ANHOLT OFFSHORE WIND FARM
VISUALIZATION REPORT

DECEMBER 2009

RAMBOLL

Anholt Offshore Wind Farm
Visualization report

Background memo for the environmental impact assessment of the Anholt Offshore Wind Farm Project

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1. INTRODUCTION

Background

In 1998 the Ministry of Environment and Energy empowered the Danish energy companies to build offshore wind farms of a total capacity of 750 MW, as part of fulfilling the national action plan for energy, Energy 21. One aim of the action plan, which was elaborated in the wake of Denmark's commitment to the Kyoto agreement, is to increase the production of energy from wind power to 5.500 MW in the year 2030. Hereof 4.000 MW has to be produced in offshore wind farms.

In the years 2002-2003 the two first wind farms was established at Horns Rev west of Esbjerg and Rødsand south of Lolland, consisting of 80 and 72 wind turbines, respectively, producing a total of 325,6 MW. In 2004 it was furthermore decided to construct two new wind farms in proximity of the two existing parks at Horns rev and Rødsand. The two new parks, Horns rev 2 and Rødsand 2, are going to produce 215 MW each and are expected to be fully operational by the end 2010.

The 400 MW Anholt Offshore Wind Farm constitutes the next step of the fulfilment of aim of the action plan. The wind farm will be constructed in 2012, and the expected production of electricity will cover the yearly consumption of approximately 400.000 households. Energinet.dk on behalf of the Ministry of Climate and Energy is responsible for the construction of the electrical connection to the shore and for development of the wind farm site, including the organization of the impact assessment which will result in the identification of the best suitable site for constructing the wind farm.

Rambøll with DHI and other sub consultants are undertaking the site development including a full-scale Environmental Impact Assessment for the wind farm.

The present report regarding the visual impacts is a part of a number of technical reports forming the base for the Environmental Impact Assessment for Anholt Offshore Wind Farm.

The Environmental Impact Assessment of the Anholt Offshore Wind Farm is based on the following technical reports:

- Technical Description
- Geotechnical Investigations
- Geophysical Investigations
- Metocean data for design and operational conditions
- Hydrography including sediment spill, water quality, geomorphology and coastal morphology]
- Benthic Fauna
- Birds
- Marine mammals
- Fish
- Substrates and benthic communities
- Benthic habitat
- Maritime archaeology
- Visualization
- Commercial fishery
- Tourism and Recreational Activities
- Risk to ship traffic

The technical report regarding visualizations contains additional photage and background information. Furthermore, all visualizations are available on the web site of Energinet.dk: www.energinet.dk.

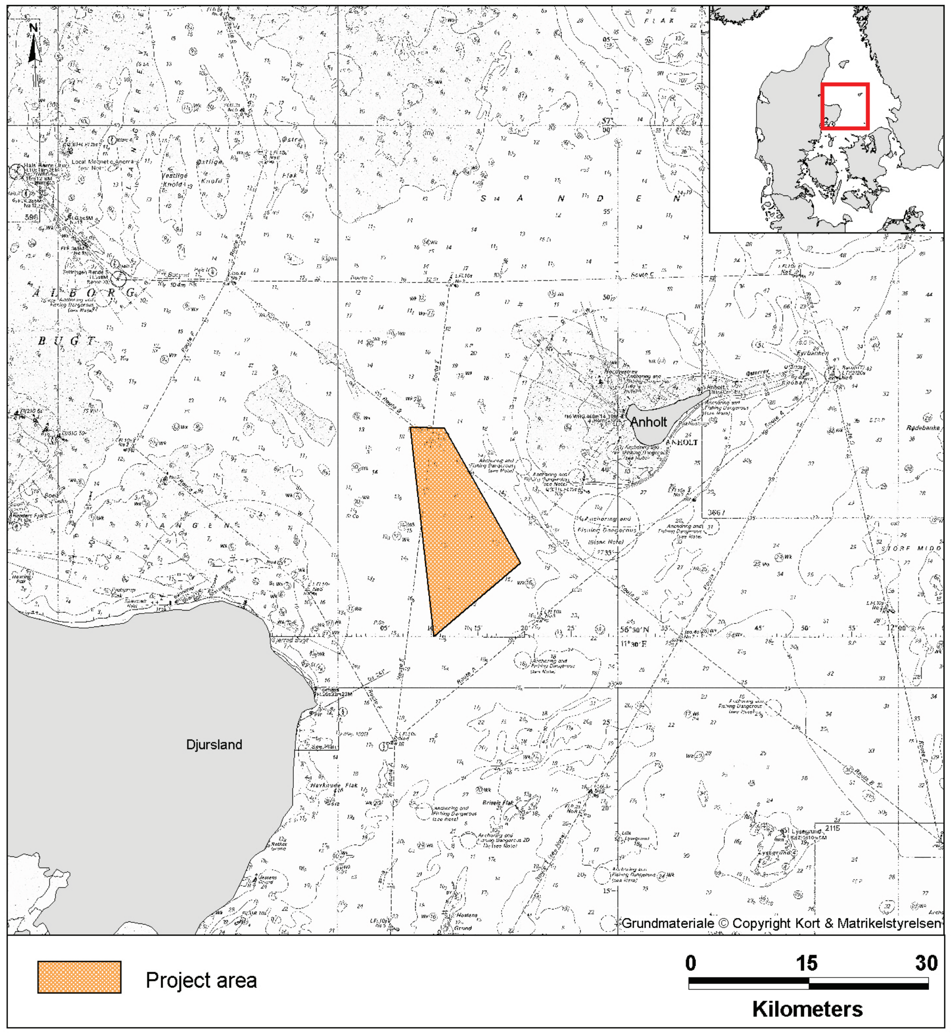

Figure 1-1 Project area

Site location

The designated investigation area for the Anholt Offshore Wind Farm is located in Kattegat between the headland Djursland of Jutland and the island Anholt - Figure 1-1. The project area is 144 km², but the planned wind turbines must not cover an area of more than 88 km². Minimum distances observer-to-park are 14.8 km from Djursland, and 18.3 km from Anholt.

1.1 Wind turbines and project layout

Turbines

The maximum rated capacity of the wind farm is by the authorities limited to 400 MW. The farm will feature from 80 to 174 turbines depending on the rated energy of the selected turbines corresponding to the range of 2.3 to 5.0 MW.

The project evaluates two possible models of turbines, namely:

- Repower 5MW, hub height approx. 90 m
- Siemens 2.3MW, hub height approx. 70 m

Preliminary dimensions of the turbines are not expected to exceed a maximum tip height of 160 m above mean sea level for the largest turbine size (5.0 MW) and a minimum air gap of approximately 23 m above mean sea level.

Lighting

The wind turbines will exhibit distinguishing markings visible for vessels and aircrafts in accordance with recommendations by the Danish Maritime Safety Administration and the Danish Civil Aviation Administration. Safety zones will be applied for the wind farm area or parts hereof.

In the following the general guidelines will be presented – however, the final regulations regarding lighting will be determined by the authorities.

During construction the temporary safety zone will be marked by yellow lights with a reach of at least 2 nautical miles.

In the operation phase the turbines will be equipped with navigations lights and markings. The safety zone for vessel traffic will as a minimum be marked by yellow navigation lights on the turbines with a reach of at least 5 nautical miles.

In case the distance between the turbines exceed 3 nautical miles it is advised to place lights on the turbines on corners of the farm as well as other turbines placed in a distance of more than 3 nautical miles.

Figure 1-2 View of a wind farm

Aviation markings include blinking lights with strength of at least 200 candela which will be placed on the turbines in each corner as well as on turbines in the centre of the farm in case the distance between the corners exceed 5 km. There are different requirements in terms of lighting depending on the height of the turbines. Turbines between 100 – 150 meters must be equipped with blinking lights of low strength whereas turbines higher than 150 meters must be equipped with flashing lights of high strength. The strengths of the lights vary according to the time of day. During daytime the lights are strongest, in twilight they are of medium strength and during night of lower strength. It is a requirement from the authorities that the flashing lights are synchronised.

Furthermore every other turbine will be equipped with red lights with low strength.

In order to make the wind farm as homogenous a unit as possible, the surface of all the turbines will be painted in a gray colour (RAL 7035 or similar) with a surface which reduces the reflection of light. The bottom of the tower will be painted yellow. The blades of all the turbines rotate anti clockwise.

Layout

The wind farm will be placed within the project area. The EIA includes two different layouts based on arcs or a radial structure as shown in Figure 1-4 and Figure 1-6.

Both layouts are placed within the project area oriented in a north-south direction in order to optimize the potential of the wind – since the prevailing direction of the wind is from the west. This way the chosen layouts represent a realistic image of the future wind farm.

Moreover the orientation of the wind farm results in a worst case situation since the turbines are spread across most of the project area parallel to the coasts of Djursland and Anholt – which increases the visibility. Consequently the visual impacts are among other things determined by the extent of the layout in the northern and southern direction.

The radial layout consists of turbines placed in straight rows whereas the turbines in the arc layout are placed in curved rows. The layouts are quite similar due to the system of rows. The geometry of the layouts can be difficult to recognize unless you can see straight through the rows. The main difference between the layouts is that the arc layout creates curved borders unlike the radial layout which has straight borders. However, this is difficult to perceive unless you view the wind farm from a short distance. Additionally the arc layout does not reach as far north and south as the radial layout but reaches further east. As a consequence the turbines are placed a bit closer to the shore of Anholt in the arc layout but more importantly, the wind farm appears to take up a smaller area since it covers less of the horizon.

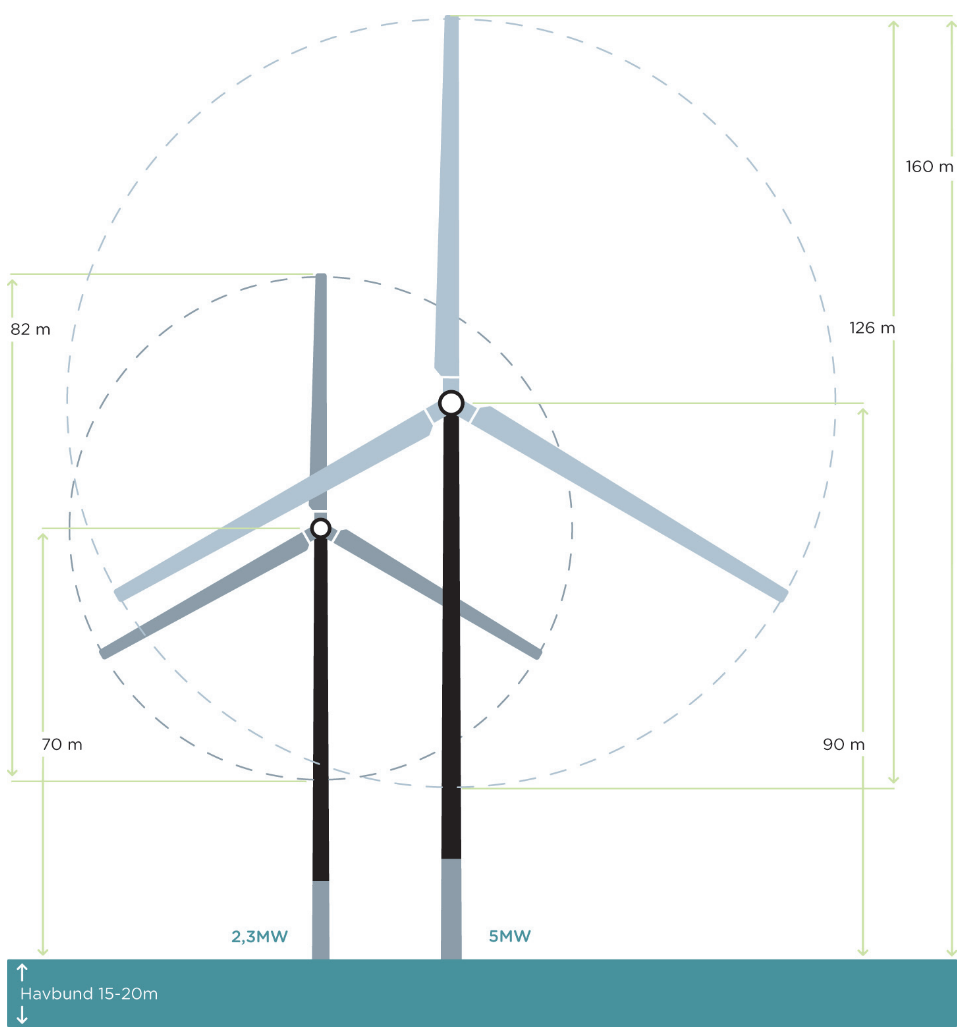

Figure 1-3 Examples of turbines

The distances between the turbines in the different layouts are as follows:

Siemens 2.3 MW, radial layout:
Distance between turbines in a row: between 679 – 715 meters, equivalent to 7 – 7.5 times the diameter of the blades.

Siemens 2.3 MW, arc layout:
Distance between turbines in a row: between 512 and 514 meters, equivalent to 5.3 times the diameter of the blades.

Repower 5MW, radial layout:
Distance between turbines in a row: between 781 and 784 meters, equivalent to 6 times the diameter of the blades.

Repower 5MW, arc layout:
Distance between turbines in a row: between 549.7 and 550.7 meters, equivalent to 4.2 times the diameter of the blades.

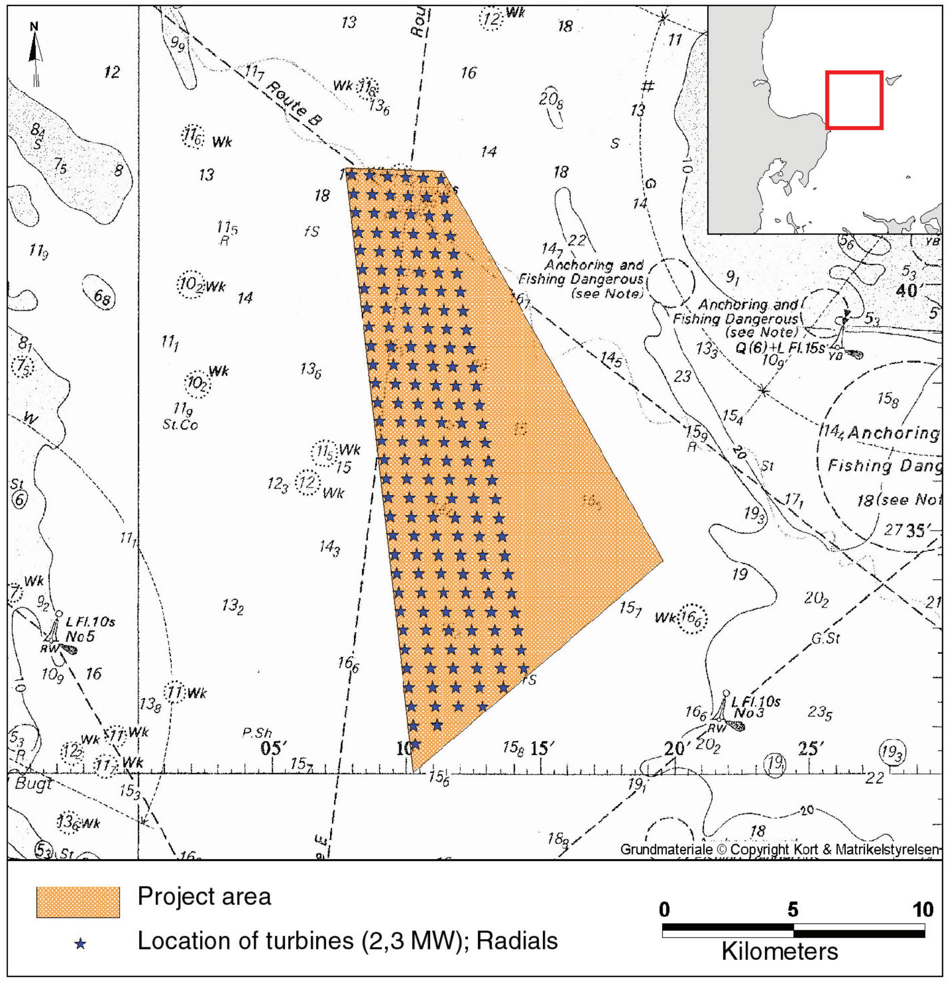

Figure 1-4 Turbines placed in radials, showing the Siemens 2.3 MW turbines (174 turbines)

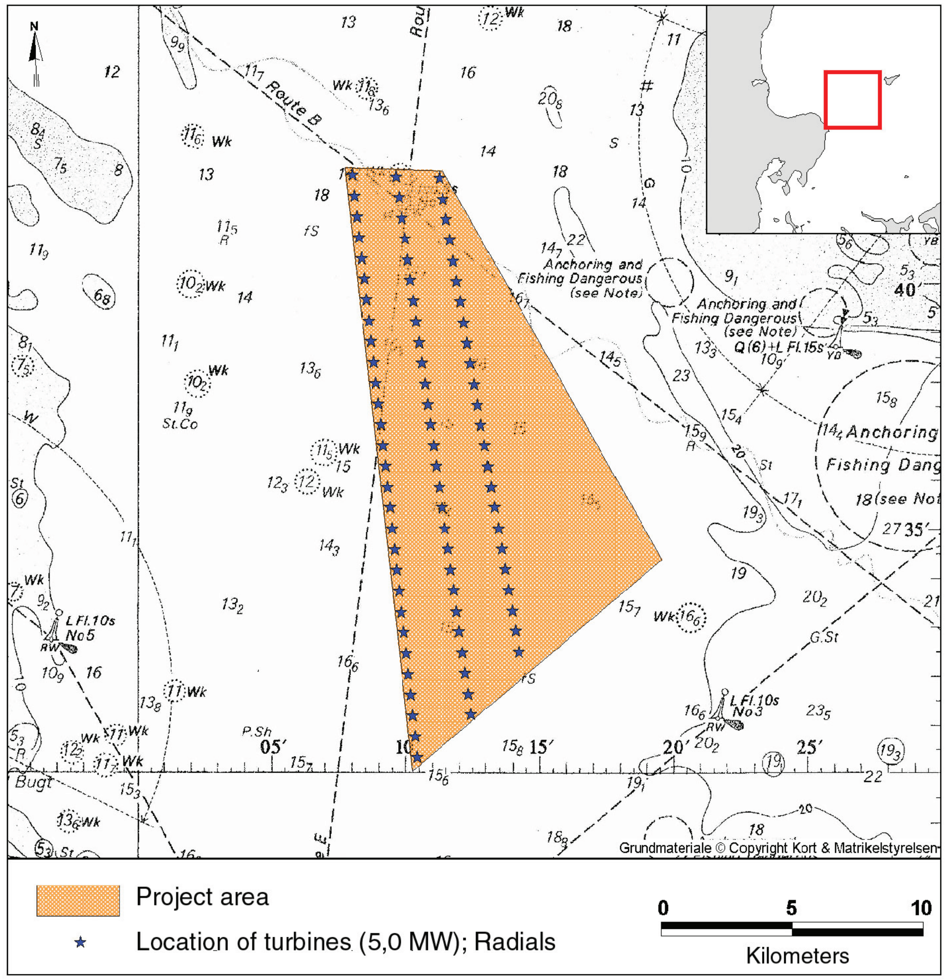

Figure 1-5 Turbines placed in radials, showing the Repower 5MW turbines (80)

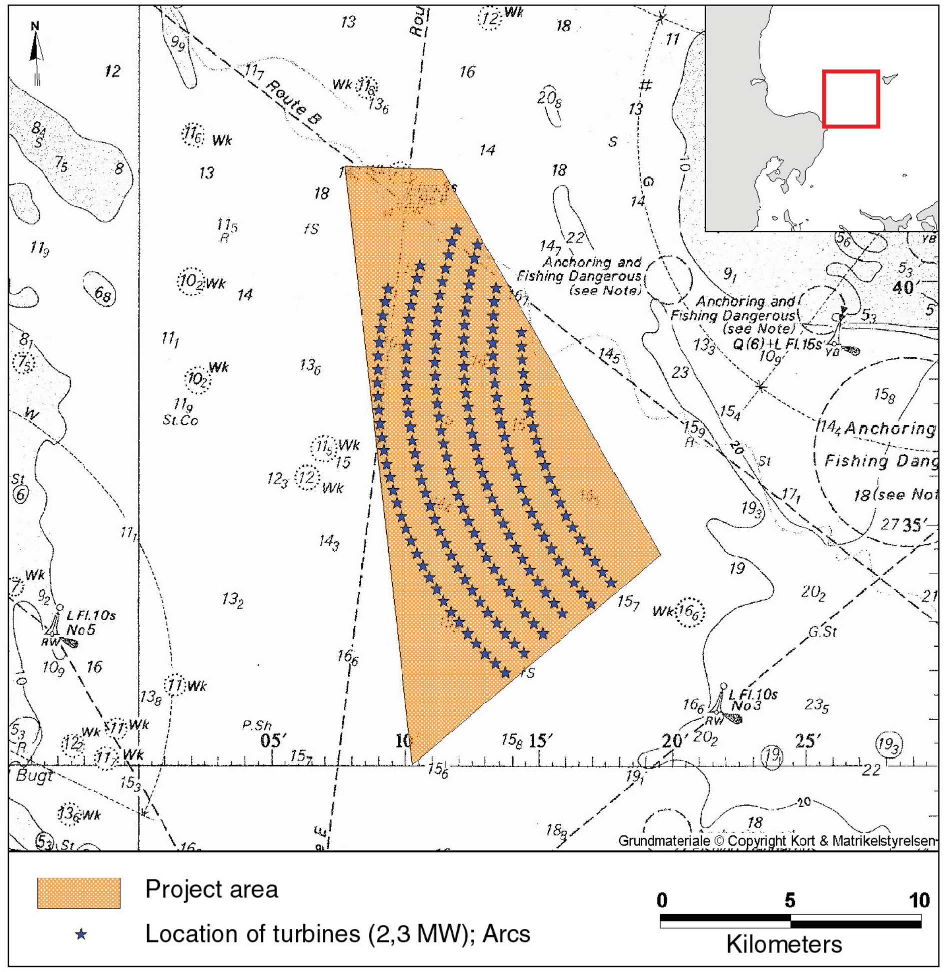

Figure 1-6 Turbines placed in arcs, showing the Siemens 2.3 turbines (174)

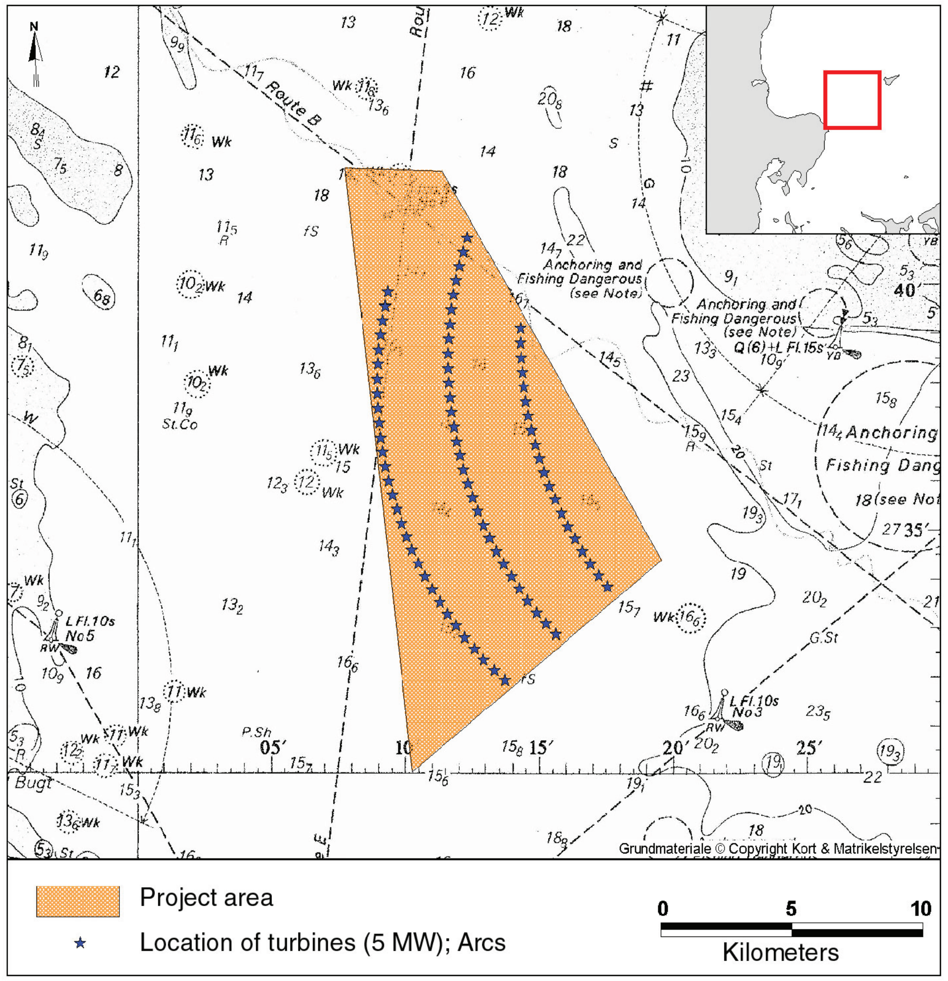

Figure 1-7 Turbines placed in arcs, showing the Repower 5MW turbines (80)

1.2 Foundations

The wind turbines will be supported on foundations fixed to the seabed. The foundations will be either driven steel monopiles or concrete gravity based structures. Both concepts have successfully been used for operating offshore wind farms in Denmark.

Due to the large distance between the wind farm and the coasts, the foundations will not be visible. They will be visible from a close distance at sea, but the visual impact from the foundation itself is estimated to be minor compared to the overall visual impact of the turbines.

1.3 Transformer platform

An offshore transformer platform will be established to bundle the electricity produced at the wind farm and to convert the voltage from 33 kilovolts to a transmission voltage of 220 kilovolts, so that the electric power generated at the wind farm can be supplied to the Danish national grid.

Energinet.dk will build and own the transformer platform and the high voltage cable which runs from the transformer platform to the shore and further on to the existing substation Trige, where it is connected to the existing transmission network via 220/440 kV transformer.

The transformer platform will be placed on a location with a sea depth of 12-14 metres and approximately 25 km from the shore of Djursland, see Figure 1-1. On the platform the equipment is placed inside a building, creating a more homogenous impression. In the building there will be a cable deck, two decks for technical equipment and facilities for emergency residence.

The transformer platform will have a design basis of up to 60 by 60 metres. The top of the platform will be up to 25 metres above sea level. The foundation for the platform will be a floating caisson, concrete gravitation base or a steel jacket.

The transformer platform is also illustrated on the visualizations. In order to create a "worst case" situation the transformer is presented as a black box. In reality the transformer will be gray and as a result less visible.

1.4 Visualization method

Viewpoints

The sites have been visited in April 2009. Prior to the field trip a range of view points were selected in order to establish a broad base for the visual impact assessment. All photos were taken either on ground or sea level from sites of importance to tourism or inhabitants in terms of the recreational use, cultural values or landscape.

After an initial review of the available material where low-quality or badly aimed pictures were discarded, the calibrations work was carried out. This consisted of a thorough visual analysis of each photo, on which an artificial rendering of the terrain surface based on the available DEM was superimposed.

A total of seven different positions have been picked for use in the final assessment, see Figure 1-10 and Figure 1-11. More photos are available in the visual background report Appendix 1.

- Grenaa (near the Kattegat Center)
- Fornæs (beach just below the lighthouse)
- Ferry (Grenaa - Anholt)
- Anholt (three different points on the western coast of the island)
- Bønnerup Strand

The view points represent areas which are allready dominated by infrastructure or elements related to industry or housing, as well as areas characterized by unspoiled landscapes and open views of the sea.

The positions represent points in the landscape from which the turbines are visible. In order to give an idea of the visibility outside these points a visibility study was carried out on Anholt. Since the view points where placed on the western side of the ridge it was interesting to analyse the visibility of the turbines on the southern side of the island where the terrain is more flat. As shown on Figure 1-8 a majority of the turbines will be visible from the southern part of the beach.

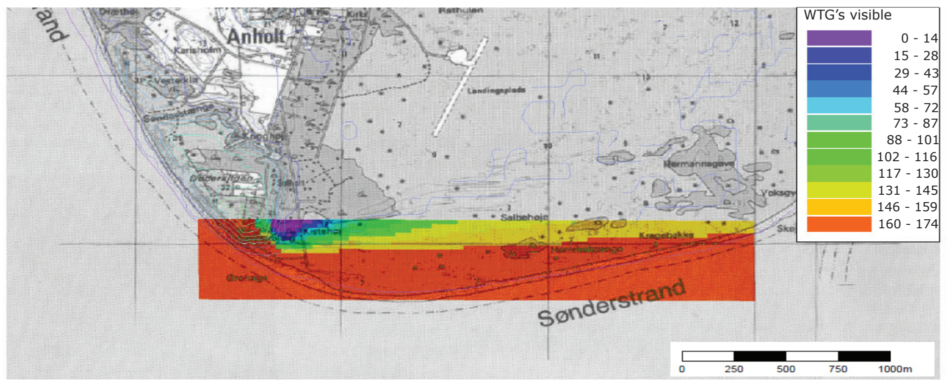

Figure 1-8 Visibility study at the coast of Anholt

Similar studies have not been carried out on Djursland, since it was estimated that most of the coastal line was covered in the chosen viewpoints.

Night visualizations

The night visualizations show the red lights on every second turbine. However, the flashing white lights are not illustrated since it is difficult to give a realistic image of non static elements. The impact of the flashing lights are nevertheless part of the overall impact assesment.

Turbines

On the actual turbines the bottom of the tower will be painted yellow, as shown on figure 1-2. This, and other details on the turbines will only be visible from short distances at sea. The overall impact is mainly determined by the size and number of turbines rather than details in colour, logo etc. Furthermore it is difficult to illustrate the effect of the paint with the anti-reflection quality which is being used on the turbines. Consequently a standardized model of the turbines is used in the visualizations, showing the turbines in a light grey colour.

All turbines in each visualization are illustrated in the same degree of clarity regardless of the distance to the viewer. This way the visual impact may be slightly exaggerated since the turbines in the background may seem less visible compared to the turbines in the foreground under real circumstances.

1.4.1 Visibility

Atmospheric conditions

The visual impacts are illustrated under four different atmospheric/environmental conditions:

- Very clear
- Clear
- Misty
- Night

The visibility varies depending on the weather and atmospheric conditions. Changes in the light and moist in the air also affect the visibility.

Given the large distances involved in the present visualizations, differences between the first two atmospheric conditions will be hardly discernible in the photomontages.

The visualizations presented in this report are showing the worst case situation, in order to give the viewer an idea of the largest possible impact. Therefore the visualizations showing the turbines under very clear conditions are presented as well as a number of night visualizations from selected view points. All visualizations can be seen in the visual background report Appendix 1.

Under some conditions the turbines may appear even more visible - if the turbines stand in 100 % contrast to the background, which may be the case if the turbines are backlit by the sun. This is not illustrated specifically in this report.

In Figure 1-9 the visibility at The Kattegat is illustrated based on observations in the period 1996-2006 /9/. In general the visibility is better at sea than on land. Furthermore the visibility in The Kattegat is slightly better compared to for instance The Baltic Sea and The North Sea /1/.

The table shows that a visibility by up to 19 km (good visibility), corresponding to the distance between the wind farm and Anholt or even more than 19 km (very good visibility), occur approx. 12-18 days per month during spring and summer and around 8-15 days per month during fall and winter. The visualizations illustrate very good weather conditions, which only occur 5-6 days per month during spring and summer and even fewer days for the remaining parts of the year. However, the wind farm will still be visible under good weather conditions.

The statistics regarding the weather will be taken into account in the final evaluation of the impacts.

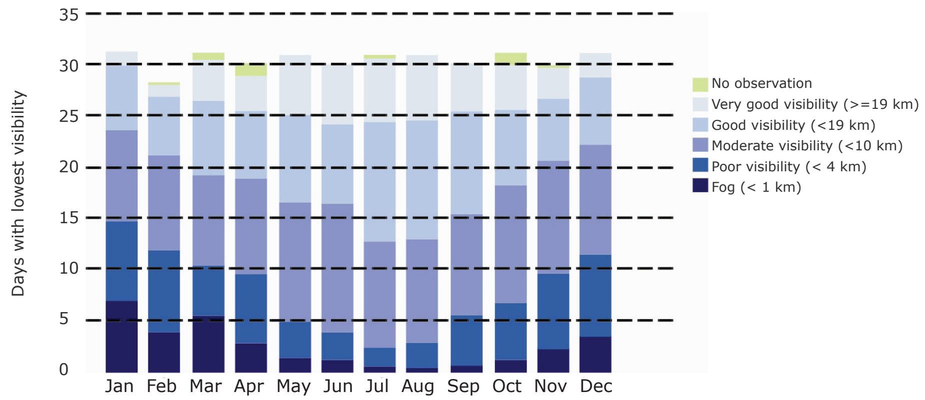

Figure 1-9 Diagram showing the weather conditions in The Kattegat, in terms of visibility (/9/)

Curve of the earth

The curve of the earth has an impact on the visibility regardless of the size of the turbines. The bottom of the turbines will be hidden gradually as the distance between the observer and the turbines increases. However, this is a minor factor in this project since the effect of the curve of the earth only has an importance at a distance of approx. 16-18 km /1/. Therefore is does not have an impact seen from Djursland but a minor impact seen from Anholt.

1.5 Method of impact assessment

The impact assessment follows the guidelines presented in the description of the methodology of the EIA /8/. However, the tables are presented in the final summarized impact assessment at the end of the document.

Sensitivity of the landscape

The impact assessment is based on a general analysis of the landscape, geology and cultural interest, which gives an idea of characteristics, values and sensitivity of the landscape. The impacts are assessed by analysing the photomontages of which a selection is presented in this report. All the photomontages can be seen in the full report covering the visualizations of the offshore wind farm, Appendix 1.

The criteria for assessing the impacts are based on the sensitivity of the affected landscape, the visibility of turbines and the relation between the coastal landscape and the wind farm. The coastal landscape is primarily used for recreational purposes both on Djursland and Anholt. The border between the land and the sea is especially along the cliffs dramatic sceneries. The beaches along the coasts of Djursland and Anholt are the areas where the visual impacts are most dominant due to the unspoiled views.

The seascape is characterized by large scale spaces without objects. This creates unspoiled views across long distances. In general the seascapes are sensitivity towards visual changes in form of large elements. In an open seascape with no other objects in the foreground or background a new wind farm will attract a lot of attention.

If there are existing objects in the landscape, the wind farm will attract less attention. This may be the case in areas near towns or harbours where there are already buildings or other large elements in the foreground. Therefore the coastal lines with unspoiled views are estimated to be more sensitive towards visible changes.

Turbines – scale, layout and movement

The visual impact of a single large turbine is more dominant than the impact of a smaller turbine due to the visibility. However, it is necessary to place a larger amount of the smaller turbines in a wind farm in order to achieve the same amount of generated energy. This result in more compact wind farms where the turbines are placed closer together.

The geometry of the layout gives different visual impressions which will change according to the viewpoint. The goal is to create a formation which is easy to recognize, homogenous which does not seem messy. At the same time it is important that the wind farm is perceived as one unit rather than scattered elements.

The movement of the turbine blades is another factor in assessing the visual impact. It has not been possible to illustrate this on the photomontages but there are some general guidelines regarding the visual impacts of moving objects. The larger turbines will have a slower rotation speed compared to the smaller turbines. Movement does in general attract the eye and slow movements seem less distracting than fast movements. In the case of the offshore wind farm the visual impact of the movements is estimated to be insignificant due to the distance of approx. 15-20 km from the coastal lines combined with the movements of the waves and the flickering movement of the rising air, which will reduce the visibility of the movements /1/.

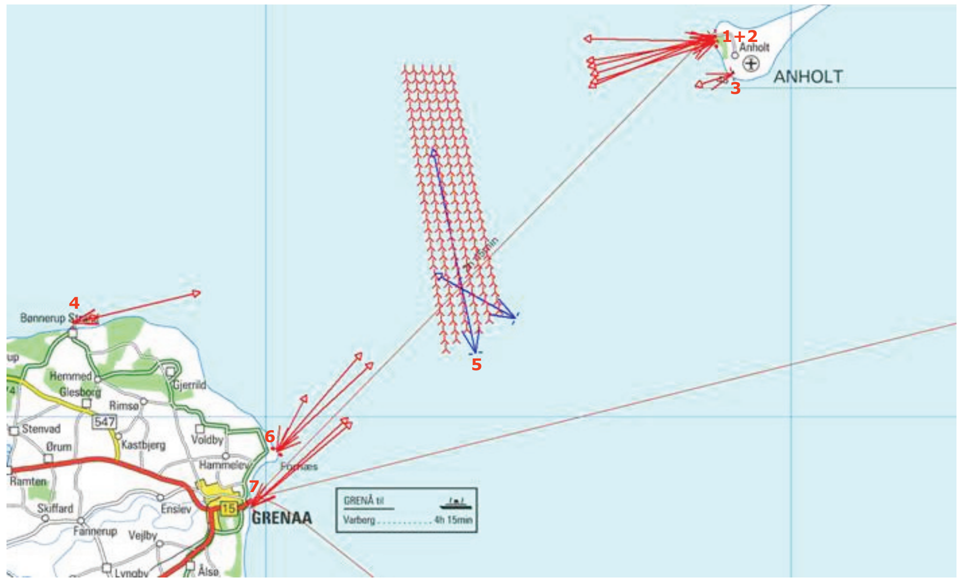

Figure 1-10 The seven observation sites shown as Windpro Camera Objects, together with the Siemens 2.3 (174 turbines) radial layout. For each site the positions of the observer sometimes varied depending on the time of day and other contingent reasons, hence the larger number of Camera Objects (shown as arrows). Pictures from the ferry refer to the distance expected between the ferry and the wind turbines with the used layouts of the turbines.

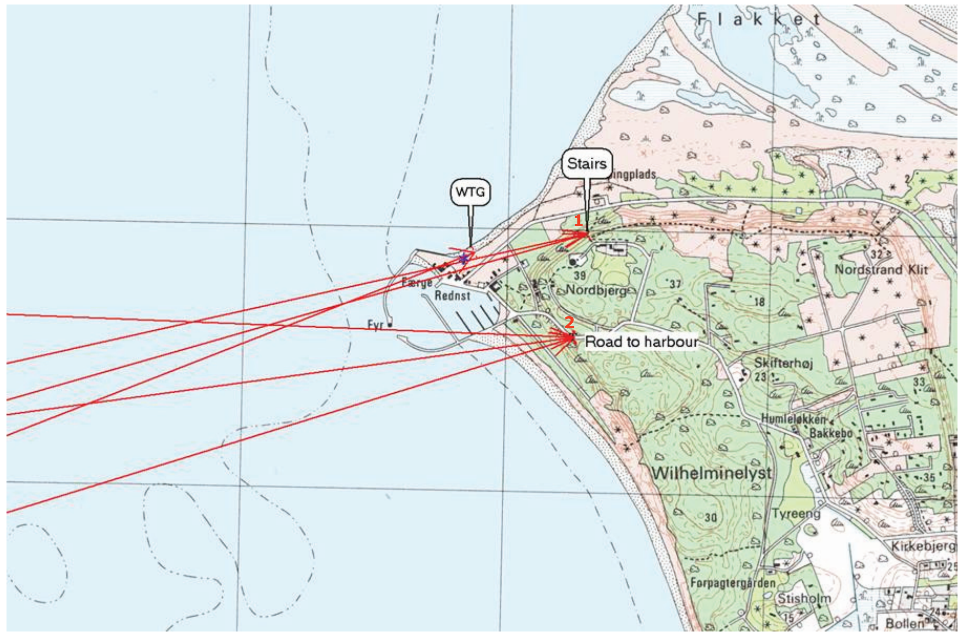

Figure 1-11 Three view points on the north western part of Anholt of which two are picked out as examples in this report - view point 1 from the stairs and view point 2 from the road to the harbour.

2. EXISTING CONDITIONS

2.1 Landscape and geology

Djursland

A large area along the coast of Djursland has been pointed out as an area with special valuable landscapes in the regional planning, Figure 2-1.

The coastal line on the north eastern part of Djursland is characterized by long sandy beaches in form of for instance Bønnerup Strand and Gjerrild Nordstrand with sand dunes and unspoilt wasteland /7/. The landscape behind the coastal line is primarily characterised by agricultural use consisting of a matrix of fields in large scale with scattered houses and farms. The landscape along the coast is in general very open and scarce in vegetation. However, the northern part of Djursland is more densely vegetated in form of plantations, such as Emmedsbo Plantation east of Bønnerup Strand.

Some sections of the coastal line contain valuable geological sites, consisting of cliffs with deposits of sediments from the two last ice ages. The cliffs at Gjerrild are up to 20 metres high and cover nearly 3 km of the coastal line /3/.

The cliffs at Karlby and Spangstrup contain deposits of chalkstone and are also areas of geological interest. Karlby Cliff is situated 8 km north of Grenaa and stretches 1 km along the coastal line. The cliffs are up to 12 metres high /4/.

Spangstrup Cliffs are up to 17 metres high and cover nearly three km of the coastal line /5/.

All the cliffs are pointed out as areas of geological interest in the regional planning of the former Århus Region /2/.

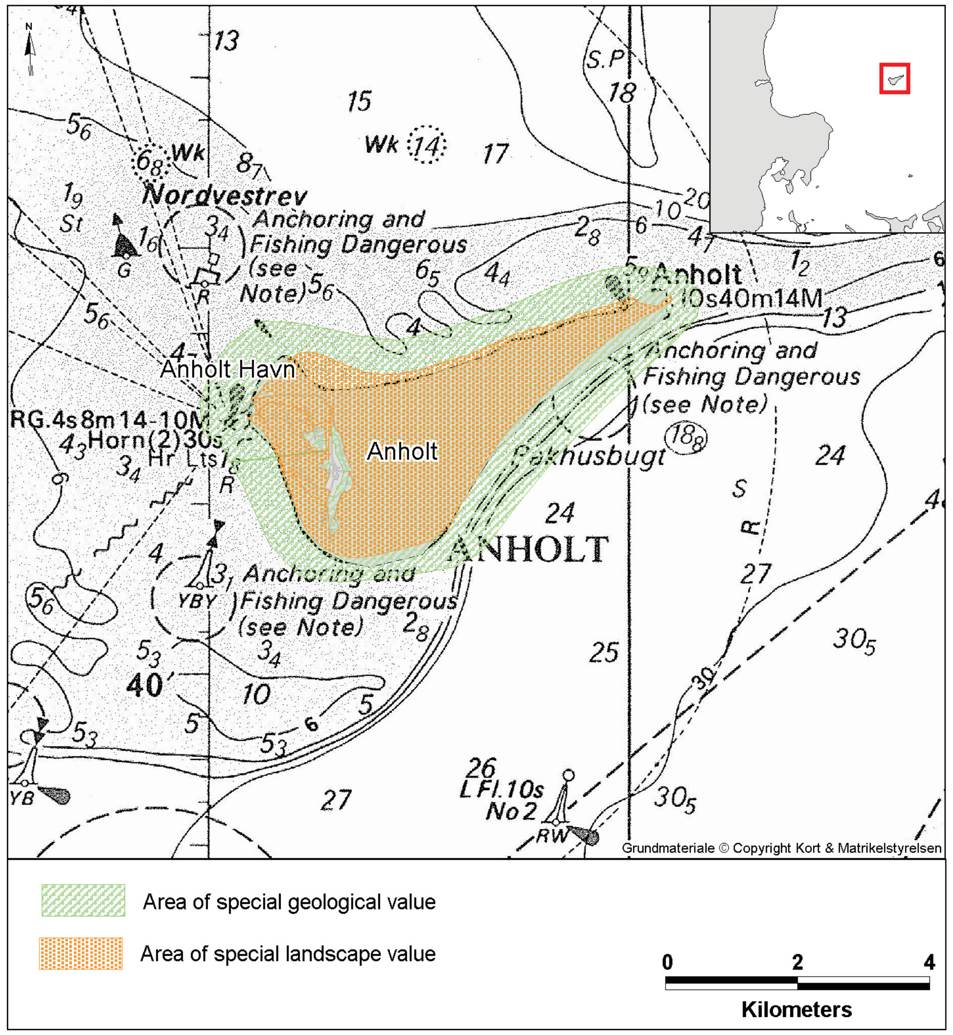

Figure 2-1 Landscape and geology - Djursland

Anholt

Most of Anholt has been pointed out as an area with special valuable landscapes Figure 2-2. The island is surrounded by sandy beaches and sand dunes. The western part of the island is characterised by steep cliffs which surround a plateau on which Anholt village is situated. The terrain reaches up to 124 metres on Nordbjerg in the northern part of the plateau and 154 at Sønderbjerg, the southern part of the plateau. The plateau is covered by vegetation in form of trees and dense bushes. The plateau and forest area is visible on Figure 1-11.

The middle and eastern part of the island, which is called The Desert, consists of primarily moorland. The terrain is lower than the plateau but still a bit hilly, with small ridges reaching up to 75 metres.

The island is pointed out as an area of geological interest. The island is a unique example of the creation of marine foreland behind a glacial landscape. The unprotected location in the Kattegat means that the geology and landscape is influenced by the forces of wind and waves. These impacts have created the shape of the island which we see today /6/.

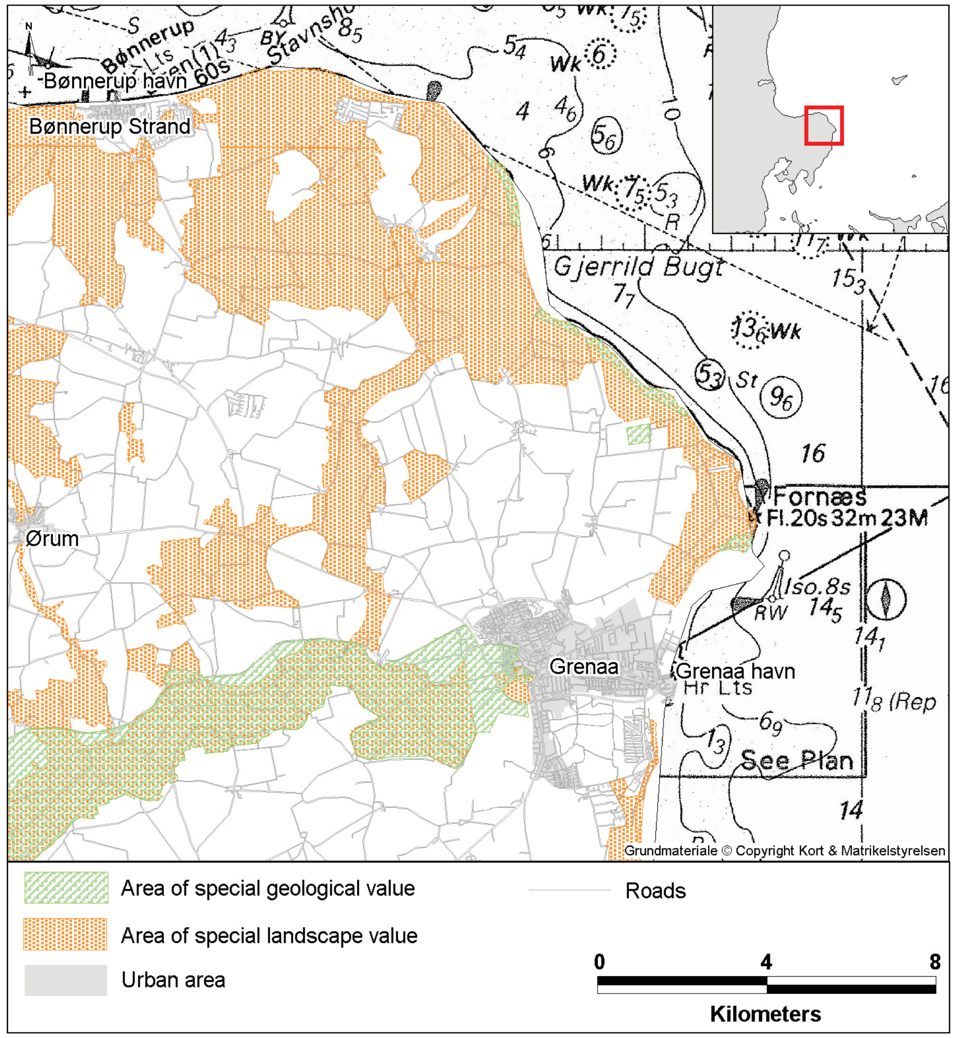

Figure 2-2 Landscape and geology – Anholt

2.2 Cultural values

Djursland contains a number of elements and structures in the landscape which have been pointed out as valuable cultural areas and elements, Figure 2-3. An area of cultural interest often contains signs of for instance early settlements or agricultural use. The presence of these elements and cultural features further adds a value to the experience of the landscape.

The landscape around Fornæs is a valuable cultural area, and a part of the area along the coast is protected. Djursland contains other protected areas along the coast, for instance around Gjerrild Nordstrand.

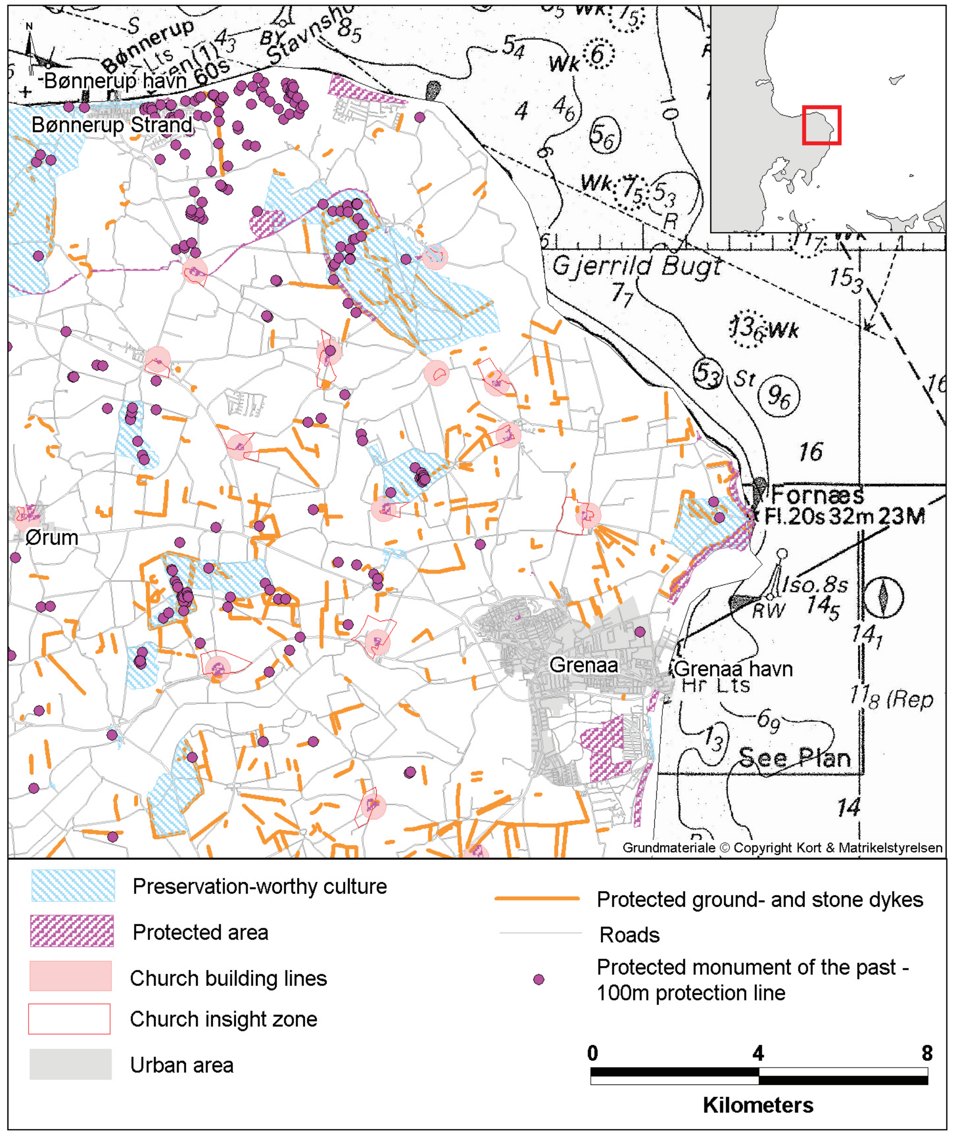

Figure 2-3 Cultural interests – Djursland

Most of Anholt is protected, apart from the plateau surrounding Anholt Village Figure 2-4.

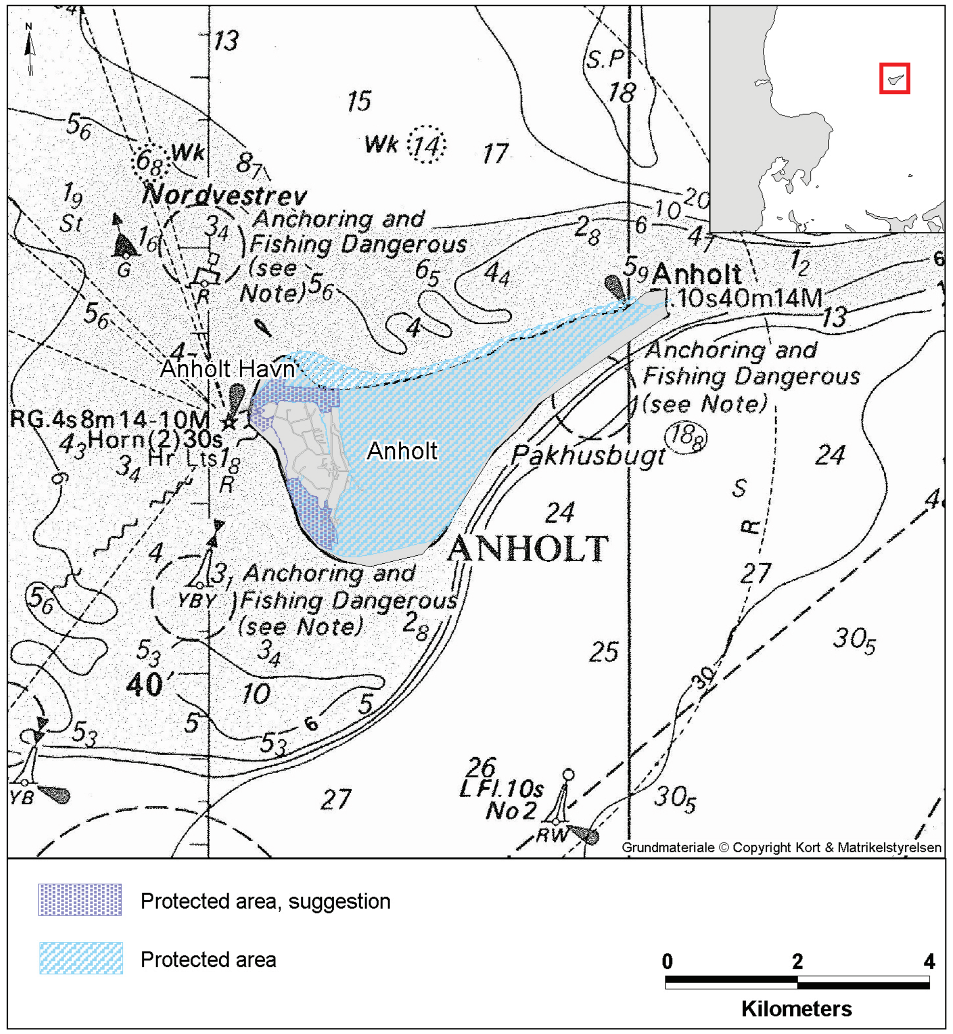

Figure 2-4 Cultural interests – Anholt

2.3 Photos – existing conditions

In the following, the photos used in the photomontages area presented, showing the existing conditions.

View point number refers to Figure 1-10.

Figure 2-5 View point 1 - Anholt harbour (north)

Figure 2-6 View point 2 - Anholt harbour (south)

Figure 2-7 View point 3 - Anholt coastal line

Figure 2-8 View point 4 Bønnerup

Figure 2-9 View point 5 Anholt - Djursland Ferry

Figure 2-10 View point 6 Fornæs

Figure 2-11 View point 7 Grenaa

3. VISUALIZATIONS FROM ANHOLT

3.1 Viewpoint 1 - Siemens 2.3 MW(174 turbines)

Siemens 2.3 MW radials

The turbines are very visible seen from the harbour on Anholt and changes the experience of the view considerably. However, the elements in the foreground in relation to the harbour distract the eye to a certain extent, which makes the landscape less sensitivity towards visual changes.

Some of the turbines are hidden due to the terrain – however most of the horizon behind the harbour is dominated by the turbines. The straight lines in the layout are to some extent recognisable. The radial layout results in a homogenous structure and the wind farm can be perceived as one unit.

The transformer platform is not visible from this viewpoint since it is hidden behind the cliff.

Siemens 2.3 MW arcs

The visual impact is comparable to the impact caused by the turbines in the radial layout.

Since the turbines are placed in a different layout the wind farm does not reach as far north as the radial layout. This fact reduces the visual impact.

The layout is recognisable since you can see some of the lines in the layout without getting the impression that the turbines are scattered across the horizon.

The transformer platform is not visible, as described above.