



# WIND TURBINES IN DENMARK

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## FOREWORD

Photo: Wind Turbine Sekretariat



This booklet, *Wind Turbines in Denmark*, aims to provide a general introduction to wind turbines in Denmark. It is directed at municipalities, wind turbine players and other interested parties, who will gain insight into relevant topics relating to wind turbines. The descriptions of the individual topics are intended to answer and elaborate on questions that are frequently asked about wind turbines.

In 2007 the Danish Government's Planning Committee for Onshore Wind Turbines published a report containing, among other things, a recommendation that there should be an increase in government information and advice on wind power for the municipalities and the public in general. This booklet is a response to that recommendation.

Further information on wind turbines can be found on the websites of the Danish Energy Agency ([www.ens.dk](http://www.ens.dk)), the Agency for Spatial and Environmental Planning ([www.blst.dk](http://www.blst.dk)), the Danish Environmental Protection Agency ([www.mst.dk](http://www.mst.dk)), and CAA-Denmark ([www.slv.dk](http://www.slv.dk)). References to other relevant websites can be found elsewhere in the booklet.

Section 1 ("Wind power – one of the solutions to the challenges of energy policy") gives an introduction to the evolution of renewable energy, the goals of energy policy, and the challenges presented by wind power. Section 2 ("The history of Danish wind power") provides facts about wind turbines and their development up to the present day. Section 3 ("Wind turbines and their surroundings") describes the environmental features of wind turbines, highlighting shadow and noise as local challenges of wind turbines.

Section 4 ("Onshore wind turbines") covers the general regulations for erecting onshore turbines and the special regulations that apply for household wind turbines and small wind turbines. Section 5 ("Offshore wind turbines") describes offshore wind turbines and the administrative 'one-stop shop' set-up.

Section 6 ("New schemes in the Danish Promotion of Renewable Energy Act") discusses the four schemes that were agreed politically in the *Energy Policy Agreement of 21 February 2008* and incorporated into the *Danish Promotion of Renewable Energy Act*: namely, the loss-of-value scheme, the option-to-purchase scheme, the green scheme, and the guarantee scheme. Section 7 ("Tariffs for electricity produced by wind turbines") presents the price supplements that are paid for wind turbine electricity. Finally, Section 8 ("Incorporation of wind power into the electricity system") examines wind power production in the context of the overall European electricity system.

Sections 3, 4 and 6 are aimed in particular at the municipalities and the planning that they undertake with regard to the erection of onshore wind turbines.

This booklet has also been published in Danish.

# 1. WIND POWER – ONE OF THE SOLUTIONS TO THE CHALLENGES OF ENERGY POLICY

## Factbox

### WIND TURBINES IN THE ENERGY POLICY AGREEMENT

As part of the efforts to secure the target of a 20% wind power share in 2011, the *Energy Policy Agreement of 21 February 2008* introduces a number of improvements in the conditions for erecting wind turbines:

- The supplement to the market price for new onshore wind turbines is increased to DKK 0.25 per kWh for 22,000 full-load hours. DKK 0.023 per kWh as compensation for balancing costs, etc., is retained
- The scrapping scheme is amended to give an additional price supplement of DKK 0.08 per kWh for 12,000 full-load hours. The deadlines for connecting new wind turbines to the grid under the scrapping scheme are extended
- The municipalities are required to plan for 75 MW wind turbines in each of the years 2010 and 2011
- A number of schemes are introduced to promote local acceptance of new onshore wind turbines: 1) a loss-of-value scheme gives neighbours the right to claim compensation for loss of value on their property if the loss is assessed to be at least 1% of the property's value; 2) an option-to-purchase scheme gives the local population the right to purchase at least 20% of new projects involving wind turbines with a total height of more than 25 metres; 3) a guarantee fund of DKK 10 million helps local wind turbine owners' associations to finance preliminary investigations, etc.; 4) a green scheme offers subsidies for municipal projects that enhance scenic values in local areas where new wind turbines are erected
- A total of 400 MW offshore wind turbine capacity is being tendered out and is expected to be put into operation in 2012 (the Anholt project)
- The *Offshore Wind Turbine Action Plan of September 2008* is being updated, and earlier site development is being considered. Clearer guidelines are being set out for the establishment of new offshore wind turbine projects via an "open-door" procedure

### 1.A. THE CHALLENGES OF ENERGY AND CLIMATE POLICY

Since the first oil crisis in 1973 Denmark has transformed its energy supply and developed its own production of oil, natural gas and renewable energy. At the same time, energy has been greatly optimised so that, in spite of considerable economic growth during this period, there has only been a marginal increase in energy consumption. Denmark is therefore better prepared for international energy crises than most other countries, regardless of whether the challenges relate to supply or price. Furthermore, Danish emissions of the greenhouse gases covered by the Kyoto Protocol were reduced by around 8% in the period 1990-2008.

In spite of these results, Danish society is still facing major challenges in its energy and climate policies. Denmark is expected, with its existing fields and finds, to be a net exporter of oil and natural gas for about 10 more years, although technological advances and any new finds may bring further production and extend this period. But there is a need to build up alternative sustainable energy production while there is still time. In *A visionary Danish energy policy 2025* the Danish Government presented a vision for the long-term phasing-out of fossil fuels such as coal, oil and gas, and appointed the Climate Commission to set out specific directions for how this can be done. A phasing-out of fossil fuels will strengthen long-term supply reliability and contribute to a reduction in CO<sub>2</sub> emissions.

### 1.B. ENERGY POLICY OBJECTIVES

*A visionary Danish energy policy 2025* was published in January 2007. It was followed by the *Energy Policy Agreement of 21 February 2008* between the Danish Government and all of the parliamentary parties with the exception of the Red-Green Alliance. This Agreement sets out ambitious goals for the development of renewable energy and for energy savings. A specific goal is that, compared to 2006, gross energy consumption should be reduced by 2% by 2011 and by 4% by 2020. Furthermore, renewable energy should cover at least 20% of Denmark's gross energy consumption in 2011.

In order to achieve these goals, the *Energy Policy Agreement of 21 February 2008* contains a number of resolutions on, among other things, improving the feed-in tariff for electricity from new wind turbines, biomass incineration, biomass gasification, and biogas. Funding was allocated to promote the introduction to the market of newly developed renewable energy technologies such as solar cells, thermal gasification of biomass, and wave power, and government support for the research, development and demonstration of energy technologies will be increased to DKK 1 billion in 2010.

The Agreement also contains a range of initiatives aimed at promoting local acceptance of and commitment to new onshore wind turbine projects. Neighbours will be entitled to seek compensation for loss of property value due to the erection of wind turbines. A local option to purchase has been introduced for new wind turbine projects. Local wind turbine owners' associations can apply for a guarantee covering their financing of essential preliminary investigations. And municipalities where new wind turbine projects are established will have access to subsidies from a green scheme for new wind turbine projects.

The *agreement of 21 February 2008* also includes initiatives to further promote the development of wind power. A follow-up to the 2004 scrapping scheme for old wind turbines was agreed. And it was also decided that the Danish Minister for the Environment should conclude an agreement on behalf of the Danish Government with Local Government Denmark with a view to facilitating local wind turbine planning. In April 2008 the Minister duly signed just such an agreement with Local Government Denmark setting out the goals for local planning of onshore wind turbines. In connection with this, the Danish Ministry of the Environment's Wind Turbine Secretariat was established to assist the municipalities with their planning.

Finally, the supporting parliamentary parties agreed that 400 MW of new offshore wind turbine capacity should be established and operational by the end of 2012.

### 1.C. EU ENERGY AND CLIMATE POLICY

The aims of the EU as a whole are for emissions of greenhouse gases to be reduced by 20% compared to the 1990 level, for renewable energy to constitute at least 20% of energy consumption (and at least 10% in the transport sector), and for energy efficiency to be improved by at least 20%, all by 2020: the so-called "20-20-20 in 2020".

The obligations to develop renewable energy are spread throughout the 27 Member States according to a range of criteria. Denmark must improve its development of renewable energy so that it can cover 30% of energy consumption in 2020. It is a matter for the Member States themselves to choose the renewable energy technologies that best suit their local energy resources and energy systems. In Denmark, biomass (including waste) and wind power are expected to be the chief renewable energy sources leading up to 2020.

### 1.D. WIND POWER – A CHALLENGING SOLUTION

The Danish climate makes wind power one of the most obvious renewable energy sources because the wind conditions are more favourable for electricity production than in most other European countries. Added to this, since the end of the 1970s Denmark has been building up a strong technological and research competence within wind power, and wind turbines have undergone such considerable technological advances that wind has become one of the most competitive renewable energy sources. In 2008 the combined global market share of the two largest Danish wind turbine manufacturers was just over 27%.

However, although wind turbines can thus be regarded as an important part of the solution to Denmark's obligations, wind power is also a technology that presents certain social challenges. Even though wind turbines have undergone considerable technological advances, it is still more costly to produce electricity with wind turbines than with conventional thermal power plants, especially all the while that the external environmental costs of conventional

electricity production are not fully incorporated into the market price. In accordance with the applicable regulations, the additional costs of producing electricity with wind turbines are paid for by the electricity consumers as a public service obligation (PSO) that is collected through their electricity bills.

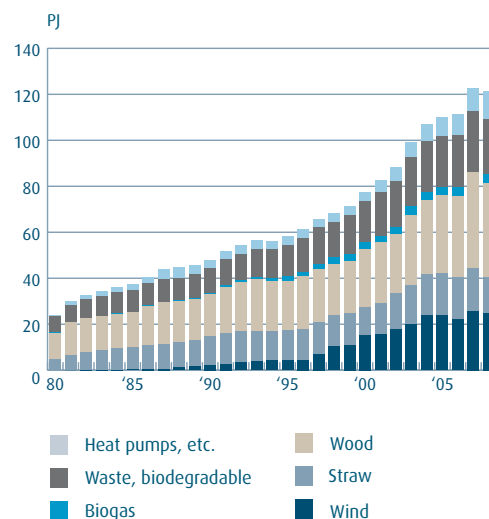
In comparison with fuel-fired power plants, electricity production from wind turbines is also more unstable because wind turbines do not produce electricity at low wind speeds (less than 4 metres per second) or high wind speeds (more than 25 metres per second). Under average wind conditions, an onshore wind turbine can produce electricity for 6,000-7,000 hours a year, corresponding to 70-80% of the total hours in the year. But the production fluctuates with the wind speed. This presents special challenges for the electricity system in incorporating the varying electricity production, and it is necessary for the system to operate with a reserve capacity in the form of power plants or cross-border connections in order to be able to cover the Danish electricity requirement in periods when the wind turbines are idle. Furthermore, work is being carried out to improve the incorporation of wind power, among other forms, by making the individual turbines easier to regulate. And the possibilities of using intelligent electricity meters, electric cars and heat pumps are being investigated.

Wind turbines erected onshore are often highly visible in the landscape. This is particularly true of the latest MW wind turbines, which have rotating blades that reach more than 125 metres high. Although new wind turbines have been designed to minimise noise nuisance, the turbines can still be both seen and heard in the immediate surroundings, which means that restrictions on distance to neighbours are imposed and the municipalities are obliged to consider the landscape in the planning that underpins the siting of new wind turbines. As a result of the ambitious objective for renewable energy, the Danish Government is seeking to promote the erection of new, more efficient wind turbines both offshore and onshore. ●



Photo: Wind turbine Secretariat

FIGURE 1.1. PRODUCTION OF RENEWABLE ENERGY



Source: Danish Energy Agency

The production of renewable energy in 2008 was calculated at 121.5 PJ, which was 1.4 PJ less than the year before. In 2008, the production of wind power fell by 0.9 PJ to 24.9 PJ due to poor wind conditions. Under the Energy Policy Agreement of 2008, renewable energy should cover at least 20% of gross energy consumption in 2011.

## 2. THE HISTORY OF DANISH WIND POWER

**FIGURE 2.1**  
**TECHNICAL SPECIFICATIONS OF A V90 NACELLE**



Illustration: Vestas Wind Systems A/S

- |                                     |                           |
|-------------------------------------|---------------------------|
| 1 Oil cooler                        | 6 Service crane           |
| 2 Water cooler for generator        | 7 OptiSpeed® generator    |
| 3 High voltage transformer          | 8 Composite disc coupling |
| 4 Ultrasonic wind sensors           | 9 Yaw gears               |
| 5 VMP-Top controller with converter | 10 Gearbox                |
| 11 Mechanical disc brake            | 14 Blade hub              |
| 12 Machine foundation               | 15 Blade                  |
| 13 Blade bearing                    |                           |

### 2.A. HOW A WIND TURBINE IS CONSTRUCTED

A wind turbine is a machine that converts the kinetic energy of wind into electricity. The idea of taking energy from wind has been known and exploited for centuries in many countries. In Denmark, wind power has historically been used to produce mechanical energy for, among other things, grinding corn.

The size of a wind turbine can be stated in several ways. It can be the wind turbine's maximum electrical output, its height from the ground to the top of the blade tip, the blade's diameter, or the area that the rotor's three blades cover in one revolution. By way of example, we might have a wind turbine of 1 MW (1,000 kW), a total height of 77 metres, a swept area (rotor diameter) of 54 metres, and a rotor area of 2,300 square metres.

A modern wind turbine consists of a rotor (the Danish design has three blades) that drives a generator that produces electricity. The rotor and generator are installed at the top of a tower, which stands on a foundation in the ground or in the seabed. The turbine cap (nacelle) and the blades are controlled based

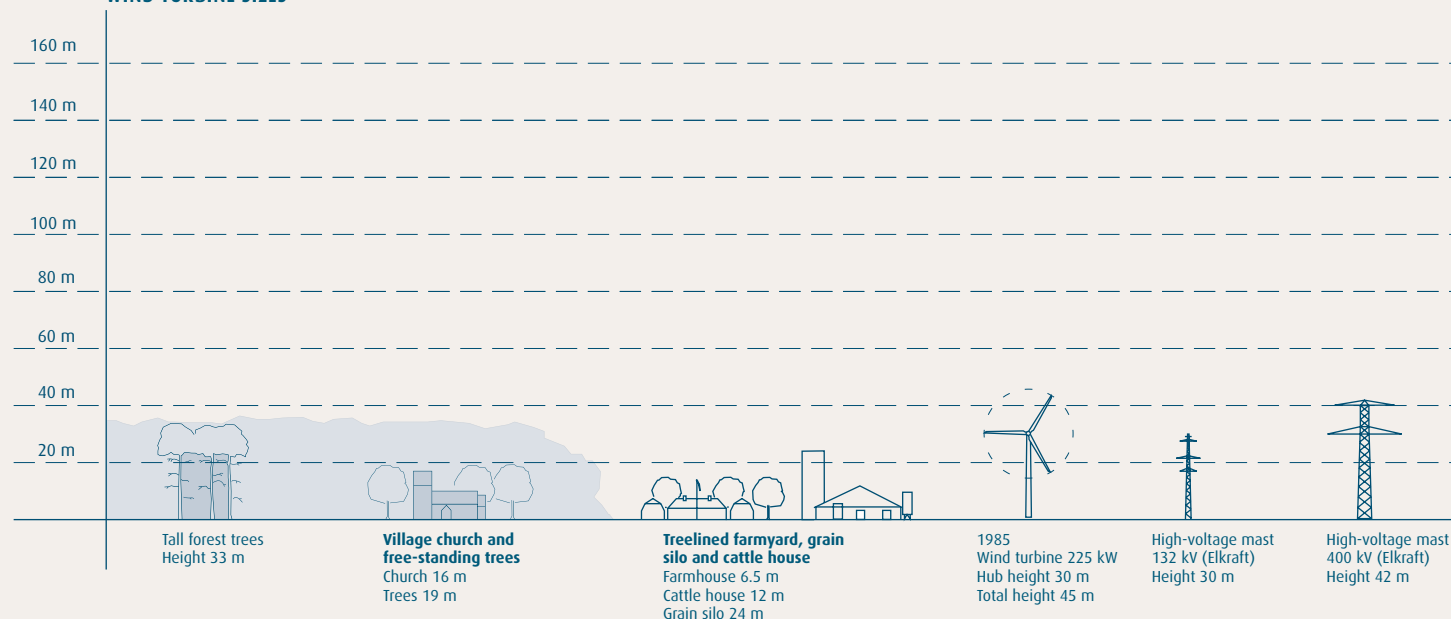
on measurements of the wind direction and speed. In order to ensure the best possible incorporation of the wind turbine's production into the electricity system, new wind turbines are fitted with advanced control electronics, and a modern wind turbine consists of up to 10,000 different components.

### 2.B. WIND TURBINE ELECTRICITY PRODUCTION

In simple terms, a wind turbine not only utilises the wind's pressure on an obliquely positioned blade, but also utilises the fact that the air current around the blade creates a negative pressure on the rear of the blade in relation to the wind. The force from this negative pressure produces a draught that causes the blades to rotate.

The electricity production of a wind turbine depends on wind conditions. Obviously the wind does not blow constantly, and wind speed varies greatly from place to place and over time. On average, the wind blows more at sea than on land. In Denmark, it blows most along the western and southern facing coasts and least inland. A turbine on the west coast of Jutland generally therefore produces twice as

#### WIND TURBINE SIZES



much as a turbine of the same size located on an unwindy point inland. Future wind turbines will generally be of megawatt scale. And as future turbines will be far more efficient, significantly fewer turbines will be needed for electricity production.

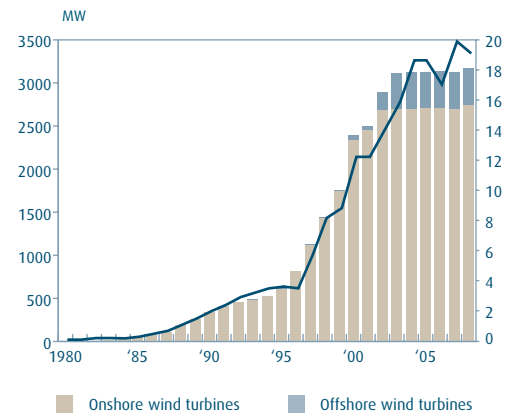
The electrical output of a wind turbine is measured in kW or MW (1,000 kW), while the production volume is measured in kWh or MWh. The maximum output that a wind turbine can produce is referred to as the rated output or, in popular terms, the turbine size. A wind turbine of 2 MW can thus produce a maximum output of 2 MW, typically at wind speeds of 15-25 metres per second. At maximum production, the turbine produces 2 MWh (2,000 kWh) in one hour, equivalent to half of an average Danish family's annual electricity consumption. Or, to put it another way, a 2 MW wind turbine can produce electricity for around 1,000 electric kettles with an output of 2 kW switched on at the same time.

The majority of wind turbines are designed so that they start producing electricity at a wind speed of 4 metres per second and reach their maximum production volume at wind speeds

of 12-15 metres per second. For safety reasons, the wind turbines stop running if the wind speed exceeds 25 metres per second. The wind meter on the individual turbine informs the turbine's control system when the wind speed is sufficient to make electricity production worthwhile (4 metres per second) or when the wind becomes too strong. In the latter case, when the wind drops so that it is safe to start producing again, the control system is informed so that the turbine can be restarted. For safety reasons, a wind turbine is fitted with two independent braking systems, at least one of which must be aerodynamic.

A new large onshore wind turbine sited where there are good wind conditions will typically produce at maximum output for around 2,500 hours a year. In an average wind year, this type of wind turbine will be able to produce around 5,000 MWh, equivalent to the annual electricity consumption of 1,250 single-family homes with an electricity consumption of 4,000 kWh. An offshore wind turbine will typically be able to produce 3,000-4,000 hours a year at maximum output; most for locations in the North Sea, less in the Baltic region and internal Danish waters.

FIGURE 2.2  
WIND CAPACITY AND SHARE OF ELECTRICITY SUPPLY



Source: Danish Energy Agency

The use of wind power increased greatly in the second half of the 1990s, reaching around 15% of the overall electricity supply in 2000. Since then, the share of wind power has further increased to around 19%. The total wind power output, which exceeds 3,000 MW, is produced by just over 5,000 wind turbines.

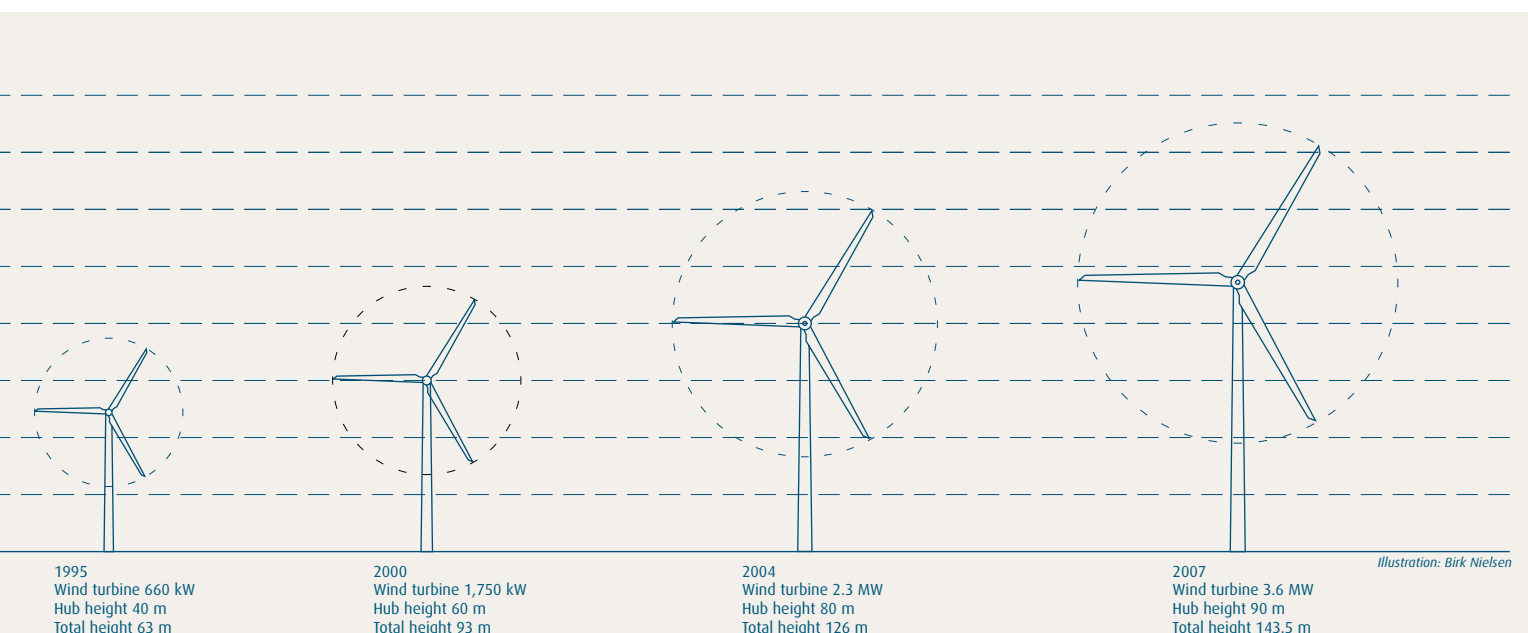
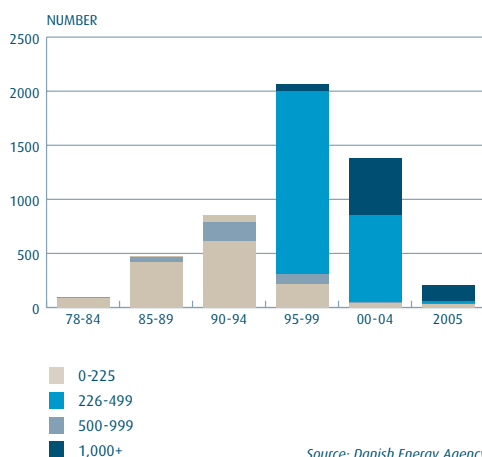


FIGURE 2.3 BREAKDOWN OF EXISTING TURBINES BY OUTPUT AND INSTALLATION YEAR

Period	0-225 kW	226-499 kW	500-999 kW	1,000+ kW	Total
78-84	91	1	0	0	92
85-89	425	43	6	0	474
90-94	616	169	65	0	850
95-99	218	91	1687	73	2069
00-04	44	2	812	526	1384
05-09	33	0	26	150	209
<b>Total</b>	<b>1427</b>	<b>306</b>	<b>2596</b>	<b>749</b>	<b>5078</b>

Source: Danish Energy Agency

FIGURE 2.3 BREAKDOWN OF EXISTING TURBINES BY OUTPUT AND INSTALLATION YEAR



Source: Danish Energy Agency

Danish wind turbines have undergone considerable upscaling. Up to the mid-1990s, the majority of wind turbines that were erected had an output of 225 kW or less, and a large proportion of these have since been replaced by fewer, larger wind turbines under the "scrapping schemes". Most of the wind turbines erected in the last decade have had an output above 500 kW. The largest new Danish wind turbines have an output of 3.0-3.6 MW.

## 2.C. THE DEVELOPMENT OF DANISH WIND TURBINES

The first batch-produced Danish wind turbines from the late-1970s had an output of 22 kW, and the wind turbines were gradually scaled up to 55, 75 and 95 kW through the course of the 1980s. Alongside this commercial production, a government-funded development programme was undertaken by the electricity companies to test considerably larger pilot wind turbines. Since the 1980s, the wind turbine industry's commercial products have become increasingly larger-scale, and the largest commercial wind turbines produced by Danish manufacturers today are 3 MW (Vestas) and 3.6 MW (Siemens Wind Power) respectively.

The 3.6 MW wind turbine has a rotor diameter of 107 metres, a swept area of 9,000 square metres, and a hub height of 80-100 metres depending on the conditions at the erection site. The 3.6 MW wind turbine can thus reach a total height of more than 150 metres and a weight of around 465 tons.

The number of wind turbines in Denmark peaked in 2000 at more than 6,200, of which more than half were older wind turbines with an electrical output of less than 500 kW. Since then, the number of wind turbines has decreased by around 1,000, while the total installed output has grown from just under 2,400 MW in 2000 to just under 3,400 MW end of 2009. In the same year, smaller wind turbines with an output of less than 500 kW accounted for around 11% of the total installed output.

The wind power share of the domestic electricity supply has been growing steadily since

1980. In 1990, the share was 1.9%, and since then it has increased sharply. In 1999 the figure topped 10%, and in 2008 it reached 19.1% of the electricity supply. In A *visionary Danish energy policy 2025* from 2007 the Danish Government formulated an objective of more wind power through strategic planning of wind turbine development. This includes a good framework for Danish wind capacity and the promotion of onshore and offshore demonstration and pilot sites as well as the drafting of an infrastructure plan for offshore wind turbines.

In 2008, the wind turbine industry's Danish production sites had a gross turnover of DKK 53 billion, and overall exports reached DKK 42 billion, equivalent to 7.2% of total Danish exports. The wind turbine sector had 28,400 employees at the end of 2008.

## 2.D. PUBLIC INVOLVEMENT

The development of wind power in Denmark has been characterised by strong public involvement. It was small machinery manufacturers that created the established wind turbine industry, and only after the consolidation of the industry through the 1990s did it become dominated by large, partly internationally owned and listed companies. Similarly, on the customer side numerous joint-owned wind turbines were established in the period 1984-94. Around two thousand of the 5,200 Danish wind turbines are still owned by local wind turbine owners' associations. These are mostly older, smaller wind turbines because the majority of wind turbines erected since 1995 are owned by individuals, energy companies and other commercial wind power companies.

The progression towards fewer joint-owned and relatively large wind turbines has made it difficult to maintain local support for new wind power projects. But to ensure continued development of wind power, it is essential to have backing in the local community. The *Energy Policy Agreement of 21 February 2008* therefore stipulated that a range of new initiatives should be undertaken to promote local acceptance and option to purchase wind turbines shares of new wind power projects. The regulations are examined in more detail in section 6. ●

## 3. WIND TURBINES AND THEIR SURROUNDINGS

### 3.A. ENVIRONMENTAL FEATURES OF WIND TURBINES

#### CLIMATE AND AIR POLLUTION

Wind power is regarded as an environmentally renewable energy source because producing electricity with wind turbines does not entail the use of fossil fuels such as oil, natural gas and coal. In terms of energy supply, wind power is advantageous because the source of the electricity production, i.e. wind, is renewable and the electricity from wind turbines is not therefore conditional on the import of fuels or the use of limited resources. In terms of the environment and climate, wind power has major benefits because it is not associated with atmospheric emissions of CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub> and particles, as is the case to a greater or lesser extent with power plants that use fossil fuels.

Emissions of SO<sub>2</sub>, NO<sub>x</sub> and particles pollute the regional and local environment around the power plants, while emissions of CO<sub>2</sub> from electricity production are regarded as the largest global contributor to the greenhouse effect, which is considered by the UN's Intergovernmental Panel on Climate Change (IPCC) to be a serious threat to the climate. "Greenhouse effect" is a term that denotes the changed balance between incoming solar radiation and heat radiated out into space, which arises due to human-created discharges of greenhouse gases such as CO<sub>2</sub>, methane and nitrous oxide.

#### ENERGY BALANCE

The energy balance of wind turbines over their lifetime is analysed using a life cycle assessment (LCA) that covers energy consumption and other effects of production, erection, ongoing operation, and scrapping when the wind turbine no longer can or needs to produce electricity. In this assessment, raw materials for the wind turbine's components as well as energy consumption for production, transport, operation and disposal are incorporated as a negative impact on the environment. The positive side includes the wind turbine's overall electricity production and any recyclable materials. Assessed over the wind turbine's normal lifetime of 20-25 years, the negative environmen-

tal impact is minimal compared with the average European electricity production. Over 20-25 years the wind turbine will typically produce more than 35 times the energy production involved in its manufacture, operation, etc. A modern MW wind turbine will take around seven months to produce the amount of energy used in its manufacture, erection, operation and disposal.

### 3.B. IMPACT ON THE IMMEDIATE SURROUNDINGS

The planning and environmental legislation sets out requirements to ensure that a wind turbine project will not cause major damage or nuisance to its surroundings, including noise and spacing requirements. It is also assumed that as a rule an environmental impact assessment (EIA) will be carried out as part of the detailed planning for specific projects. As well as describing the environmental impacts, this ensures, among other things, that the legislative requirements are observed. The overall impact of wind turbines on their immediate environment includes visual impact, noise, shadow, the effects of lighting, impacts on nature, etc. The nature of these impacts depends on how the wind turbine is positioned in the landscape, the type of landscape, the wind turbine's size, and proximity to the wind turbine. In order to minimise the overall impact, when planning the siting of wind turbines the municipalities should seek to limit these nuisances, including ensuring that noise and spacing requirements are observed. Similarly, wind turbine manufacturers are continuously working to optimise turbine design so that they not only produce optimally but also reduce the impact on their surroundings as much as possible.

#### SHADOW

A wind turbine casts shadows when the sun is shining. In windy, sunny weather, an area of the turbine's surroundings will be affected by rotating shadows from the blades. In Denmark the area lying to the south of the wind turbine will never be affected by shadow from the blades. Nuisance from shadow, which takes the form of a rapid change between direct light and short "flickers" of shadow, depends on



Photo: Wind Turbine Secretariat



Illustration: Odense Environment Centre, based on calculations from CUBE Engineering

**FIGURE 3.1.**  
**SHADOW CHART IN THE EIA**

In new wind turbine projects, the project developer must provide information in an Environmental Impact Assessment (EIA) on the shadow cast by wind turbines. The chart shows the area of calculated shadow for "real case" (weather-dependent) in relation to Danish neighbours in an alternative project involving 5 x 3 MW wind turbines at Rens Hovedgaard Plantage in Aabenraa Municipality. Number of hours per year.



Photo: Wind Turbine Secretariat

where the wind turbine is standing from the perspective of the neighbour, the distance between the wind turbine and the neighbour, the wind turbine's hub height, and the length of the blades.

The critical times for shadow occur mainly in the early morning and late evening, with long shadows at a greater distance from the wind turbines than the neighbour distance requirement of four times the total height of the wind turbine. The impact of shadow is calculated as the total number of hours annually that a neighbour is subjected to shadow and will vary with seasonal changes in the weather. The assessment of the anticipated number of annual hours of shadow is therefore calculated based on the anticipated normal distribution of operating hours and sunshine hours during the course of the year.



Photo: Wind Turbine Secretariat

It is recommended that the calculated normal distribution of shadow hours for neighbours not exceeds 10 hours a year. By taking these issues into consideration in the planning of wind turbine sitings, the periods during which shadow actually occurs can be limited. If a full assessment shows that the most suitable siting entails that the recommended maximum of 10 hours' shadow cannot be observed, the owner of the wind turbine may alternatively be required to shut down the wind turbine in critical periods. The wind turbines can be fitted with meters so that the operation can be halted if the sun shines during critical periods; this can reduce operating losses.

Usually the gloss value will be less than 30, which is regarded as sufficiently low for reflections from the wind turbine not to be a problem.

#### MARKING OF WIND TURBINES IN RELATION TO AIR TRAFFIC

In order that installations should not compromise the safety of air traffic, any obstacles – including wind turbines – with a total height of more than 100 metres must be approved by Civil Aviation Administration-Denmark (CAA-Denmark). Around state-approved airports and airfields, aircraft are protected against obstructions using the approved obstacle limitation surfaces. The approach plan's height restrictions are registered with easements or notified in the municipal plans.

All wind turbines with a total height of minimum 150 metres must be provided with high-intensity, white flashing lights. The exact regulations are set out in the *BL 3-10 Regulations for Civil Aviation* based on applicable international standards and recommendations. The basis for the regulations is a desire for obstructions to air traffic to be visible at a suitable distance so that the pilot can take the necessary operational actions in time. In the case of wind turbines of 100-150 metres in height, which will typically be pertinent in connection with projects under the scrapping scheme and new onshore wind turbines, CAA-Denmark will carry out a specific assessment of the need for marking, including taking into consideration Danish Defence's assessments of military flights in the area. Under normal circumstances, the marking of the wind turbines with low-intensity fixed red obstruction lights on the nacelle plus painting the wind turbine white will be sufficient. Where special air safety factors apply, marking with medium-intensity flashing obstruction lights will be necessary in addition to painting the wind turbine white. It would be appropriate for requirements for air traffic marking to be clarified with CAA-Denmark before an EIA, where one is required, is drawn up.

Previous attempts to counteract light nuisance from TV-station transmitting masts have shown that it is not possible to effectively shield sur-

## Factbox

### SHADOW

Shadows cast by rotating turbine blades are experienced by neighbours as a nuisance, with the shadows passing across their homes for a short duration but at a high frequency. The applicable spacing requirements ensure that neighbours are mainly subjected to shadows in the early morning and late evening. Shadow is normally calculated as "real case", i.e. taking into consideration the normal distribution of sunshine hours and wind. Possible remedial measures include switching off the wind turbines at critical times.

### REFLECTION

As wind turbine blades must have a smooth surface to be able to produce optimally and repel dirt, the blades can produce reflective flashes. As part of the type-approval of wind turbines, the reflective qualities of the blades are stated. Typically, the reflective effect of the blades will be halved during the wind turbine's first year of operation, and in their planning the municipalities can set requirements for anti-reflective treatment of the blades. Normally, the blades from the manufacturer will be surface-coated to obtain a low gloss.

rounding houses against obstruction lights. Any shielding must be carried out taking into consideration that obstruction lights must be observable by the pilot from all directions in the horizontal plane.

### 3.C. NOISE

Wind turbines emit a relatively weak but characteristic noise. The noise emanates from the operation of the turbine's gear and generator as well as from the movement of the blades through the air. In relation to generated output, modern wind turbines emit considerably less noise than the earliest wind turbines from the 1970s and 1980s. In particular, the mechanical noise from the turbine's gear and generator are significantly reduced in comparison with earlier models. In modern wind turbines, the machine house is soundproofed, the generator and gear are suspended in rubber elements, and the nacelle's cabin is tight-closing and fitted with sound locks that dampen airborne noise. Blade design has developed so that the noise from the movement of the blades through the air is minimised.

In order for a wind turbine to be certified for erection in Denmark, it must satisfy a number of requirements set out in the *Danish Ministry of the Environment Order on noise from wind turbines* (no. 1518 of 14 December 2006). Among other things, a noise survey must be carried out and the noise level calculated at the premises of immediate neighbours.

Sound is measured in decibels (dB). The human ear can just detect a change in sound intensity of 1-2 dB. If the sound intensity increases by 6-10 dB, it will be heard as a doubling of the sound intensity. Similarly, a reduction of 6-10 dB will be heard as a halving of the sound intensity. The intensity of the sound is generally measured using a method that mimics the ear's sensitivity and is stated by the measuring unit decibel-A, dB(A).

In accordance with the Danish Ministry of the Environment's Order, the noise in the open land immediately outside the neighbour's house and in open spaces up to 15 metres from the house

may not exceed 44 dB(A) at a wind speed of 8 metres per second. This corresponds roughly to the noise of soft speech. In more densely built-up areas, summer home areas and noise-sensitive recreational areas, the noise may not exceed 39 dB(A). The limits are lower for lower wind speeds. The municipalities monitor compliance with these noise limits.

The relatively weak noise from wind turbines also includes some low-frequency noise, i.e. deep sound with a low frequency. Low-frequency noise is where a significant proportion of the sound energy is found in the frequency range below around 160 Hertz (Hz). Hertz is a designation for the number of oscillations per second. None of the noise surveys that have been carried out suggest that there are special problems with low-frequency noise from wind turbines. In the assessment of the Danish Environmental Protection Agency, wind turbines that observe the limits for ordinary noise do not give low-frequency noise higher than the recommended limit. In order to shed further light on the issues of low-frequency noise, thereby giving municipalities and players in the wind power industry a more reliable basis for evaluating new wind turbine projects, DELTA – Danish Electronics, Light and Acoustics – has headed up a research project that has been mapping the issues of low-frequency noise from modern wind turbines since 2006. The project is expected to be completed in spring 2010.

Infrasound is sound with a frequency lower than 20 Hz and thus constitutes the "deepest" part of the low-frequency range. Previously it was thought that infrasound could not be detected by the human ear, but infrasound can actually be heard if it is strong enough, and even weak infrasound is regarded as a nuisance. The threshold for hearing infrasound has been well researched, and the Danish Environmental Protection Agency recommends a limit that is 10 dB lower than the hearing threshold. The infrasound emitted by modern wind turbines is of no consequence for the surroundings and is much weaker than the Danish Environmental Protection Agency's recommended limit. ●

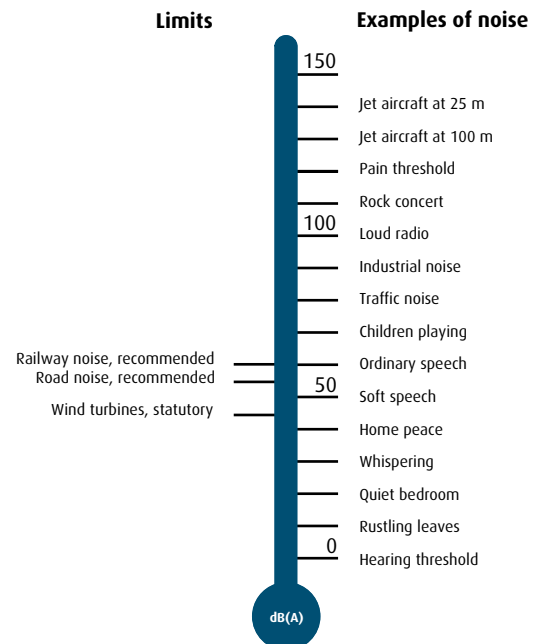


Illustration: Factsheet from the Danish Wind Turbine Owners' Association

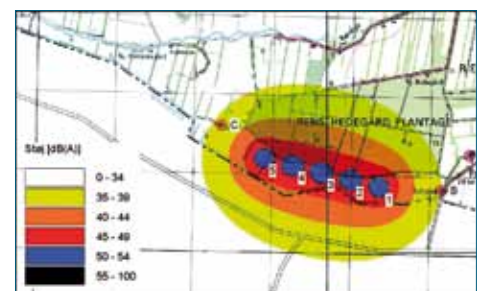


Illustration: Odense Environment Centre, based on calculations from EMD International

**FIGURE 3.2**  
CHART OF CALCULATED NOISE ZONES IN THE ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

The two charts from the EIA for the wind turbine project at Rens Hovedgaard Plantage show the calculated noise zones for Danish neighbours from 5 x 1.8 MW wind turbines. The chart on the left shows noise zones at a wind speed of 6 metres per second, while the chart on the right shows the same noise zones for a wind speed of 8 metres per second. The noise level is stated in dB(A). The colours indicate the noise level: the darker the colour, the higher the noise level.

## 4. ONSHORE WIND TURBINES

### Factbox

#### WIND TURBINE PLANNING PHASES

A typical planning process passes through the following steps:

##### Designation of wind turbine areas

- Consideration of potential areas, process and political aims in the municipality
- Idea phase and scoping
  - Invitation to submit ideas and proposals
  - Consultation with relevant authorities
  - Citizen meeting, where required
- Processing of any comments and consultation responses received
- Drafting of proposed municipal plan, including acceptance and rejection of alternatives, based among other things on a general environmental assessment of the plan and political aims
- Drafting of an environmental report summarising the general environmental assessment of the plan
- Public phase
  - Announcement of proposed municipal plan and environmental report
  - Citizen meeting, where required
- Processing of objections and comments received
- Any necessary revision, plus consultation period and any new public phase
- Final adoption of the plan
- Period for complaints

##### Planning for a specific wind turbine project

- Application for a specific project by a project sponsor in the designated wind turbine area
- Decision on whether an EIA is required
- Idea phase and scoping
  - Invitation to submit ideas and proposals
  - Consultation with relevant authorities
  - Citizen meeting, where required



Photo: Birk Nielsen

*The perception of order is a basic aesthetic precondition. It is therefore recommended that wind turbines should be erected in geometric (usually linear) formations that create a contrast with the landscape. The photo shows the visualisation for Lønborg Hede.*

#### 4.A. POLITICAL FRAMEWORK CONDITIONS FOR THE DEVELOPMENT OF WIND TURBINES

The political framework conditions for the erection of onshore wind turbines have been agreed in part in the *Energy Policy Agreement of 21 February 2008* and subsequently implemented in the *Danish Promotion of Renewable Energy Act*, which was adopted by the Danish Parliament in December 2008 and entered into force on 1 January 2009. The municipalities are responsible for securing the necessary planning basis for wind turbines with a total height of up to 150 metres in the form of designated wind turbine areas with associated guidelines in the municipal plan as well as supplements to the municipal plans with associated EIAs and local plans for the specific wind turbine projects under application. In the case of wind turbines over 150 metres, the Environment Centres within the Danish Ministry of the Environment are the planning authority. The Environment Centres are also tasked with monitoring that the municipalities plan for wind turbines in accordance with government interests.

As part of the objective for renewable energy to constitute 20% of gross energy consumption in 2011, the Danish Government entered into an agreement with Local Government Denmark that the municipalities, through their planning,

should reserve areas that can accommodate onshore wind turbines with a total output of 150 MW; 75 MW in each of the years 2010 and 2011.

It was also agreed that the Danish Ministry of the Environment should strengthen its follow-up on the municipalities' work of implementing the scrapping scheme adopted as part of the *Energy Policy Agreement of 29 March 2004 on wind energy and decentralised combined heat and power*.

#### 4.B. MUNICIPAL PLANNING AND REGULATIONS ON EIAs

Following the Local Government Reform, the planning authority for onshore wind turbines up to 150 metres has passed to the municipalities. The regulations for municipal planning ensure that citizens, associations, authorities and other stakeholders are continuously involved in the process. In order to be able to assist the municipalities in this work, the Danish Ministry of the Environment has set up the Wind Turbine Secretariat under the Agency for Spatial and Environmental Planning.

In order to allow enough time for drafting various materials, citizen involvement, etc., both the municipal designation of wind turbine areas and the municipality's subsequent

processing of a specific project normally take at least a year.

Apart from household and small turbines, wind turbines may only be erected in areas designated through reservations and guidelines in the municipal plan. The municipality must therefore assess which areas are suitable for erecting wind turbines.

The local council must ensure in its planning that it gives full consideration to neighbouring residences, nature, the landscape, cultural-historical values, agricultural interests, and the possibility of exploiting the wind resource.

The municipal plan must include guidelines and a framework, and must be accompanied by a statement on the assumptions underlying the local council's proposed plan. The guidelines for designated wind turbine areas must include regulations on the anticipated maximum number and size of the turbines as well as the spacing between the turbines.

The further planning of specific projects then awaits the initiative of a project sponsor, a wind turbine owners' association or others wishing to use the designated area to erect wind turbines.

A project sponsor wishing to establish a wind turbine project must notify the project to the municipality. The planning process for projects requiring an EIA begins with an idea phase in which the municipality drafts a discussion paper inviting proposals from citizens on the content of the EIA and the supplement to the municipal plan. This idea phase, which is also called the pre-public phase, must last at least two weeks.

The planning must also satisfy the requirements for environmental assessment of plans and programmes, which include consultation with the relevant authorities, including neighbouring municipalities, the region 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.

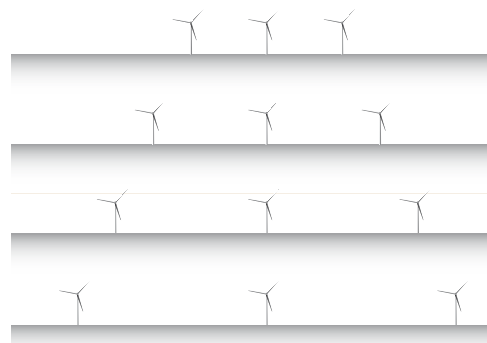
Taking into consideration the feedback that it receives, the municipality draws up guidelines on the further local planning in a supplement to the municipal plan and determines the scope of the EIA, which the project owner and the municipality often prepare jointly. This material is sent for public consultation lasting at least eight weeks. In this public phase, property owners, neighbours, associations, authorities, etc., may submit objections, comments and alternative proposals.

After this, the municipality can finally adopt the wind turbine project and give the project sponsor an EIA approval. If a local plan also has to be drawn up for the project, the local council draws this up in parallel. The local plan for a wind turbine area must include regulations on the turbines' exact siting, number, minimum and maximum total height, and appearance.

In accordance with the *Danish Planning Act*, a supplement to the municipal plan for a wind turbine project involving turbines with a total height of more than 80 metres or a group of more than three turbines must be accompanied by an EIA assessing the consequences of the project for the environment. Other projects are screened by the local council, which decides whether a project has such major consequences for the environment that an EIA should be drawn up or whether only a rural zone permit should be issued. *Order no. 1335 of 6 December 2006 on the assessment of certain public and private installations' impact on the environment* contains regulations on EIAs.

The EIA must assess how the wind turbine project will affect neighbouring residences in terms of, among other things, noise and shadow, nature, the landscape, cultural-historical values, and agricultural interests, as well as giving information on local wind conditions. This normally requires the project owner to draw up a visualisation of the project so that citizens can more easily form a realistic impression of the implications of the wind turbine project.

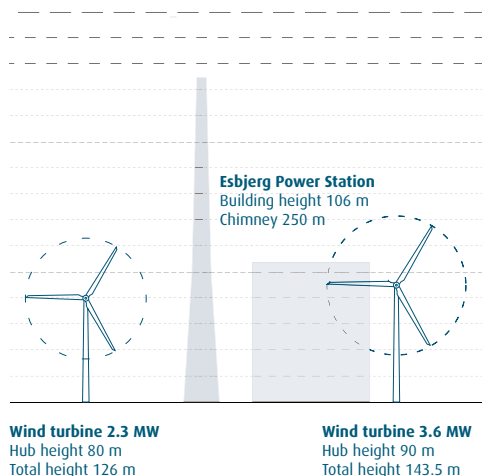
**FIGURE 4.1**  
**EXAMPLES OF SPACING IN A WIND TURBINE PROJECT**



*Illustrations: Birk Nielsen*

*With regard to both turbulence and aesthetics, it is recommended that in projects involving multiple wind turbines their spacing should be three to four times the rotor diameter. The illustrations from Birk Nielsen show examples of wind turbines spaced at intervals of two times the rotor diameter (top), three times the rotor diameter, four times the rotor diameter, and five times the rotor diameter (bottom) respectively.*

- Processing of any comments and consultation responses received
- Drafting of supplement to municipal plan and local plan, including adjustment of the project based on a general environmental assessment of the plan
- Drafting of an EIA for the project
- Public phase
  - Announcement of the proposed plans, incl. EIA for the project
  - Citizen meeting, where required
- Processing of any objections and comments received
- Any revision, plus consultation period and any new public phase
- Final adoption of the plans and issuing of EIA approval
- Period for complaints



**FIGURE 4.2 WIND TURBINE IN A TECHNICAL LANDSCAPE**

*Birk Nielsen's sketch shows the siting of MW wind turbines at Esbjerg Power Station.*

## Factbox

### All EIAs, including those for wind turbine projects, must include:

- A description of the project.
- A summary of major alternatives to the execution of the proposed project that the project sponsor has investigated (minimum the zero alternative, i.e. the situation if the project is not implemented).
- A description of the impact of the project on people, fauna, flora, soil, water, air, climate, landscape, tangible property, and the Danish cultural heritage.
- A description of the project's short-term and long-term, direct and indirect, derived and cumulative impacts on the environment.
- A description of environment-improving measures, including preventive measures.
- A non-technical summary of the assessment.

In the case of wind turbine projects that do not require an EIA, the rural zone regulations of the *Danish Planning Act* set out requirements for informing neighbours about the project. Generally, there is no requirement for the information to include a visualisation, but Energinet.dk (the Danish transmission system operator) may require this if it would be a precondition for neighbours being able to realistically assess whether the project will entail a loss of value on their properties, cf. 6.b.

Decisions of the local council concerning wind turbine projects may be contested with the Nature Protection Board of Appeal.

The Danish Ministry of the Environment's Wind Turbine Secretariat is a type of "flying squad" that provides the municipalities with guidance and practical help in wind turbine planning – such as identifying the sites that are most suitable in respect of neighbours and nature protection interests, formulating idea proposals, decision-making documentation and proposals for wind turbine plans, or arranging citizen meetings, etc.

Most of Denmark's municipalities are in dialogue with the Wind Turbine Secretariat, either to get answers to specific questions or to obtain formal assistance with the planning process. The Wind Turbine Secretariat has a Danish website, [www.vind.mim.dk](http://www.vind.mim.dk), via the Agency for Spatial and Environmental Planning. Here you can find answers to frequently asked questions as well as tools for use in municipal wind turbine planning, including:

- A summary of essential siting considerations.
- A process line with a model of the planning process and a timeframe.
- Links, including to applicable regulations and the Agency for Spatial and Environmental Planning's spacing map.

### 4.C. REGULATIONS FOR SITING ONSHORE WIND TURBINES

The siting 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, other technical installations, and regard for the landscape and nature. This balancing is brought about through the municipal wind turbine planning, which directly involves affected citizens, organisations, authorities, etc. The key principles for erecting wind turbines are wind conditions, distance to neighbours, and regard for specific affected interests, e.g. nature protection areas and areas of culturo-historical interest.

The regulations for siting are set out in the *Danish Planning Act* and implemented in *Wind Turbine Circular no. 9295 of 22 May 2009*. The aim of the Circular is to ensure regard for landscape, neighbours, etc. Generally, new wind turbines must as a minimum be sited at a distance from the nearest neighbours of at least four times the wind turbine's total height.

Special consideration must be given to the coastal zone, which is defined in the *Danish Planning Act* as a three-kilometre zone along the coast throughout the country that is generally to be kept free of buildings and installations. If a municipality wants to erect wind turbines in the coastal zone, this requires special planning or functional justification, for example that there are especially favourable wind conditions along the municipality's coasts, as is the case in the West Jutland municipalities. Visualisation is an excellent method for illustrating the implications of new wind turbines for landscape and nature. Landscapes that in the past have been dominated by large technical installations will often be suitable for erecting large wind turbines because the turbines will not significantly increase the impact on the landscape. These technical installations might be CHP plants, waste incineration plants, high-voltage masts, industrial activities with tall chimneys, harbour areas with large cranes, etc. These installations are already highly visible in the landscape.

Large and uniform landscapes will also usually be suitable for erecting large wind turbines. The reason for this is that the landscape matches the large dimensions because it is often characterised by flat or evenly sloping

terrain with large units of area and "landscape space".

Small-scale landscapes will often be less suitable for erecting large wind turbines. These landscapes are characterised by small hills or gentle slopes with less "landscape space", where large wind turbines would contrast starkly with the nature of the landscape.

A more exhaustive description of the impact of large wind turbines on different types of landscape can be found in the report *Store vindmøller i det åbne land – en vurdering af de landskabelige konsekvenser (Large wind turbines in the open countryside – an assessment of implications for the landscape)*, which can be downloaded (in Danish only) from [www.blst.dk](http://www.blst.dk).

The oldest wind turbines were often erected spread out in the landscape, which meant that they impacted a very large area in relation to their installed electrical output. As a starting point, the aim is to site new wind turbines in groups wherever possible so as to achieve a high installed electrical output with impact on a relatively small area. Furthermore, the municipality can require wind turbines in a group to be uniform and arranged in a simple geometric pattern, for example in a single row, so that the wind turbines create a calmer impression. It is also important that wind turbines erected as a group should appear harmonious and uniform in design. A wind turbine is regarded as harmonious if there is a balance between tower height and rotor diameter. Generally, experience suggests that the most harmonious rotor/tower ratio for larger wind turbines is 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 rotor/tower ratio of 1.25.

#### 4.D. TECHNICAL CERTIFICATION OF WIND TURBINES

In order to help ensure that new wind turbines are safe and can be incorporated into the electricity system, a Secretariat for the Danish Wind

Turbine Certification Scheme has been set up and located at Risø DTU (National Laboratory for Sustainable Energy at the Technical University of Denmark). The specific regulations are described in *Danish Energy Agency's Order no. 651 of 26 June 2008 on the technical certification scheme for the design, manufacture, installation, maintenance and servicing of wind turbines*. The secretariat has a website at [www.vindmoellegodkendelse.dk](http://www.vindmoellegodkendelse.dk). The technical prescriptions for the connection of wind turbines to the electricity grid can be found at [www.energinet.dk](http://www.energinet.dk).

#### 4.E. HOUSEHOLD WIND TURBINES AND SMALL WIND TURBINES

A household wind turbine is normally understood to be a smaller, stand-alone turbine with a total height of less than 25 metres that is erected directly connected to existing housing in the open countryside, usually in a rural zone. Small wind turbines are normally understood to be stand-alone turbines with a rotor area of up to 1 m<sup>2</sup> ("micro turbines") or 1-5 m<sup>2</sup> ("mini turbines"). The turbine may be installed on a building.

For all turbine types the *Danish Ministry of the Environment Order on noise from wind turbines* must be respected when erecting and operating the turbines. Turbine types with a rotor area in excess of 1 m<sup>2</sup> are subject to the *Danish Energy Agency's Order no. 651 of 26 June 2008 on the technical certification scheme for the design, manufacture, installation, maintenance and servicing of wind turbines*. In the case of turbines with rotor area 1-5 m<sup>2</sup>, however, only a registration notification is required.

Wind turbine projects must as a minimum be screened in accordance with the regulations of the *EIA Order*. Household and small turbines will not normally require an EIA, supplement to the municipal plan and EIA.

#### ERECTION OF WIND TURBINES IN RURAL ZONES

It is the task of the municipalities, as the rural zone authority, to issue rural zone permits. In this regard, the municipality must carry out



Illustrations: Birk Nielsen

**FIGURE 4.3  
TOWER/BLADE RATIOS**

The ratio between a wind turbine's tower and blades (the "harmony ratio") is important for the turbine's own aesthetics. New types of large turbine have a more slender design than older models, and the tower can therefore better support long blades with a large rotor area and production capacity. The recommended harmony ratio thus depends on the size of the wind turbine. For wind turbines with a total height of less than 100 metres, the recommended rotor diameter is  $\pm 10\%$  in relation to the tower height, while for larger wind turbines with a total height of up to 150 metres, the recommended rotor diameter is between  $+10\%$  and  $+35\%$  in relation to the tower height.



Photo: Wind Turbine Secretariat

planning appraisals in respect of ongoing planning. Furthermore, landscape considerations and any building lines as per the *Danish Nature Protection Act* as well as any supplementary considerations regarding neighbours (view, reflection, etc.) must also be taken care of.

In the case of household and small turbines, the *Wind Turbine Circular* does not set out fixed requirements for the distance to neighbouring homes, etc., in relation to the turbine's total height.

The municipalities must carry out individual assessments of cases/applications. However, the fact that the decision must always be taken on the basis of a specific assessment does not preclude the municipality from clarifying in its municipal planning guidelines other protection interests and considerations that

receive particular attention in its case-handling, including of course any guidelines for erecting smaller wind turbines. ●

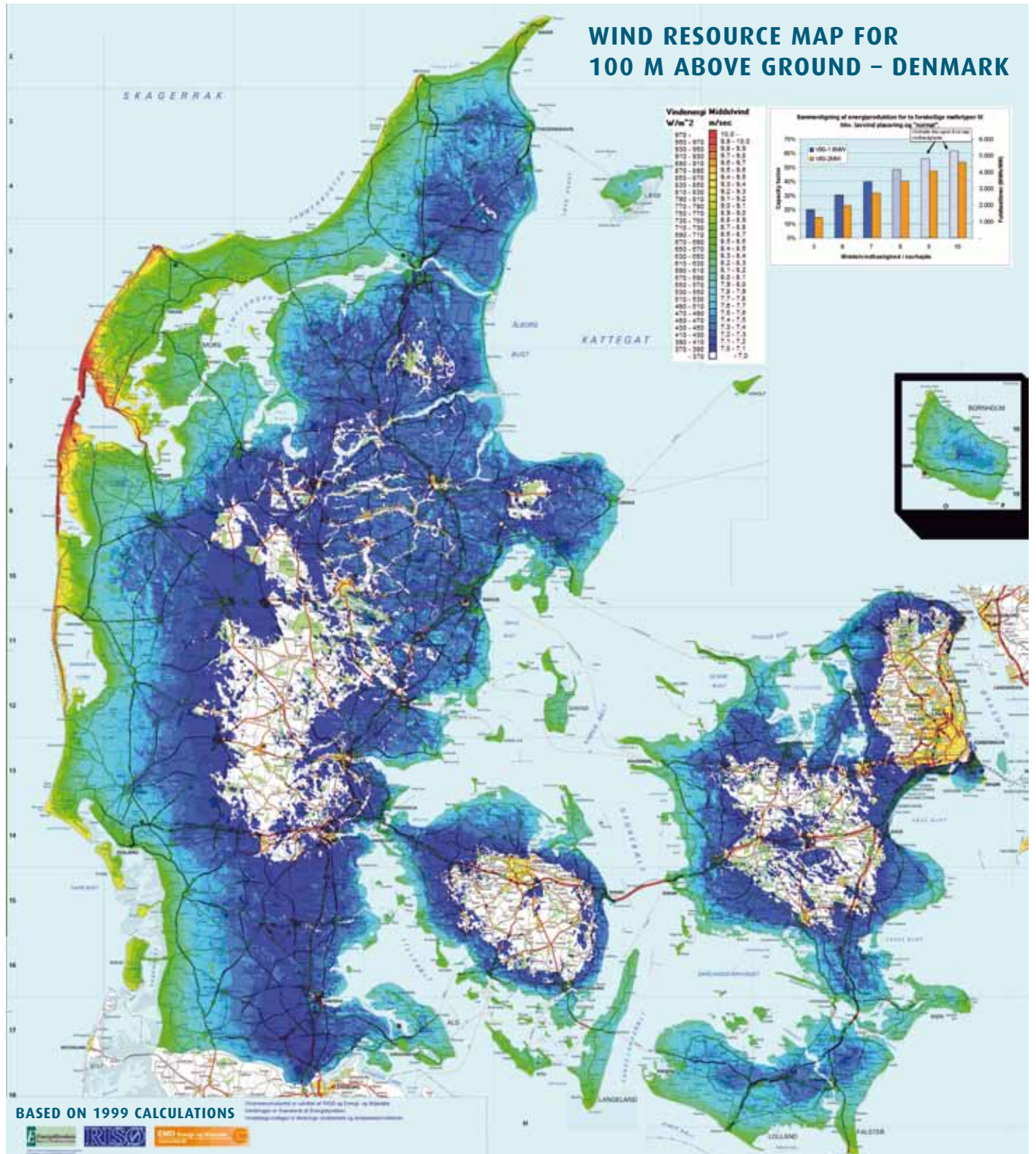
#### WIND RESOURCE ATLAS FOR DENMARK:

In 1998, with funding from the Danish Energy Agency, Risø DTU's Wind Energy Division teamed up with the Danish software and consultancy firm EMD International to compile the Wind Resource Atlas for Denmark, which can be seen on page 17. Areas with the highest average wind speeds are shown in red and yellow, while areas with less wind are shown in green and blue.



Photo: Samsø Energy Academy

In addition to large wind turbines, the Samsø Renewable Energy Island project has also established household wind turbines, one of which (shown below) can be seen in front of the solar-panelled roof of Samsø Energy Academy.



## 5. OFFSHORE WIND TURBINES



Photo: DONG Energy

With 209 MW produced by 91 wind turbines, the Horns Rev II offshore wind farm, which was opened in September 2009, is the largest offshore wind farm in the world to date. The turbines are located 30 km from the coast and can produce electricity to cover the consumption of 200,000 households.



Photo: Samsø Energy Academy

The offshore wind farm at Paludans Flak 4 km south of Samsø comprises 10 wind turbines with a combined output of 23 MW that produce approximately 77,500 MWh a year. The offshore wind farm was commissioned in 2002, and in the long term its production will make it possible to cover electricity consumption for the operation of electric cars and hydrogen for transportation on the island. Half of the wind turbines are owned by the municipality, while the inhabitants of Samsø own most of the rest.

### 5.A. OFFSHORE WIND TURBINES IN DENMARK

In 1991 Denmark became the first country in the world to take wind turbines out to sea with 11 x 450 kW turbines in the Vindeby offshore wind farm. This was followed by a number of smaller demonstration projects, leading to the first two large offshore wind farms Horns Rev I and Nysted (Rødsand I) with outputs of 160 and 165 MW respectively. Some offshore wind farms have been built because power companies were given political orders to do so or via tenders, while others are wholly or partly owned by local wind turbine owners' associations such as Middelgrunden and Samsø.

With 660 MW offshore wind turbines connected to the electricity grid in 2009, Denmark is still one of the largest developers of offshore wind farms. Only the United Kingdom has a larger capacity.

In 2010 the offshore wind turbines at Rødsand II will be erected with an output of just over 200 MW. The Danish Energy Agency has tendered out another offshore wind turbine project at Anholt/Djursland with an output of around 400 MW. These projects are the result of the *Energy Policy Agreement of 29 March 2004* and the *Energy Policy Agreement of 21 February 2008* respectively.

It is considerably more expensive to build and operate offshore wind turbines than onshore wind turbines. On the other hand, the production conditions are better at sea with higher wind speeds and more stable wind conditions.

The increased costs are reflected in the feed-in tariff that the project developers for the latest offshore wind farms have obtained through the Danish Energy Agency's tender. DONG Energy, which is the project sponsor for Horns Rev II, receives DKK 0.518 per kWh for 10 TWh, corresponding to around 50,000 full-load hours, after which the electricity produced has to be sold under market conditions. E.ON AB from Sweden, which won the tender for Rødsand II, receives DKK 0.629 per kWh for 10 TWh, corresponding to around 50,000 full-load hours.

### 5.B. THE DANISH ENERGY AGENCY AS A ONE-STOP SHOP

The Danish Energy Agency is the authority responsible for the planning and erection of offshore wind turbines. 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 owner wishing to establish an offshore wind turbine project only has to deal with one body – namely the Danish Energy Agency – to obtain all the necessary approvals and licences.

As a one-stop shop, the Danish Energy Agency involves other relevant authorities such as the Agency for Spatial and Environmental Planning, the Danish Maritime Authority, the Danish Maritime Safety Administration, CAA-Denmark, the Heritage Agency of Denmark, Danish Defence, etc. The Danish Energy Agency also arranges consultation with the relevant stakeholders and issues all the necessary approvals and licences. Energinet.dk is responsible for transmitting the electricity production from offshore wind turbines to the electricity grid and owns both the transformer station and the underwater cables that carry the electricity production of offshore wind farms to land.

In comparison with the official administration of offshore wind farms in other countries, the Danish model has provided a quick, cost-effective process to the benefit of operating economy in the individual projects and the development of offshore wind turbines as a whole.

### 5.C. MAPPING OF FUTURE SITES FOR OFFSHORE WIND FARMS

In order to ensure that the future development of offshore wind turbines does not clash with other major public interests and that the development is carried out with the most appropriate socio-economic prioritisation, the Danish Energy Agency, in conjunction with the other relevant authorities, has mapped the most suitable sites for future offshore wind farms. This mapping is a dynamic process because the framework conditions for developing offshore wind farms are continually changing. In 2007

the Danish Energy Agency published a technical mapping report designating 23 suitable sites, each with space for around 200 MW.

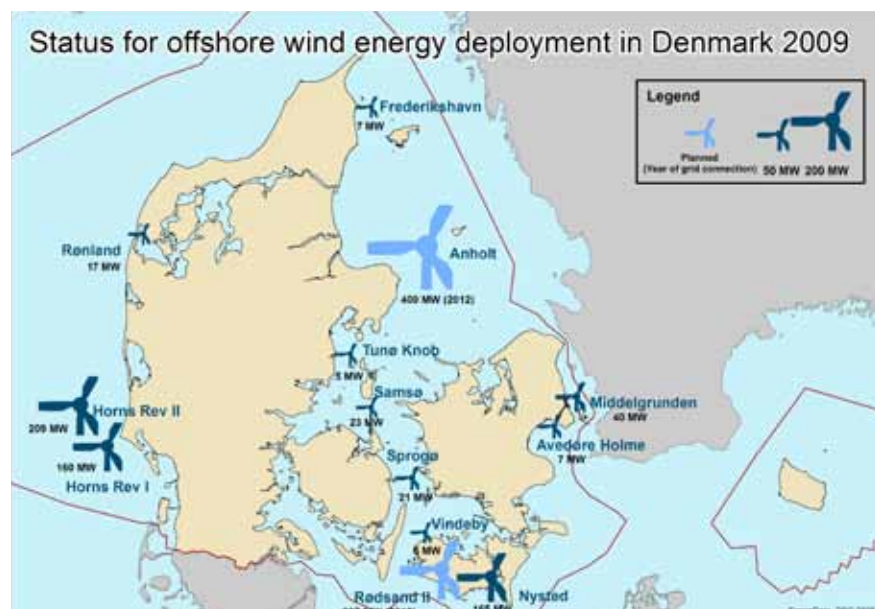
These possible offshore wind farms could achieve a total installed output of 4,600 MW, and with average wind speeds of around 10 metres per second they could produce around 18 TWh annually, equivalent to more than half of current Danish electricity consumption. The sites are prioritised according to public interests such as regard for grid transmission, navigation, nature, landscape, raw material extraction, and the anticipated cost of establishing and operating the offshore wind farms. The cross-ministry committee work has placed its emphasis on a planned and coordinated development of offshore wind farms and the transmission grid, and the chosen sites have been submitted to a strategic environmental assessment in order to prevent any future conflicts with environmental and natural interests.

Through its *Offshore Wind Turbine Action Plan* of September 2008 the Danish Energy Agency updated the mapping in light of the *Energy Policy Agreement* of 21 February 2008. The good wind conditions at the chosen sites allow the 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, a balance has been struck between economic considerations and the visual impact on land.

#### 5.D. TENDERING OUT OF OFFSHORE WIND FARMS

The establishment of offshore wind turbines can follow two different procedures: a government tender procedure run by the Danish Energy Agency; or an open-door procedure. For

*The Committee for Future Offshore Wind Power Sites updated its mapping of potential locations in September 2008. The purple colour on the map indicates 26 potential sites, each of which can be developed with 200 MW, giving a total of 5,200 MW, while the existing large offshore wind farms are indicated in blue.*



The map of Denmark shows the locations of existing and planned offshore wind farms. Up to now offshore wind farms have been located with a considerable geographical spread, which has made it easier for Energinet.dk to incorporate the varying electricity production into the electricity system. Following a government tender initiated in 2009, a 400 MW offshore wind farm is to be established between Anholt and Djursland.

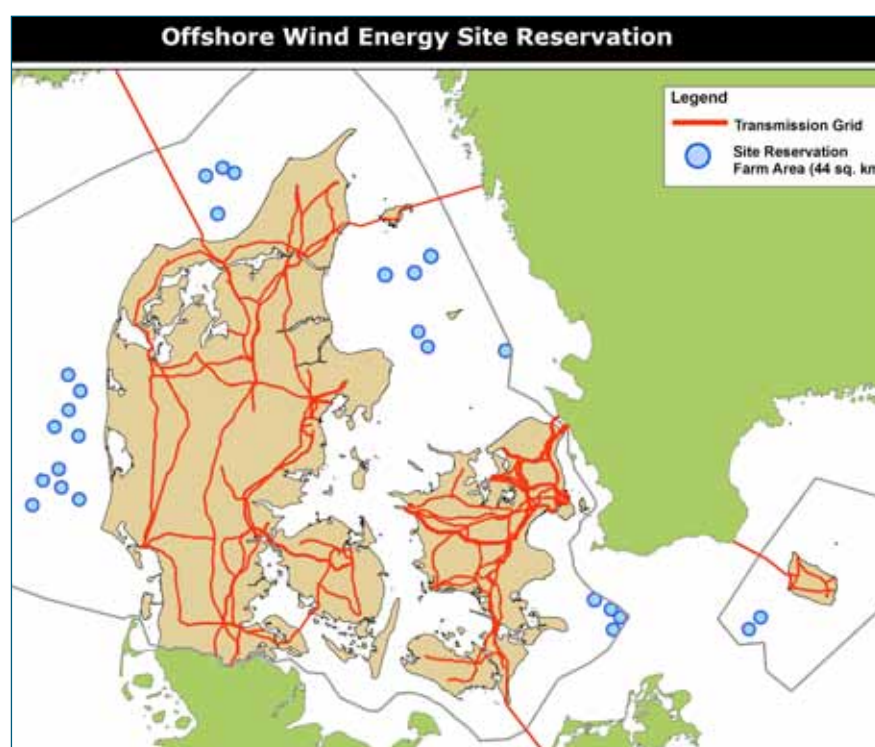




Photo: DONG Energy

*Horns Rev II will predominantly be serviced by operating and maintenance personnel who will live for one week at a time on a habitation platform linked to the offshore wind farm. This will help reduce transport time and costs, thereby optimising operating economy.*

## Factbox

### Two types of procedure for establishing offshore wind farms

In Denmark, new offshore wind farm projects can be established according to two different procedures: a government tender or an open-door procedure.

A government tender is carried out to realise a political decision to establish the project as part of the Danish development of renewable energy. The Danish Energy Agency tenders out the project in an open competition to obtain the lowest possible costs. Energinet.dk may be responsible for preparing the Environmental Impact Assessment (EIA) and the electricity link to land.

In an open-door procedure, the project developer applies to the Danish Energy Agency for a licence to carry out preliminary investigations and establish an offshore wind farm in the given area. The Danish Energy Agency clarifies whether there are any competing public interests and, where possible, issues the required licence. The project developer receives the same price supplement as for new onshore wind turbines and has to finance the connection of the project to the electricity grid on land.

both procedures, the project developer must obtain a licence to carry out preliminary investigations, a licence to finally establish the offshore wind turbines, a licence to exploit wind power for a given number of years, and – in the case of wind farms of more than 25 MW – an approval for electricity production.

In the government tender procedure, the Danish Energy Agency announces a tender for an offshore wind turbine project of a specific size, e.g. 200 MW, within a specifically defined geographical area. A government tender is carried out to realise a political decision to establish a new offshore wind farm at the lowest possible cost.

Depending on the nature of the project, the Danish Energy Agency invites applicants to submit a quotation for the price at which the bidders are willing to produce electricity in the form of a fixed feed-in tariff for a certain amount of produced electricity, calculated as number of full-load hours.

The winning price will differ from project to project because the result of a tender depends on the project location, the wind conditions at the site, the competitive situation in the market at the time, etc. In the two tenders so far the winning price has been higher than the feed-in tariff that is paid for an open-door project which corresponds to the feed-in tariff for new onshore wind turbines. As well as the lowest feed-in tariff, the technical and financial capacity of the bidding companies or consortia to implement the project are assessed.

Based on the experiences of the Rødsand II offshore wind farm, where the winner of the first tender ultimately chose not to implement the project due to changed market conditions, the Danish Energy Agency has tightened the conditions in the latest tenders so that the project developer has to pay a fine if the project is not implemented as planned or is delayed.

In projects covered by a government tender, Energinet.dk owns both the transformer station and the underwater cable that carries the electricity to land from the offshore wind farm. In

the tender for the Anholt offshore wind farm, which is being implemented in 2009-2010, Energinet.dk will also undertake the EIA and preliminary geotechnical and geophysical surveys of the seabed. The winner of the tender will pay Energinet.dk's costs for these preliminary surveys.

In the open-door procedure, the project developer takes the initiative in establishing an offshore wind farm in a specific area. This is done by submitting an unsolicited application for a licence to carry out preliminary investigations in the given area. The application must as a minimum include a description of the project, the anticipated scope of the preliminary investigations, the size and number of turbines, and the limits of the project's geographical siting.

In an open-door project, the developer pays for the transmission of the produced electricity to land. An open-door project cannot expect to obtain approval in the areas that are designated for offshore wind farms in the report *Future Offshore Wind Power Sites – 2025* from April 2007 and the follow-up to this from September 2008.

Before the Danish Energy Agency actually begins processing an application, as part of the one-stop shop concept it initiates a hearing of other government bodies 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 Danish Energy Agency has approved applications within the open-door procedure for the following offshore wind turbine projects: Avedøre Holme, involving three demonstration wind turbines (DONG Energy); Frederikshavn, involving six demonstration wind turbines (NearshoreLAB); and Sprogø, involving seven offshore wind turbines (Sund & Bælt).

### 5.E. IMPLEMENTATION OF AN OFFSHORE WIND TURBINE PROJECT

Once the Danish Energy Agency has granted the project developer a licence to carry out preliminary investigations, all projects follow the same procedure. 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. The EIA must demonstrate, describe and assess the environmental consequences of implementing the project in respect of:

- a) people, fauna and flora
- b) seabed, water, air, climate and landscape
- c) tangible property and Danish cultural heritage
- d) interaction between these factors.

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

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 organi-



Photo: Samso Energy Academy

sations 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, 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 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 have been granted.

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. Any appeals must be submitted in writing within four weeks of the publication of the decision. ●

### Factbox

#### The environmental impact of offshore wind farms

As an integral part of the projects for the first two large demonstration offshore wind farms, Horns Rev I and Nysted, from 1996 to 2006 an Environmental Monitoring Programme was carried out to document the impact of the projects on the marine environment. On completion of the programme, at the recommendation of an international expert panel a small follow-up programme was launched focusing on the long-term effects for porpoises, water birds (common scoters, divers, long-tailed ducks, etc.) and fish.

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 were only affected in the short term during the construction work, while porpoises, which disappeared from the area while the wind farm was being built, have to some extent returned. Birds have been able to avoid the offshore wind farms.

The results of the Environmental Monitoring Programme are quality-assured by the international expert panel and regularly published on the English pages of the Danish Energy Agency's website, [www.ens.dk](http://www.ens.dk).

## 6. NEW SCHEMES IN THE *DANISH PROMOTION OF RENEWABLE ENERGY ACT*

Photo: Visualisation by Birk Nielsen



### Factbox

#### Claims for payment for loss of value on real property

The *Energy Policy Agreement of February 2008* introduced a scheme giving neighbours of new wind turbine projects the right to have loss of value on their property covered if the loss is assessed to be at least 1% of the property's value. The scheme was introduced to create greater local acceptance of and involvement in the erection of new onshore wind turbines.

In order for their claims to be processed, neighbours living within a distance of six times the wind turbine's total height must notify their claims for payment for loss of value within four weeks after the wind turbine project developer has conducted the prescribed information meeting. Neighbours living further away must pay a fee of DKK 4,000. If the claim for payment for loss of value is upheld, the fee is repaid.

The loss of value is assessed by an impartial valuation authority appointed by the Minister for Climate and Energy. In all there are five valuation authorities covering the whole country, each consisting of a lawyer and an expert in assessing real property value in the local area. Decisions of the valuation authority cannot be contested with another administrative authority, but they may be taken before the courts.

Energinet.dk's Front Office administers the loss-of-value scheme and has placed forms and other material for use in the case-handling on its website, [www.energinet.dk](http://www.energinet.dk), where it also provides regular updates on new decisions.

#### 6.A. A COMPREHENSIVE ACT ON RENEWABLE ENERGY

The *Danish Promotion of Renewable Energy Act* (L 1392 of 27 December 2008), which entered into force on 1 January 2009, covers, among other things, price supplements for installations producing electricity with renewable energy, technical and safety-related requirements for wind turbines, and special regulations for offshore wind turbines. The *Energy Policy Agreement of 21 February 2008* required that these regulations should be combined into one act on renewable energy.

Further to this agreement, the *Danish Promotion of Renewable Energy Act* also contains four new schemes aimed at promoting the local population's acceptance of and involvement in the development of onshore wind turbines: a loss-of-value scheme for neighbours of new wind turbines; an option-to-purchase scheme with preference given to the local population; a green scheme so that municipalities can improve the scenery and recreational values in areas where wind turbines are erected; and a guarantee scheme to support local initiative groups with preliminary investigations. All the schemes are administered by Energinet.dk.

#### 6.B. THE LOSS-OF-VALUE SCHEME

Any party erecting new wind turbines with a height of 25 metres or more, including offshore wind turbines erected without a government tender procedure, must pay for any loss of value on real property if the erection of the wind turbines results in a loss of at least 1% of the property value. In order to give neighbours the opportunity to assess the consequences of

the wind turbine project, the erector must draw up information material on the project and invite the neighbours to a public information meeting. The material must include a list of the properties lying within a distance of up to six times the wind turbine's total height. Energinet.dk, which must approve the information material, can require that the material should also include a visualisation of the project. The meeting must be convened with a reasonable period of notice by means of an announcement in local newspapers and must take place at the latest four weeks before the municipal planning process ends.

Property owners who believe, based on the information material and the information meeting, that the erection of the wind turbines will reduce the value of their property must notify the loss of value to Energinet.dk within four weeks of the meeting. If a property owner lives further away than six times the wind turbine's total height, the owner must pay a fee to Energinet.dk of DKK 4,000. Neighbours who live closer to the wind turbine project are not required to pay this fee. The fee is repaid if the property owner is granted the right to compensation for loss of value.

The wind turbine erector may enter into a voluntary agreement concerning compensation for loss of value with property owners who have notified their claims to Energinet.dk. If this is not done within four weeks, Energinet.dk will submit the owners' claims to a valuation authority. The Danish Minister for Climate and Energy has appointed five valuation authorities consisting of a lawyer and an expert in assessing real property value. The valuation authority will decide, on the basis of a specific assessment, the extent to which property owners' claims can be accommodated.

If the property owner's claim for compensation is upheld, the wind turbine erector will pay the valuation authority's costs. If the property owner's claim is rejected, Energinet.dk pays the case costs not covered by any fee of DKK 4,000. This cost is recouped from the electricity consumers as a PSO contribution.

Decisions of the valuation authority cannot be contested with another administrative body but may be brought before the courts as civil proceedings by the owner of the property against the wind turbine erector.

#### 6.C. THE OPTION-TO-PURCHASE SCHEME

Erectors of wind turbines with a total height of at least 25 metres, including offshore wind turbines erected without a governmental tender, shall offer for sale at least 20% of the wind turbine project to the local population. Anyone over 18 years of age with his/her permanent residence according to the National Register of Persons at a distance of maximum 4.5 kilometres from the site of installation or in the municipality where the wind turbine is erected has the option to purchase. If there is local interest in purchasing more than 20%, people who live closer than 4.5 kilometres from the project have first priority on a share of ownership, but the distribution of shares should ensure the broadest possible ownership base.

In order to give local citizens an adequate decision-making platform, wind turbine erectors must provide information on the nature and financial conditions of the project. This must be done through sales material containing as a minimum the articles of association of the company that will be erecting the wind turbine, a detailed construction and operating budget, including the financing for the project, the liability per share, and the price of the shares on offer. The sales material must be quality-assured by a state-authorised public accountant. Energinet.dk must approve the sales material as a condition for the wind turbine erector obtaining the price supplement provided for in the *Danish Promotion of Renewable Energy Act*.

The wind turbine erector must run through the sales material at an information meeting convened with a reasonable period of notice by announcement in a local newspaper. Following the information meeting, local citizens have a period of four weeks to make a purchase offer. In the case of both the loss-of-value and option-to-purchase schemes, transitional regulations exempting wind turbines where the



Photos: Visualisations by Birk Nielsen

municipality has published a supplement to the municipal plan with an associated EIA or announced that the project does not require an EIA apply until 1 March 2009. The wind turbine project must also be connected to the grid before 1 September 2010.

#### 6.D. THE GREEN SCHEME

In order to further promote the local council's commitment to wind turbine planning and local acceptance of new wind turbine projects, the *Danish Promotion of Renewable Energy Act* has introduced a green scheme for the financing of projects that enhance the scenery and recreational opportunities in the municipality. Energinet.dk, which administers the scheme, pays DKK 0.004 per kWh for the first 22,000 full-load hours from wind turbine projects that are connected to the grid on 21 February 2008 or later. The money for the green scheme is recouped from electricity consumers as a PSO contribution.

The money is lodged in a special account for the given municipality; the amount of money depends on how many wind turbines and of what size are connected to the grid in the municipality. A wind turbine of 2 MW generates a total sum of DKK 176,000. In order to

*Visualisations are an important element of an Environmental Impact Assessment (EIA) for new onshore wind turbine projects, and the method has been described in the report *Store vindmøller i det åbne land – en vurdering af de landskabelige konsekvenser* (Large wind turbines in the open countryside – an assessment of implications for the landscape). This example from the project in Gisselbæk illustrates the difference between a project with 3 x 1.75 MW wind turbines, each with a total height of 93 metres (top), and a layout of 3 x 3.6 MW wind turbines, each with a total height of 150 metres. The distance from the observer to the nearest wind turbine is 1.6 kilometres.*

*The visualisations were produced using a wind turbine model taken from the list in the WindPro software program: Siemens Wind Power's 3.6 MW wind turbine. The report's visualisation examples assume that the turbines have a standard grey anti-reflective coating. The spacing is three times the rotor diameter, which is recommended in respect of the wind turbine project's own aesthetics and to avoid problems with turbulence. For 3.6 MW wind turbines, this means a distance between the wind turbines of 321 metres.*



Photo: Samsø Energy Academy

*SAMSØ RENEWABLE ENERGY ISLAND: These three wind turbines, each 1 MW with a total height of 77 metres, are owned by local farmers and a wind turbine owners' association with around 450 members. The wind turbines, which were erected in 2000 as part of the Samsø Renewable Energy Island project, are an example of how it really is possible to create strong public support for the erection of large onshore wind turbines by financially involving the local population in new projects.*

*In addition to these three wind turbines near the village of Permelille, a further eight 1 MW wind turbines have been erected at two other sites on Samsø. The total construction cost for the 11 onshore wind turbines was around DKK 66 million, and in a normal year the turbines produce around 25,300 MWh, equivalent to the electricity consumption of some 6,500 households. Samsø Municipality has approximately 4,000 inhabitants.*

promote local involvement in new wind turbine projects, during processing of the project the municipality may apply to Energinet.dk for a subsidy for certain development works or activities that draw on the full amount so that citizens become aware of the benefits that are obtained from the wind turbine erection.

However, the subsidy can only be paid once the wind turbine project is connected to the grid. If several wind turbine projects are implemented in a municipality, the subsidies can be used for one combined project. In order for the money to be paid, the municipality must demonstrate to Energinet.dk that the money will be used in accordance with the application.

The green scheme may wholly or partly finance development works for enhancing scenic or recreational values in the municipality. A subsidy may also be granted for municipal cultural activities and informational activities in local associations, etc., aimed at promoting acceptance of the use of renewable energy sources in the municipality. The municipalities may not raise complaints about Energinet.dk's handling of subsidies within the green scheme, but they can refer Energinet.dk's calculation of

the municipality's share of the green scheme to the Energy Board of Appeal.

#### 6.E. THE GUARANTEE SCHEME

In order to give local wind turbine owners' associations and other initiative groups the opportunity to initiate preliminary investigations, etc., for wind turbine projects, Energinet.dk has set up a guarantee fund of DKK 10 million that will make it easier for local initiatives to obtain commercial loans for financing preliminary investigations and keep the initiative-takers financially indemnified if the project cannot be realised. The money for the guarantee fund is recouped from electricity consumers as a PSO contribution.

A local initiative may apply to Energinet.dk for a guarantee to take out a loan of maximum DKK 500,000. There are conditions that the wind turbine owners' association or initiative group must have at least 10 members, the majority of whom have a permanent residence in the municipality, and that the project prepared involves onshore wind turbines with a total height of at least 25 metres or offshore wind turbines that are established without a government tender.

The guarantee can be given for activities that may be regarded as a natural and necessary part of a preliminary investigation into establishing one or more wind turbines. This might be an investigation of the siting of wind turbines, including technical and financial assessments of alternative sitings, technical assistance with applications to authorities, etc. However, it is a condition that at the time of application the project is financially viable in the opinion of Energinet.dk. Guarantees can be awarded for a maximum total sum of DKK 10 million. If this limit has been reached, new applications are placed on a waiting list. The guarantee shall lapse when the wind turbines are connected to the grid or if the local group sells its project to another party.

Energinet.dk's decisions concerning the guarantee fund may be contested with the Energy Board of Appeal.

#### 6.F. ENERGINET.DK'S FRONT OFFICE

In order to ensure smooth, efficient administration of the four new schemes, Energinet.dk has set up a Front Office to take care of all direct contact with users of the schemes, while Energinet.dk's technical experts (back offices) undertake the actual legal and financial case-handling. In order to make the work easier for wind turbine erectors, neighbours and municipalities, there is a link (in Danish only) on the Energinet.dk website to a small library where all relevant application forms and other documents can be downloaded via the menu item "Nye vindmøller – hjælp til ejere, naboer og kommuner m.fl." (New wind turbines – help for owners, neighbours and municipalities, etc.).

The website also gives access to information (in Danish only) on the new schemes: the menu item "Kunder" (Customers) gives access to information and material on the loss-of-value scheme and the option-to-purchase scheme, while the menu item "Klima og miljø" (Climate and the environment) gives access to information on all four schemes via the sub-menu "Danish Promotion of Renewable Energy Act". The Front Office staff can be contacted during business hours (9:00 am to 3:00 pm) by telephone on +45 70 20 13 53, or by e-mailing [fo@energinet.dk](mailto:fo@energinet.dk).

The majority of initial inquiries have been about the loss-of-value scheme. In the first project to pass through the scheme's procedures, around half of the neighbours who made a claim for compensation obtained a voluntary settlement with the wind turbine erector, while the valuation authority has been involved in the other claims. Compensation was paid in two cases, while two claims were rejected. The valuation authority's specific decisions, which are published in anonymous form, can be monitored via the website [www.taksationsmyndigheden.dk](http://www.taksationsmyndigheden.dk) (in Danish only).

The website [www.energinet.dk](http://www.energinet.dk) also contains a summary of the individual municipalities' accounts in the green scheme so that you can see whether a municipality currently has funds available for projects and activities. ●



Photos: Mogens Holmgård/Vattenfall Wind Power



The Vattenfall electricity company, which is the largest owner of Danish onshore wind turbines, was also responsible for the largest project under the scrapping scheme at Nørrekær Enge, where 77 older wind turbines were replaced with 13 x 2.3 MW turbines. In the photo, the installers are setting up one of the new wind turbines, which were connected to the grid in 2009.

### Factbox

#### The scrapping scheme

Part of the current projects involving new onshore wind turbines is being carried out under the scrapping scheme, which was agreed in the *Energy Policy Agreement of 2004*. Older and less efficient wind turbines with an output of maximum 450 kW can be dismantled in return for a scrapping certificate giving an erector the right to an extra supplement of DKK 0.08 per kWh for 12,000 full-load hours for new wind turbines with a total output up to twice as high as that of the dismantled turbines.

The scrapping scheme covers wind turbines totalling 175 MW, equivalent to the erection of new wind turbines with scrapping certificates for a total of 350 MW.

The scheme for earning scrapping certificates and redeeming them for new projects is administered by Energinet.dk, which also pays the price supplements connected with the scrapping scheme as a PSO-financed contribution.

## 7. TARIFFS FOR ELECTRICITY PRODUCED BY WIND TURBINES

### Factbox

#### Tariffs for electricity produced by wind turbines

The development of wind power in Denmark has been promoted since the late 1970s by paying wind turbine owners a supplement to the electricity production price. Even though the electricity market in Denmark was liberalised in 1999 so that the market price could fluctuate according to supply and demand, the wind turbine owners were guaranteed a fixed feed-in tariff.

In the *Energy Policy Agreement of 2004* the wind turbine owners' production subsidy was established as a supplement to the market price of DKK 0.10 for 20 years. In the *Energy Policy Agreement of February 2008* it was decided to increase the production subsidy to make it more attractive to erect onshore wind turbines.

As the 4,700 or so onshore wind turbines were erected at different times, the production subsidy varies depending on the date of grid connection and the size of the wind turbines. The detailed conditions are set out in the *Danish Promotion of Renewable Energy Act*, which contains all the tariffs for electricity produced by wind turbines. New onshore wind turbines connected to the grid after the *Energy Policy Agreement of 21 February 2008* receive a supplement to the market price of DKK 0.25 per kWh. This supplement applies for the first 22,000 full-load hours, after which the wind turbine owner only receives the market price. Furthermore, a supplement of DKK 0.023 per kWh is paid to cover balancing costs for the full lifetime of the wind turbine. New wind turbines established with a scrapping certificate receive an extra supplement of DKK 0.08 per kWh for 12,000 full-load hours.

Offshore wind turbines established under an open-door procedure receive the same supplement as new onshore wind turbines, i.e. DKK 0.25 per kWh plus DKK 0.023 per kWh. In the case of offshore wind turbines established as part of a government tender, the supplement depends on the price at which the tendering party is prepared to produce electricity. This price will usually depend on the estimated construction costs, the local wind conditions, and the project developer's financing terms.

#### 7.A. THE NEED FOR FINANCIAL SUPPORT FOR WIND TURBINE ELECTRICITY

Right from the late 1970s, there has been financial support for electricity produced by wind turbines. In the early years, this support took the form of both installation grants and electricity production subsidies. Since the beginning of the 1990s, the support has taken the form of a guaranteed feed-in tariff or a supplement to the market price. The support is offered as compensation for wind turbine owners because electricity production from wind turbines still cannot compete financially with conventional production at power plants using coal, natural gas or oil.

The current supplement to the market price is paid by Energinet.dk, which recoups the sum as a public service obligation (PSO). The amount is indicated on electricity bills. In recent years, when the average market price in the Nordic spot market has been fluctuating between DKK 0.20 and 0.35 per kWh, the PSO tariff has been around DKK 0.10 per kWh. As well as wind turbines, which receive around half of these PSO contributions for environmentally friendly electricity production, the contributions are also spent on supporting decentralised CHP plants, electricity production from biomass, solar power, etc.

#### 7.B. PRICE SUPPLEMENTS FOR ONSHORE WIND TURBINES

The price supplement for electricity produced by wind turbines is regulated in the *Danish Promotion of Renewable Energy Act* in accordance with the *Energy Policy Agreement of 21 February 2008*. Here, a broad political majority in the Danish Parliament agreed to increase the supplement to make it more attractive to erect onshore wind turbines. The electricity produced is supplied to the electricity supply grid, and the turbine owner sells the actual electricity on the market under market conditions. A DKK 0.25 supplement to the market price is paid for electricity produced by wind turbines connected to the grid on or after 21 February 2008. The price supplement applies for the first 22,000 full-load hours. Furthermore, a supplement of DKK 0.023 per kWh is

paid to cover balancing costs throughout the turbine's lifetime.

In the case of wind turbines that were connected to the grid before 21 February 2008, there are special regulations that depend on the date of connection and the size.

Household wind turbines and small turbines, i.e. wind turbines with an output of less than 25 kW, that are connected in a household's own consumption installation, receive a price supplement which, together with the current market price, amounts to DKK 0.60 per kWh.

If a wind turbine erector has earned or purchased scrapping certificates from older wind turbines with an output of 450 kW or less and dismantles the turbines in the period 15 December 2004 to 15 December 2010, the erector may receive a scrapping price supplement of DKK 0.08 per kWh, which is added to the general price supplement of DKK 0.25 per kWh. The scrapping price supplement is paid for the first 12,000 full-load hours at double the dismantled wind turbine's output. The supplement is conditional on the wind turbine being connected to the grid by 31 December 2010.

#### 7.C. PRICE SUPPLEMENTS FOR OFFSHORE WIND TURBINES

The price supplement for electricity produced by offshore wind farms established as part of a government tender is determined as part of the given tender. The winners of the tenders to date have been the bidders that could offer the lowest feed-in tariff. In the two government tenders carried out so far, the feed-in tariff for Horns Rev II, which is owned by DONG Energy, was set at DKK 0.518 per kWh for 10 TWh, corresponding to around 50,000 full-load hours, and the feed-in tariff for Rødsand II, which is owned by E.ON AB, was set at DKK 0.629 per kWh for 10 TWh, corresponding to around 50,000 full-load hours. Wind turbines established under an open-door procedure receive the same price supplement as new onshore wind turbines, i.e. DKK 0.25 per kWh for 22,000 full-load hours plus DKK 0.023 per kWh for the full lifetime of the turbine. ●

## 8. INCORPORATION OF WIND POWER INTO THE ELECTRICITY SYSTEM

### 8.A. VARYING ELECTRICITY PRODUCTION OF WIND TURBINES

Over the decades Denmark has built up a well-functioning electricity system that gives consumers technical supply reliability that is among the best in the world. The electricity system has traditionally been based on a limited number of large thermal power stations whose heat surplus is used to feed the district heating supply of the largest towns. In the last 15-20 years this set-up has changed significantly, with the predominant proportion of new capacity being established as decentralised CHP plants, waste-based CHP plants, and wind turbines. This decentralised electricity production set-up has required the development of new methods for controlling and regulating the electricity system.

With a total installed capacity of around 3,200 MW, wind turbines today can annually cover around 20% of domestic electricity supply. By way of example, to cover around half of the electricity consumption with wind power in 2025 would require an increase to around 6,700 MW.

With the current wind turbine capacity there are already periods of the year when the electricity production of the wind turbines exceeds the total Danish consumption. This occurs in particular at night, when the wind blows strongly.

In a European context, Denmark is located between Norwegian and Swedish systems dominated by hydroelectric power and a continental system dominated by thermal power stations south of the border. In Germany, the Netherlands and Belgium, as well as in Norway and Sweden, there are currently plans for a major development of wind power, and the Danish electricity system will therefore assume an important role in linking areas with hydroelectric power, wind power and thermal electricity production respectively. The cross-border connections from Denmark to Norway, Sweden and Germany currently play a key role in optimum utilisation of the fluctuating electricity production of the wind turbines. When it is windy in Denmark and electricity consumption

is relatively low, Denmark exports electricity to Norway and Sweden, which turn down their hydroelectric power stations' turbines accordingly. In this way the hydroelectric power stations' water reservoirs function as an indirect store for wind-power-produced electricity because the hydroelectric power stations can quickly increase their production when the wind turbines can no longer cover such a large proportion of electricity consumption.

As the electricity system also has to be able to supply Danish consumers in periods when Danish wind turbines are not producing due to a lack of wind or storms, the system can either be fed by thermal power stations or via cross-border connections. In this way, the development of strong cross-border connections acts as an alternative to Danish back-up capacity with thermal power stations.

An anticipated major development of Danish wind power capacity increases the need to develop methods and means to make electricity consumption more flexible so that electricity consumers are encouraged to reduce consumption in periods of low production capacity in return for increasing consumption when production is high. Practical trials have demonstrated various forms of flexible electricity consumption: electric heat consumers can be switched off for a few hours without inconvenience; cold stores can switch off the electricity supply without the temperature increasing to a critical level; washing machines and dishwashers in private homes can be switched on when electricity prices are low; and so on.

However, a greater effect on the electricity system's overall flexibility can be achieved by integrating electric car batteries and heat pumps into a flexible electricity consumption. This will help reduce Denmark's greenhouse gas emissions from the sectors of society that are not covered by the European CO<sub>2</sub> quota regulation. (The European quota regulation regulates CO<sub>2</sub> emissions for large dischargers such as electricity and heating plants and energy-intensive industry.) Given that from 2013 Denmark will have a special climate emission



Photos: Ricky John Molloy/Energinet.dk



*GREAT BELT ELECTRICITY LINK: In order to be able to connect up the two separate parts of Denmark into one electricity system, work has been carried out in recent years on an electricity link under the Great Belt. The link is expected to begin operating in 2010 with a transmission capacity of 600 MW, equivalent to about one tenth of the total Danish electricity consumption on a cold winter's day.*

*The Great Belt link has a construction budget of approximately DKK 1.2 billion and estimated annual operating costs of just over DKK 100 million. This is regarded as a good investment for Danish society because the link will make it possible to exploit Danish wind turbine power more efficiently within Denmark.*

*The link will also reduce the need for reserve production capacity in the electricity system and increase competition in the electricity market.*

*The electricity link consists of a 32 km underwater cable and two land cables of 16 km on Funen and 10 km on Zealand. The link will run from Fraude on Funen to Herslev on Zealand.*

*The above photos show the underwater cable being laid in summer 2009.*

target duty for the sectors that are not covered by the quota system, the reduction of emissions in these sectors will be of particular value. At the same time, the transport sector is still completely dominated by oil, from which Denmark has a long-term goal to free itself. There are therefore environmental, supply-related and economic benefits associated with converting energy consumption from the sectors that are not quota-regulated into electricity and district heating. At the same time, an increase in electricity consumption's share of total Danish energy consumption makes it possible to use a relatively larger proportion of the electricity production from the wind turbines in Denmark, especially if this can be done with a more flexible electricity consumption.



#### 8.B. RESEARCH INTO AN INTELLIGENT ENERGY SYSTEM

Converting the Danish energy system requires the introduction of more intelligent and self-regulating methods for controlling the system. In order to maintain a high technical level of supply reliability there must be a constant balance between production/supply and consumption in the Danish electricity system. As the electricity production from wind turbines can be changed at very short notice, there is a need for advanced communication between production installations, the system operator and consumers. The quicker and more efficiently the system operator can regulate both production and consumption, the lower the energy system's economic costs become. In order to ensure this development of the electricity system, for several years intensive research has been carried out into advanced methods for regulating the electricity system, and Danish research environments are among the most competent in the world. Furthermore, research is being undertaken into components that make individual wind turbines easier to regulate by the system operator. By combining new advanced regulation methods with intelligent electric meters installed in the premises of consumers, the operation of the electricity system can be optimised and it will be technically possible to incorporate ever greater amounts of fluctuating electricity production from wind turbines, wave power installations, solar cells, etc. ●



Illustration: Energinet.dk

#### Key

- 400 kV overhead line, a/c
- ⋯ 400 kV cable, a/c
- Overhead line, d/c
- ⋯ Cable, d/c
-  Transformer station
-  Converter station

The map of Denmark from Energinet.dk shows the Danish high-voltage grid and associated cross-border connections to Norway, Sweden and Germany. Strong cross-border connections are regarded as a vital precondition for efficient utilisation of the varying Danish electricity production from wind turbines.

Currently there are plans to expand the connections between Denmark and Norway (Skagerrak IV) and between Denmark and Germany. Furthermore, it is possible to expand the connections between Denmark, Sweden and Germany by connecting a large offshore wind farm on Kriegers Flak to the grid. A possible offshore wind farm south of Læsø could also pave the way for a stronger connection between Jutland and Sweden. And finally, work is being carried out on plans for an underwater cable connection between Denmark and the Netherlands (Cobra), which in the long term would make it possible to carry electricity production from Denmark and Danish offshore wind farms in the North Sea to continental Europe.

## FURTHER INFORMATION



The legal provisions on wind power can be found in the *Danish Promotion of Renewable Energy Act* (L 1392, adopted by the Danish Parliament on 27 December 2008), bill no. 55 of 5 November 2008 with explanatory notes. Both can be downloaded (in Danish) from [www.retsinformation.dk](http://www.retsinformation.dk).

More detailed regulations on onshore wind turbines can be found in *Circular no. 9295 of 22 May 2009* on planning and rural zone permits for the erection of wind turbines. The Circular and the associated guideline (no. 9296) can be downloaded (in Danish) from [www.blst.dk/Landsplan/Vindmoeller](http://www.blst.dk/Landsplan/Vindmoeller).



The Birk Nielsen visualisation report entitled *Store vindmøller i det åbne land – en vurdering af de landskabelige konsekvenser* (Large wind turbines in the open countryside – an assessment of implications for the landscape) can be downloaded (in Danish) from [www.skovognatur/Udgivelser/2007/Storevindmoller.htm](http://www.skovognatur/Udgivelser/2007/Storevindmoller.htm).

The report of the Danish Government's Planning Committee for Onshore Wind Turbines, published in 2007, can be downloaded in Danish from [www.blst.dk/Landsplan/Vindmoeller/Vindmoelleudvalg](http://www.blst.dk/Landsplan/Vindmoeller/Vindmoelleudvalg). An interactive map for assistance with wind turbine planning can be accessed via [www.blst.dk/Landsplan/Vindmoeller/afstandskort](http://www.blst.dk/Landsplan/Vindmoeller/afstandskort).

An English summary of the report of the Danish Government's Committee for Future Offshore Wind Power Sites entitled *Future Offshore Wind Power Sites – 2025*, published in April 2007, can be downloaded from [www.ens.dk/en-US/supply/Renewable-energy/WindPower/offshore-Wind-Power/Future-offshore-wind-parks/Sider/Forside.aspx](http://www.ens.dk/en-US/supply/Renewable-energy/WindPower/offshore-Wind-Power/Future-offshore-wind-parks/Sider/Forside.aspx) and the updated *Offshore Wind Turbine Action Plan 2008*, published in April 2008, can be downloaded (in Danish) from [www.ens.dk/da-DK/UndergrundOgForsyning/VedvarendeEnergi/Vindkraft/Sider/Forside.aspx](http://www.ens.dk/da-DK/UndergrundOgForsyning/VedvarendeEnergi/Vindkraft/Sider/Forside.aspx).



The Danish Ministry of the Environment's Wind Turbine Secretariat has a website at [www.vind.mim.dk](http://www.vind.mim.dk) and can be contacted during business hours (09:00 am to 4:00 pm) by telephone on +45 72 54 05 00, or by e-mailing [vind@mim.dk](mailto:vind@mim.dk).



Energinet.dk's Front Office can be contacted during business hours (09:00 am to 3:00 pm) by telephone on +45 70 20 13 53, or by e-mailing [fo@energinet.dk](mailto:fo@energinet.dk).

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