hard bottom habitats, e.g. the turbine foundation and scour protection.

Fish: Studies of the distribution of fish around the wind turbines and the scour protection and the impact of electromagnetic fields on fish.

Marine mammals: Studies of the behaviour of harbour porpoises (small whales), and seals in and near the wind farm areas.

Birds: Studies of migrating, resting, foraging and moulting birds, including modelling of collision risks and monitoring of bird collisions with wind turbines.

Attitudes: Sociological and environmental economic studies of people's attitudes towards the wind farms.

On completion of the programme a smaller follow-up programme was launched focusing on the long term effects for harbour porpoises, water birds and fish.

The general conclusion from the environmental programme is that offshore wind power is possible to plan and set up in an environmentally sustainable manner[24].

The results show that the foundations of the offshore wind farms have created new artificial habitats, thereby contributing to increased biodiversity and better living conditions for the local fish communities. Seals and harbour porpoises were only affected in the short term during the construction work. Birds are able to find their way around the offshore wind farms, without significant collision risk. Resting and foraging birds seem to be able to habituate.

The results of the studies have been positively evaluated by an International Advisory Panel of Experts on Marine Ecology, consisting of experts with unique competence within the individual branches of the entire monitoring programme.

The decision-making process relating to the programme has been characterised by openness and dialogue between all parties involved. For instance a dialogue with representatives from the main green NGOs[25] was organised.

24. The results of the Environmental Monitoring Programme are published on the website of the Danish Energy Agency, www.ens.dk/EN-US/SUPPLY/RENEWABLE-ENERGY/WINDPOWER/OFFSHORE-WIND-POWER/ENVIRONMENTAL-IMPACTS/Sider/Forside.aspx
25. World Wide Fund for Nature (WWF), the Danish Society for Nature Conservation, the Danish Outdoor Council, Greenpeace, the Danish Ornithological Society and the Danish Organisation for Renewable Energy.

The Danish Energy Agency, in conjunction with the other relevant authorities and the national TSO again in 2007 mapped Danish waters for future large-scale offshore wind farms.

The report: "Future Offshore Wind Turbine Locations – 2025" was published by The Committee for Future Offshore Wind Turbine Locations in April 2007. The report charts a number of possible offshore areas where offshore turbines could be built to an overall capacity of some 4,600 MW that potentially could generate approximately 18 TWh, or around 8% of total energy consumption in Denmark. This corresponds to approximately 50% of Danish electricity consumption. The committee examined in detail 23 specific possible locations each of 44 square kilometres as indicated in figure 7. The sites were prioritised according to public interests such as wind speed, grid transmission, naval and air navigation, nature, landscape, raw material extraction, and the anticipated cost of establishing and operating the offshore wind farms. In particular the committee examined the engineering, economic and planning options for landing power and the consequences for the underlying grid. The committee attached importance to a planned and coordinated expansion of wind power and the transmission network with a view to obtain the greatest possible economic benefits in respect to the results of the environmental monitoring programme. The 400 MW at Anholt commissioned 4 September 2013 was ranked as the number one priority.

Designated areas, 2007

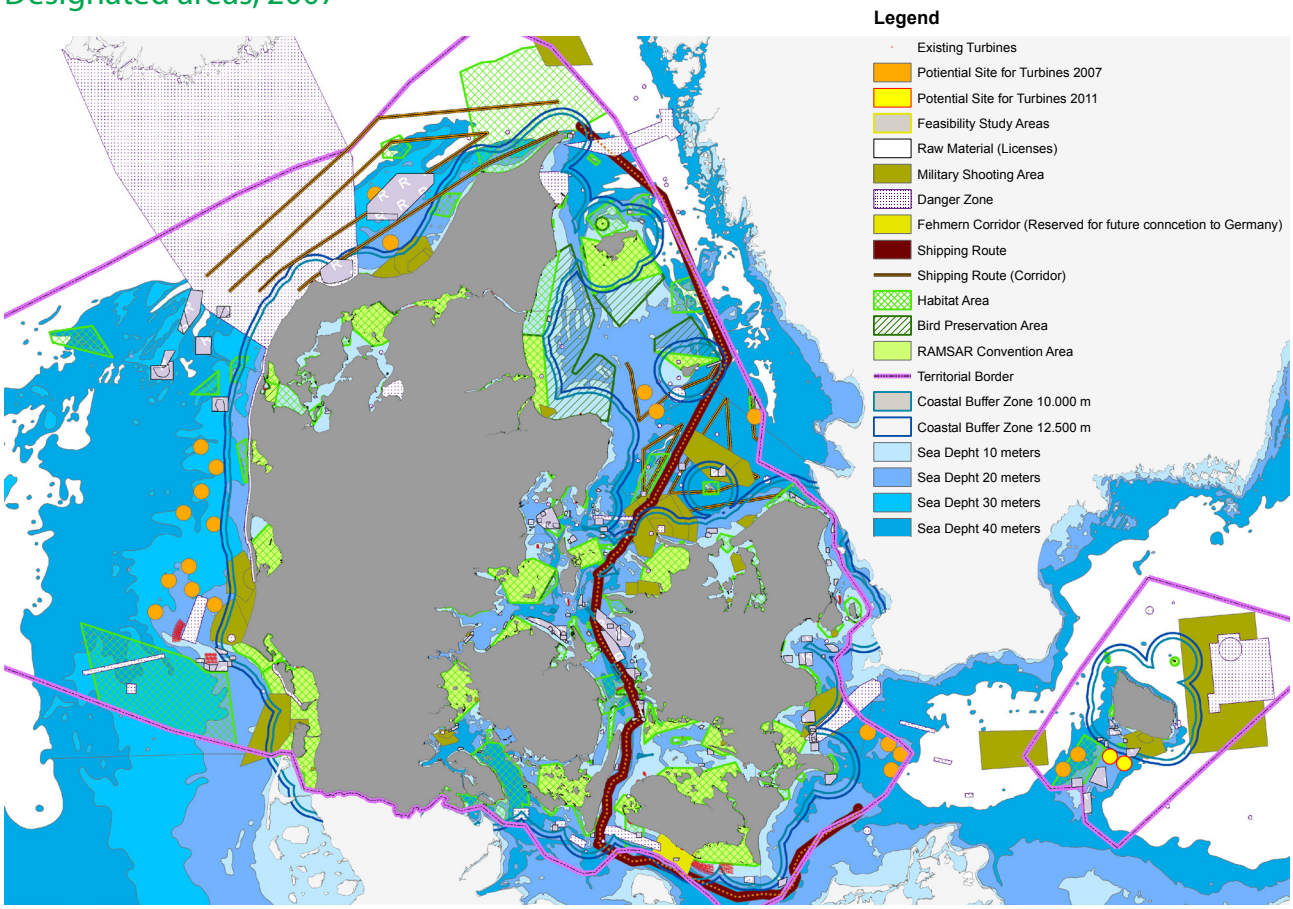


Figure 7.

Subsequently the mapping exercise was updated in 2011. The update was carried out with due consideration to the ever changing framework conditions for developing offshore wind farms caused by the emergence of new interests such as bridges, pipelines, harbours, fishing quotas. In other words the update recognised that mapping it is a dynamic process.

6 locations – within the sites identified in 2007 – were re-evaluated according to the updated area interests and number of trade-offs such as economic, technical, grid connection, sailing, nature, landscape, mining and dredging, etc. That exercise resulted in slightly different priorities and is the current basis for the planning and expansion of offshore wind power.

In addition to the large offshore areas 15 suitable nearshore sites have been identified in a mapping exercise carried out in 2011. The 15 sites were submitted to a strategic environmental assessment in order to prevent any future conflicts with environmental and natural interests. Special emphasis was put on ensuring a planned and coordinated development of offshore wind farms and the associated transmission grid.

Designated areas, 2011

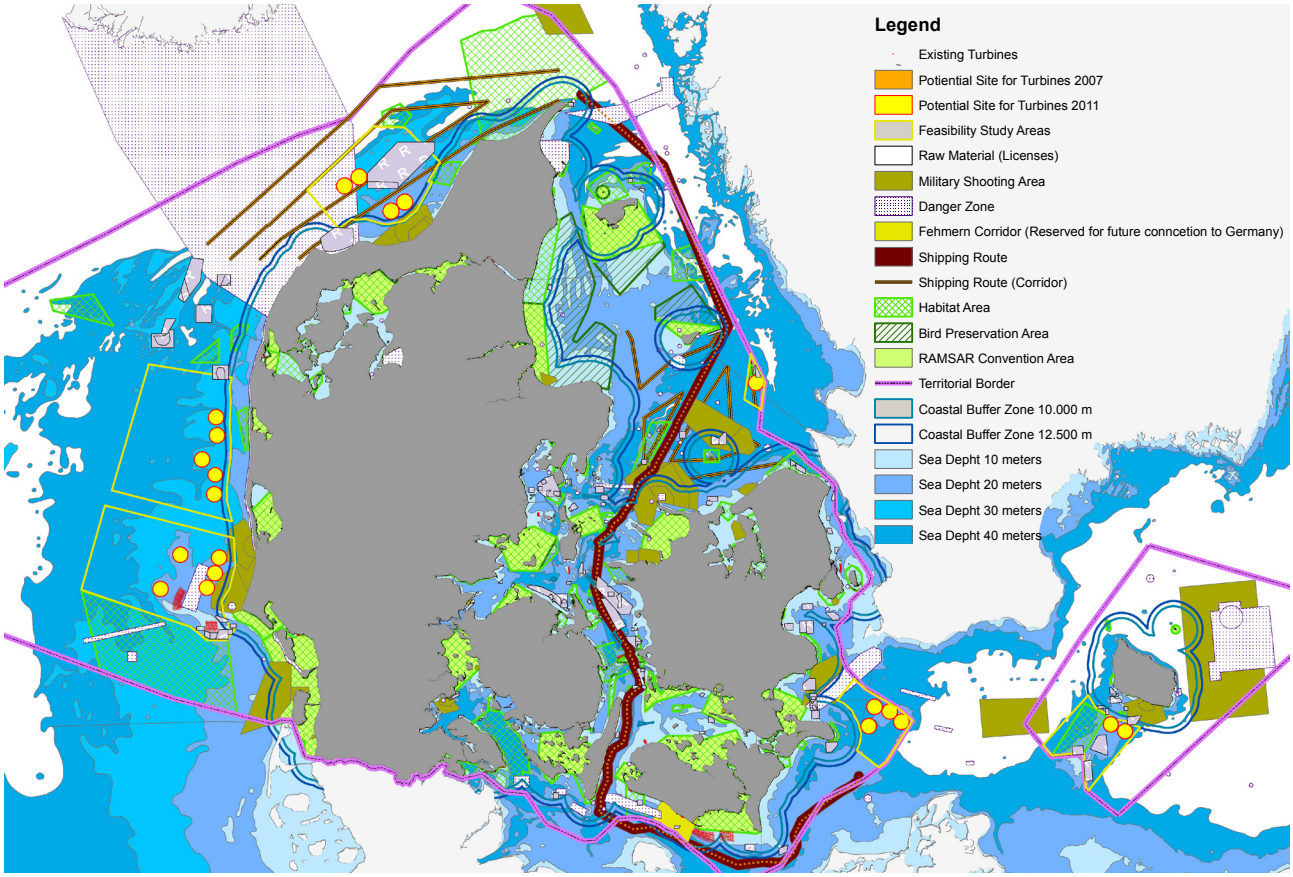


Figure 8.

KEY

Key points and recommendations from the Danish case:

- Carry out a thorough screening and planning before designating areas for offshore wind turbines.
- Take wind conditions, sea depths, grid connection options, seabed conditions, marine life etc. into consideration when screening for suitable sites for offshore wind farms.
- Consult with evidence from effect studies on environmental impacts already assessed and accessible in the public domain before requiring expensive and time consuming analysis as part of the EIA requirements.
- Consider to set up a general framework for environmental impact assessments (EIAs).

Consent procedure

In total 4 licences are required to establish an offshore wind project in Denmark. All licences are granted by the Danish Energy Agency, which serves as a "One-stop-shop" for the project developer in relation to the many – often opposing – interests connected to the establishment of offshore wind power projects. The 4 licences are:

1. License to carry out preliminary investigations.
2. Licence to establish offshore wind turbines.
3. Licence to exploit wind power for a given number of years, and – in the case of wind farms of more than 25 MW – a particular approval for electricity production in compliance with the electricity legislation.
4. Licence for grid connection. (can be included in the licence to establish the offshore wind turbines for smaller projects).

The 4 licenses are given successively for a specific project. As part of the licence to establish offshore wind turbines an EIA must be carried out. The specific procedure for the EIA regarding offshore electricity producing installations is described in an executive order issued by DEA.[26]

In the Danish case, new offshore wind farm projects can be established according to two different procedures: a government tender or an open door procedure. The procedures have been gradually developed as experience has been gained since the first offshore wind power projects.

For all types of offshore and near-shore projects significantly and individually affected parties as well as relevant environmental organisations may appeal the Danish Energy Agency's decisions to the Energy Board of Appeal within four weeks of the publication of the decision to establish a project. Likewise the onshore infrastructure may be appealed to the Environmental Board of Appeal.

Due to the thorough strategic planning in identifying suitable locations offshore ahead of the EIA for concrete projects – evidence show that projects are rarely appealed. In one case of an open door decision – a project to be located nearby a harbour was reduced both in number and size after an appeal. The reduced project once again was appealed – but the appeal board sustained the decision made by DEA.

Offshore Tender

In the government tender procedure, the Danish Energy Agency on the background of a political decision announces a tender for an offshore wind turbine project of a specific size, e.g. 400 MW, within a defined geographical area. A government tender is accordingly carried out to form the political decision to establish a project. The Danish Energy Agency runs the tender in a designated area and brings the project in an open competition round to ensure the best project at the lowest possible costs. The objective is to ensure that the licences are given to the most cost-effective projects in a fully transparent process and that all bidders are on an equal footing. Allocation of designated areas for offshore wind power is based on economic, technical, grid and environmental considerations.

A procedure was introduced in 2008 in preparation for the tender of the 400 MW Anholt offshore wind farm aiming to further minimise the risk premium in the tender offers. In the new model the TSO is responsible for the EIA, geophysical surveys as well some geotechnical surveys to be carried out in the planning phase ahead of the call for tenders. This early action is implemented in order to reduce the length of the approval process. At the same time it provides potential bidders with a high investment security and thus supports a reduced risk premium. The winner of the tender eventually has to reimburse the TSO for the costs of these preliminary surveys.

Simultaneously with the preliminary surveys the TSO also undertakes planning, procurement, and financing of the substation and sea cable to shore. This important part of the project must be ready by the time the offshore wind farm is up and running. If this should not be the case, the wind farm is entitled to compensation by the TSO.

In the cause of a political decision making process – 2 sites at Horns Rev and Krieger's Flak were identified to be suited for the next tenders. The areas have average

26. Order no. 815 of 28 August 2000 on assessments of impacts on the environment of offshore electricity producing installations sets out the detailed conditions for this type of EIA.

wind speeds of around 10 metres per second. The good wind conditions at the chosen sites will allow offshore wind farms to produce for around 4,000 full-load hours a year. With sea depths of 10-35 metres and a distance to the coast of 22-45 kilometres in the mapped suitable sites, a balance has been struck between economic considerations and the visual impact observed from the shoreline.

The model of "preparation for tender" is also used in the forthcoming government call for tenders for 1 GW offshore at Horns Rev 3 and Kriegers Flak. In order to obtain better competition new tenders include dialogue, openness and flexibility in the procedures. The Danish TSO was in 2013 well underway with preliminary investigations of areas including environmental impact assessments, geophysical and geotechnical surveys. The results of the preliminary investigations will be published in good time before completion of the tendering procedure. The costs of the preliminary investigations will subsequently be refunded by the owner of the concession. Also the expected costs will be published well before tenders for the wind farm are to be made.[27]

27. For more information on the 2 tenders please consult: www.ens.dk/en/supply/renewable-energy/wind-power/offshore-wind-power/new-offshore-wind-tenders.

FACT

Factsheet

Horns Rev 3

Horns Rev 3 is located in the North Sea, north of the two existing offshore wind farms; Horns Rev 1 and 2.

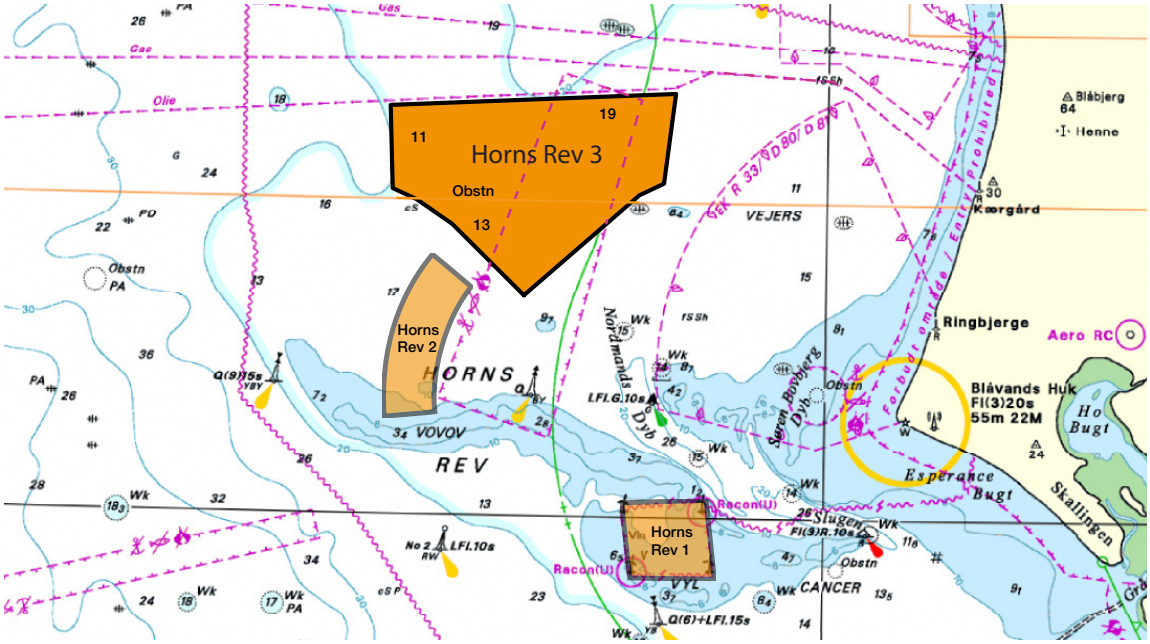


Figure 9

The area in the North Sea has good wind conditions. Sea depths of less than 20 metres and good conditions for foundations mean there are attractive natural conditions for establishing offshore wind farms. Facts:

- Distance to shore 10 – 30 km
- Distance to harbour 25 – 55 km
- Mean wind speed 9.8 m/s
- Sea depth 10 – 20 m
- Seabed (surface), sand
- Tide, 1 – 2 m

The area for preliminary investigations area at Horns Rev 3 is about 190 km^2. The location of the area and its borders have been determined on the basis of sea depths, distances from the coast, navigation, a nearby military area, distance to Horns Rev 2, etc. The specific area for construction will be specified before the tendering procedure is completed. However, there will be a degree of flexibility for the owner of the concession within the area.

Detailed planning of the offshore grid connection infrastructure has commenced and the transformer substation for Horns Rev 3 will be commissioned no later than 31 December 2016. This means that the owner of the concession has a guarantee that the produced power can be routed onshore from 1 January 2017. However, there is no requirement that power must be produced from this date. The wind farm must be ready for full production from the start of 2020. There is full flexibility for establishment and grid connection within this period.

FACT

Factsheet

Kriegers Flak

With its 600 MW Kriegers Flak will become Denmark's largest offshore wind farm. The wind farm should be ready to produce power by 2020.

The wind farm will be located at Kriegers Flak in the Baltic Sea close to the border with Sweden and Germany. On the German side of Kriegers Flak construction of the Baltic 2 offshore wind farm is in progress. A permit has also been issued to establish an offshore wind farm on the Swedish side of Kriegers Flak, but construction is pending.

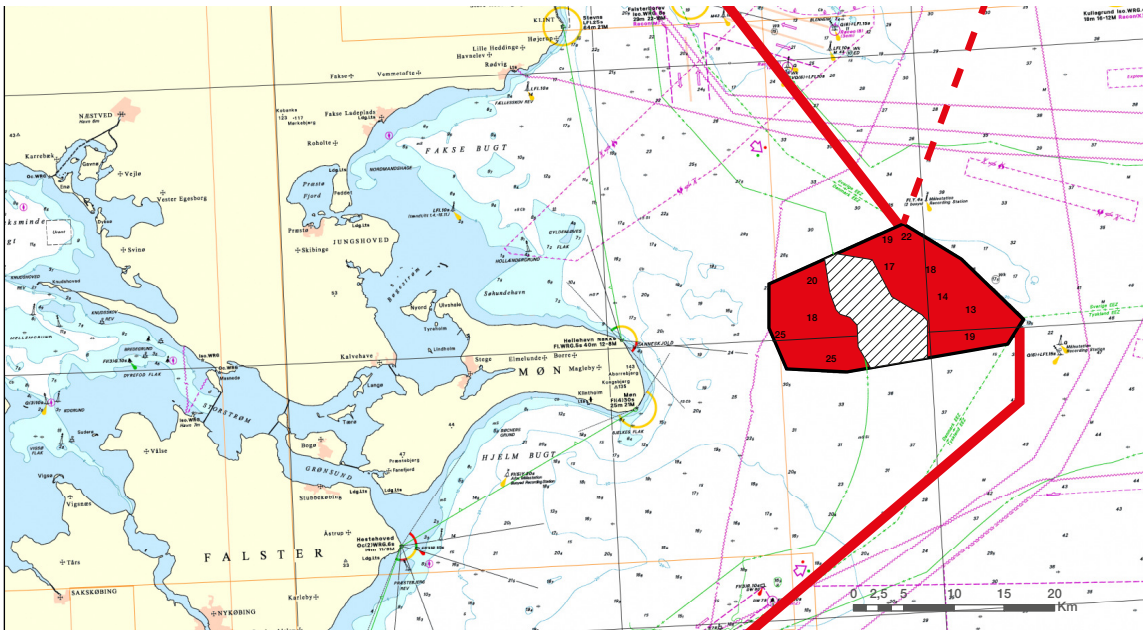


Figure 10

The area for preliminary investigations at Kriegers Flak is about 250 km^2. The location and borders of the area have been determined on the basis of limits related to sea depths, distance to the coast, borders with Sweden and Germany, existing cables, and dredging (see the marked striped space). The specific area for construction will be specified before the tendering procedure is completed. However, there will be a degree of flexibility for the owner of the concession.

There are good wind conditions and the waters are more sheltered than in the North Sea. Facts:

- Distance to shore 15 km
- Distance to harbour 20 – 40 km
- Mean wind speed 9.5 m/s
- Sea depth 15 – 30 m
- Seabed (surface), sand and residual sediments (from moraine/till deposits)
- Tide, none

The wind farm will be connected to the German farm, Baltic 2. There will be common grid solution which will ensure that power can be led to both Denmark and Germany and that the cable can also be used as an interconnector to exchange electricity between the two countries. A potential extension to Sweden will be possible. There will be grid connection for Kriegers Flak from 1 July 2018.

Near-shore Tender

6 near-shore sites out of the originally 15 have been politically chosen to host a total of 450 MW to be commissioned before 2020, each with room for up to 200 MW and a minimum of 4 km from shore. An area may, however, include several smaller projects. The areas have been designated in accordance with a number of criteria, including construction and operating costs and municipal support. The near-shore tenders include dialogue, openness and flexibility in the procedures. The areas will be in competition with each other – thus it is not expected to be built in all 6 areas. 3 to 4 areas are the most likely scenario. The near shore wind farms will be visible from shore. Therefore local support for the projects is very important. Thus the 6 areas have been selected partly because there is already significant municipal support for the wind farm project in these areas. In order to maintain local support, it has been decided that concession owners will be required to offer at least 20% of each project to local residents and enterprises – like in the case for onshore projects. Note that there is only an obligation to offer this share, not to achieve it. In order to give an additional incentive for gaining public support a higher feed-in tariff will be available to projects that achieve at least 30% community ownership on the date of grid connection.

The TSO will carry out EIAs for all 6 sites. The results of the geophysical surveys are expected published by November 2014. By February 2015 a full draft EIA is planned to be published and sent for public consultation.

The developer must pay for grid connection to the nearest coast. From that point , costs will be carried by electricity consumers as part of the PSO fee.

Near-shore designated areas

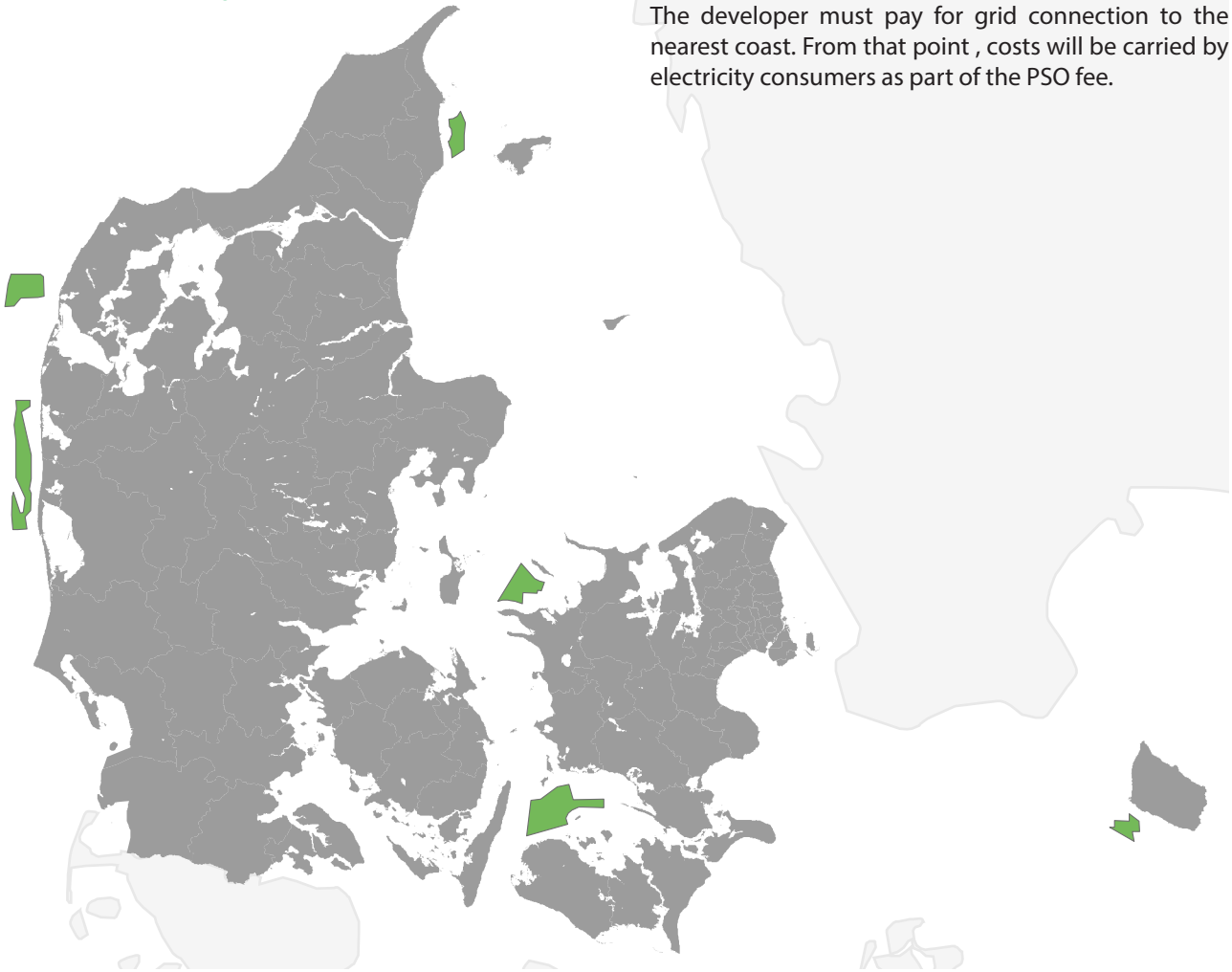


Figure 11. The following areas have been designated: North Sea (south), North Sea (north), Sæby, Sejerøbugten, Smålandsfarvandet and Bornholm – see the map

Turbines for test and demonstration

A call for 50 MW near-shore turbines for test and demonstration not tied to the designated areas to be located anywhere conditions allow has been announced running until end 2019. The projects must have a clear technological development objective aimed at reducing the future costs of offshore wind turbines. The test projects can include up to eight turbines.

Open door

In the open-door procedure, the project developer takes the initiative in establishing an offshore wind farm in a particular area. This is done by submitting an unsolicited application for a licence to carry out preliminary investigations in the given area outside areas that already are – or areas planned to be – designated wind power areas. 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. Before the Danish Energy Agency actually begins processing an application, a hearing of other government bodies is initiated to clarify whether there are other major public interests that could block the implementation of the project. On this basis, 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.

The preliminary investigations include as a minimum an EIA as well as geophysical and geotechnical surveys of the seabed to clarify what type of foundation should be used.

The EIA must assess the offshore wind farm's impacts on the environment. On the basis of responses from the initial consultation of authorities and other stakeholders, the Danish Energy Agency determines what the EIA should include offshore. As an EIA needs to examine the total coherent project i.e. also the onshore infrastructure necessary, hence the Danish Nature Agency and municipalities are the EIA authority regarding what to include for these parts. The EIA must demonstrate, describe and assess the environmental consequences of implementing the project in respect of: people, fauna and flora, seabed, water, air, climate and landscape, tangible property and Danish cultural heritage.

Furthermore, the EIA must describe proposals for alternative siting and proposals for how demonstrated environmental nuisances can be prevented or reduced.

The project developer's application to establish the offshore wind farm must include a full description of the project's expected scope, size, geographical location, coordinates for turbines, grid connection plans and cable trace, etc., as well as the results of the preliminary investigations.

Once the Danish Energy Agency has received the EIA together with a final application to establish the offshore wind farm, it sends both for public consultation with a deadline for reply of at least eight weeks. The consultation is announced on the Danish Energy Agency's website and in national and local newspapers. This gives other authorities, interested organisations and citizens the opportunity to voice objections and other comments, which the Danish Energy Agency includes in its processing of the application and the EIA.

If the Danish Energy Agency does not receive any objections with weighty arguments for cancelling the project such as detrimental impact on a protected species, it grants a licence to establish the offshore wind farm. In this regard, the Danish Energy Agency will generally require the project developer to document, prior to starting the construction work, a detailed project description.

The project developer must finally apply for a licence to exploit wind power from the offshore wind farm and, in the case of wind farms of more than 25 MW, for an authorisation to produce electricity. This must be done after the installation work has begun and at the latest two months before the first wind turbine is ready to begin operating. The offshore wind farm must not supply electricity to the grid until the licence and, where required, the approval has been granted. In this way it is assured that all obligations given in the consented document is fulfilled.

In open door concessions in locations outside designated offshore wind areas – the project developer receives the same price premium as for new onshore wind turbines. In offshore open door concessions and near shore concessions the developer finances the grid connection up to the nearest shore.

FACT

Factsheet

One Stop Shop

In order to make preparation of new offshore wind turbine projects as simple as possible for project developers, the Danish Energy Agency has organised the overall official handling as a "one-stop shop", which means that a project developer wishing to establish an offshore wind turbine project primarily has to deal with one authority to obtain all the necessary approvals and licences. The aim is to ensure a rapid and un-bureaucratic processing.

As a one-stop shop, DEA involves other relevant authorities. DEA also arranges consultation with the relevant stakeholders and issues all the necessary approvals and licenses. The Danish model has provided a quick process improving the development and deployment of offshore wind turbines as a whole.

DEA serves also as a one stop shop when tendering concessions. The enterprise or consortium which wins a concession will use DEA as the entrance to assistance on issues related to all permitting. The tender material provides drafts of all the necessary permits needed for constructing, owning and operating the offshore wind farm.

Immediately after being awarded a concession contract after completion of the tendering procedure, the enterprise or consortium can expect to obtain a permit to carry out preliminary investigations (preliminary investigations permit) and a permit to establish an offshore wind farm within a specified area of territorial waters on the framework conditions and terms stipulated in connection with the tender itself (permit for the establishment of an offshore wind farm).

The preliminary investigations permit will allow an enterprise or consortium which is awarded the concession contract to very quickly conduct geotechnical and geophysical surveys to supplement the surveys already carried out.

Similarly, the concession owner will be able to commence the detailed planning and prepare the final project in detail with the permit for the establishment of an offshore wind farm. A detailed project has to be approved before actual construction work can start. Primary requirements are that the wind farm itself fits within the EIA report for the project and that the terms in the permit for the establishment of an offshore wind farm will be fulfilled.

Furthermore, a permit will be obtained to exploit the wind resources in the area to produce electricity. The permit is not usually issued until the construction work has started and no later than grid connection of the first turbine. It is also important to be able to document compliance with the terms of the permit for the establishment of an offshore wind farm.

Before the installation is connected to the grid, a permit to produce electricity will be granted (electricity production permit). The requirements regarding technical capacity and financial capacity in connection with the prequalification and tender submission will be adapted to the requirements for an electricity production permit. This will provide assurance that an enterprise or consortium will also be granted an electricity production permit.

All of the permits mentioned above are included in the tender specifications as draft permits. They are issued by DEA which, by that time, will have consulted all other relevant authorities in advance, or when the need may arise during the construction phase.

KEY

Key points and recommendations from the Danish case:

- Consider establishing a one-shop-stop for investors, planners and contractors, i.e. providing one and primary government entry point.
- Consider to have all preliminary investigations including EIAs be carried out by state authorities so that the designated areas are ready for tenders and with limited risks for investors and developers.

Key Messages

Choosing the optimal locations for wind turbines should be based on a carefully designed and informed planning process that takes economic, environmental and public considerations into account.

Wind resource assessments are fundamental to estimate the wind power production of potential sites and are in turn the basis for designating areas to wind turbines through a local planning exercise with due consideration to other land use interest.

Generally physical planning of wind power may concern several different local as well as national authorities. This may significantly increase costs for investors and developers. It may defer them from entering the market and possibly discourage bids on tenders. Developers in Denmark experience relatively few interactions with authorities in the planning process. This fact speed up procedures and prevent pit holes. To overcome administrative barriers and based on the Danish experiences it is recommended to establish a "one stop shop" that compiles all relevant information and makes necessary processes more streamlined and effective. It is also recommended that the state provides guidance and practical assistance to local authorities e.g. via a wind turbine and planning task force.

Further authorities can pave the way for investors and developers by carrying out the EIAs as well as other preliminary investigations in advance of a project and hereby minimising the investment risks.

Grid connection of wind power is yet another possible stumbling block which needs to be addressed. Clear and transparent rules and procedures regarding distribution of authority and responsibility ensure consistency and uniformity and provide investors and developers with knowledge on the scope of necessary grid connection investments and time frames. It should be considered to establish a balanced cost-sharing framework between the grid company and the wind turbine owner e.g. who funds which part of the grid from the turbine(s) to the nearest appropriate distribution- or transmission grid connection point.

Public consultation at an early stage of a project proposal is fundamental to gain and sustain acceptance. The consultations have at times in Denmark resulted in revised plans and sittings and have thereby mitigated public concern and generally increased public support and appreciation of wind power.

Finally long-term policy targets on promotion and expansion of wind power can establish stability and security for investors, developers and producers. A long-term investment horizon and well-designed and appropriate support schemes have in the Danish case been essential for investment decisions.

Annex

Historic overview of main policies and measures promoting wind power in Denmark

Government support and regulation has been a key to wind power deployment in Denmark:

- In 1984 subsidies (corresponding to the electricity tax) for electricity produced by wind turbines and other RE supplied to the grid was introduced.
- In 1985, an obligation was given to power utilities to install 100 MW wind turbines.
- In 1990, "Energy 2000 – an action plan for sustainable development" was introduced. This action plan formulated the national objective of a 20 % reduction in CO_2 emissions by 2005 compared to 1988 with a focus on savings in energy consumption, increased efficiency of the supply system, conversion to cleaner sources of energy and on research and development.
- In 1992 an agreement was made in parliament on priority access for renewable energy and power utilities where given an obligation to develop or enhance the overall electricity grid to connect wind turbines.
- In 1992 the subsidy corresponding to the electricity tax was converted into a direct state subsidy.
- In 1994, municipalities were ordered to decide in their municipal plan, where and to what extent wind turbines could be installed.
- In 1996, obligations were given to power utilities to establish additional 900 MW wind turbines up to 2005.
- In 1998, obligations were given to power utilities to engage with large scale offshore wind power. That subsequently resulted in commissioning of 325 MW offshore wind distributed in 2 large scale demonstration wind farms in 2002 and 2003.
- In 1999, the electricity market was liberalised.
- In 2001 the subsidies system was fundamentally changed from state subsidies to a price supplement, – a Public Service Obligation (PSO) – , paid by all electricity consumers.
- In 2004 an energy agreement included a call for tenders concerning two offshore wind farms of 200 MW each with grid connection in 2007/2008.
- In 2008 an energy agreement included a call for tenders with regard to an offshore wind farm of 400 MW to be commissioned in 2013. In addition, the agreement determined the introduction of four new schemes with the aim to enhance public support for particular onshore wind.
- In 2012 a broad majority in parliament agreed on a package of initiatives towards 2020 – with the target of 50 % wind share of domestic power supply adding 2 GW to the wind power capacity.

Energy Policy Toolkit on

Physical Planning of Wind Power

Experiences from Denmark

This is one of a series of energy policy toolkits by the Danish Energy Agency providing specific, technical and concrete information on Danish experiences and measures and results in promoting renewable energy and energy efficiency, targeting practitioners, governmental energy experts and policy makers.

The Danish Energy Agency can also offer to engage in assessing the measures and policies from the Danish case under specific country circumstances through cooperation with countries and in the form of workshops and seminars.

Comments to this policy toolkit as well as queries on the Danish Energy Agency's Global Assistance initiatives are most welcome. The idea is to further refine recommendations according to identified needs in growth economies and developing countries.

Comments to this paper as well as queries on the Danish Energy Agency's Global Assistance initiatives are most welcome and may be directed to:

Mr. Steffen Nielsen, Special Advisor, srn@ens.dk, phone +45 3392 6696 or
Mr. Kristian Havskov Sørensen, Chief Advisor, khs@ens.dk, phone +45 3392 6738.

For more information on the Danish Energy Agency's Global Assistance please visit www.ens.dk/en/Global-assistance

Published 2015 / ISBN 978-87-93071-98-8

DANISH ENERGY AGENCY