Horns Rev 3

Technical Project Description for the large-scale offshore wind farm (400 MW) at Horns Rev 3

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Document no. 13/93461-2897, dated 28.04.2014

ENERGINET/DK

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1. Introduction

This document outlines the proposed technical aspects encompassed in the offshore-related development of the Horns Rev 3 Offshore Wind Farm (OWF). This includes: wind turbines and foundations, internal site array cables, transformer station and submarine cable for power export to shore. Each technical component will be dealt with, with respect to construction (i.e. installation), operation, and maintenance and decommissioning.

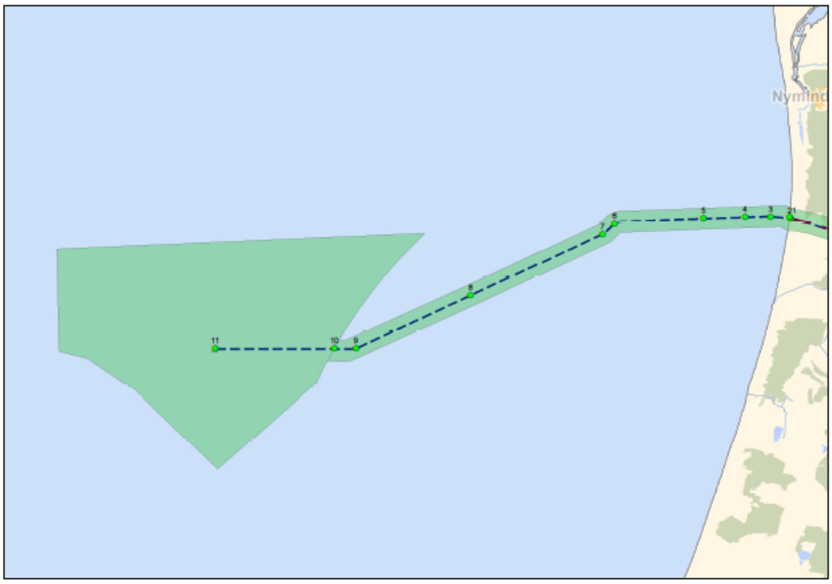
Substations and export cable to shore are owned and installed by Energinet.dk, while the actual wind farm developer has not yet been assigned by the Danish Energy Agency. Therefore, parts of the technical solutions within the wind farm are not projected to final detail yet. However, to assess environmental aspects (EIA), which is a prerequisite prior to development and construction, the span of possible solutions in terms of likely minimum and maximum components and corresponding methods of installation are described. Nevertheless, changes and substitutions of technicalities might occur prior to construction and the EIA will assess impacts from a worst case scenario.

This is not a design description for the final wind farm at Horns Rev 3. This is a realistic and a best guess on how a future concessionaire will design the final wind farm. This technical project description thus provides the framework which a concessionaire can navigate within. The EIA will relate to a worst-case scenario within this framework. A future concessionaire may wish to deviate from the worst-case scenario, and sometimes also from the framework. Whether deviations from the framework can be contained within the EIA permit/authorization for establishment must be determined individually by the authorities on a case by case basis.

To examine and document the general seabed and sub-seabed conditions at the Horns Rev 3 site, geophysical, geological and geotechnical pre-investigations have been undertaken since 2012. The results of these geo-investigations, which also include assessments of the UXO risk, have been used to carry out assessments of the environmental impacts on the seabed for the Environmental Impact Assessment (EIA) as well as they can be used by wind farm developers and other parties to evaluate the soil conditions to estimate limitations and opportunities related to the foundation of offshore wind turbines, substations and other installations.
Furthermore, a comprehensive site specific metocean analysis is currently being conducted, but no preliminary data is yet available. Hence, the description presented is based on existing information about site specific metocean characteristics.

2. Horns Rev 3 – Site Location

The planned Horns Rev 3 OWF (400 MW) is located north of Horns Rev (Horns Reef) in a shallow area in the eastern North Sea, about 20-30 km northwest of the westernmost point of Denmark, Blåvands Huk. The Horns Rev 3 pre-investigation-area is app. 160km^2. The Horns Rev 3 area is to the west delineated by gradually deeper waters, to the south/southwest by the existing OWF named Horns Rev 2, to the southeast by the export cable from Horns Rev 2 OWF, and to the north



by oil/gas pipelines (
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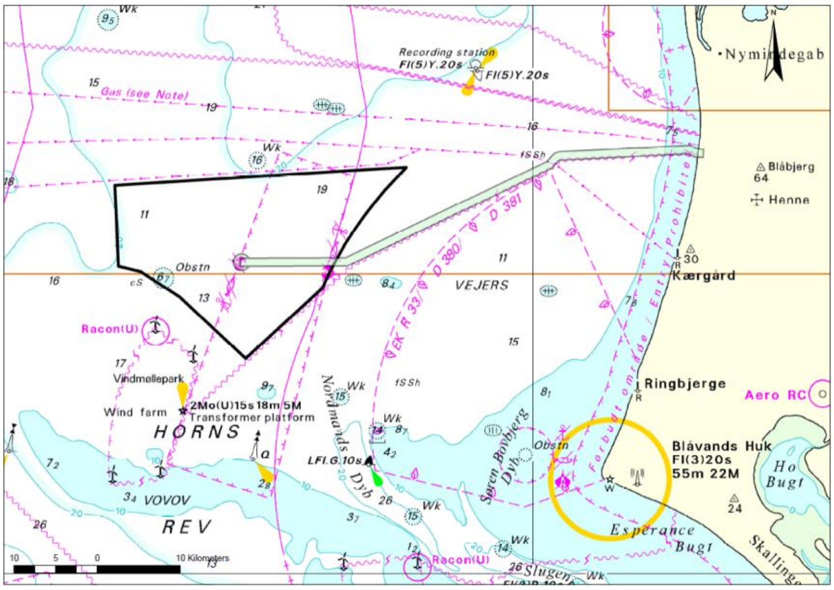

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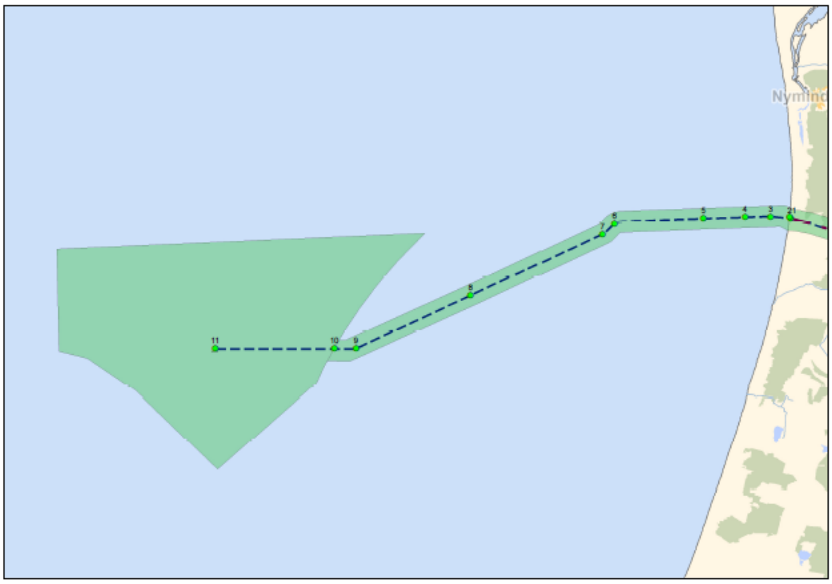


Figure 1. Location of the Horns Rev 3 OWF (400 MW) and the projected corridor for export cables towards shore. The area enclosed by the polygon is app. 160 km^2.

	WGS84 [DD MM.mmm]	
ID	**Longitude**	**Latitude**
PRE-INVESTIGATION AREA		
1	7° 32,941' E	55° 44,228' N
2	7° 33,176' E	55° 41,264' N
3	7° 34,614' E	55° 41,076' N
4	7° 37,176' E	55° 40,164' N
5	7° 41,423' E	55° 37,901' N
6	7° 46,398' E	55° 40,473' N
7	7° 46,779' E	55° 40,948' N
8	7° 47,256' E	55° 41,469' N
9	7° 47,888' E	55° 42,099' N
10	7° 48,514' E	55° 42,640' N
11	7° 48,961' E	55° 43,002' N
12	7° 49,292' E	55° 43,250' N
13	7° 49,771' E	55° 43,591' N
14	7° 50,445' E	55° 44,051' N
15	7° 51,837' E	55° 44,883' N
16	7° 50,036' E	55° 44,830' N
PLATFORM		
	7° 41,163' E	55° 41,421' N
EXPORT CABLE		
1	8° 10,561' E	55° 45,465' N
2	8° 10,504' E	55° 45,483' N
3	8° 9,529' E	55° 45,515' N
4	8° 8,217' E	55° 45,482' N
5	8° 6,084' E	55° 45,425' N
6	8° 1,520' E	55° 45,251' N
7	8° 0,921' E	55° 44,942' N
8	7° 54,198' E	55° 43,096' N
9	7° 48,377' E	55° 41,494' N
10	7° 47,271' E	55° 41,484' N
11	7° 41,163' E	55° 41,421' N

Table 1. Overview of coordinates delineating the Horns Rev 3 OWF and associated export cable corridor. (

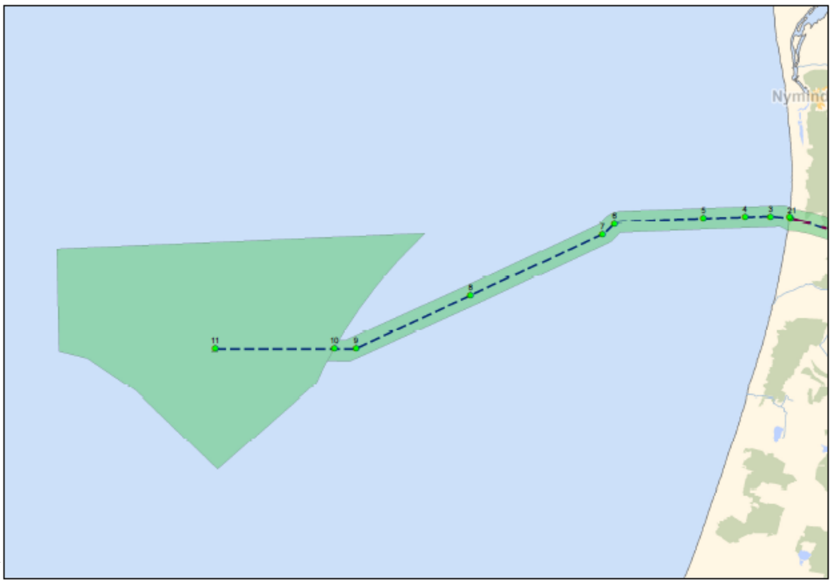


Figure 1).

In the central-eastern part of the Horns Rev 3 area there is a 'no fishing, no anchoring' zone occupying app. 43% of the area. This zone is classified as a former German WWII minefield. South/southeast of the Horns Rev 3 area, an existing military training field is delineated in Figure 1. A desk study on potential UXO contaminations in the Horns Rev 3 area has concluded that in the central and eastern parts of the area there is a medium to high UXO threat present (the minefield from WWII), while for the western part of the Horns Rev 3 area a lower UXO threat is present. According to the permission normally given by the DEA, a 400 MW wind farm must use up to 88 km^2.

2.1 Physical characteristics

The water depths in the Horns Rev 3 area vary between app. 10-21 m (Figure 2). The minimum water depth is located on a ridge in the southwest of the site and the maximum water depth lies in the northeast of the area. Sand waves and mega-ripples are observed across the site.

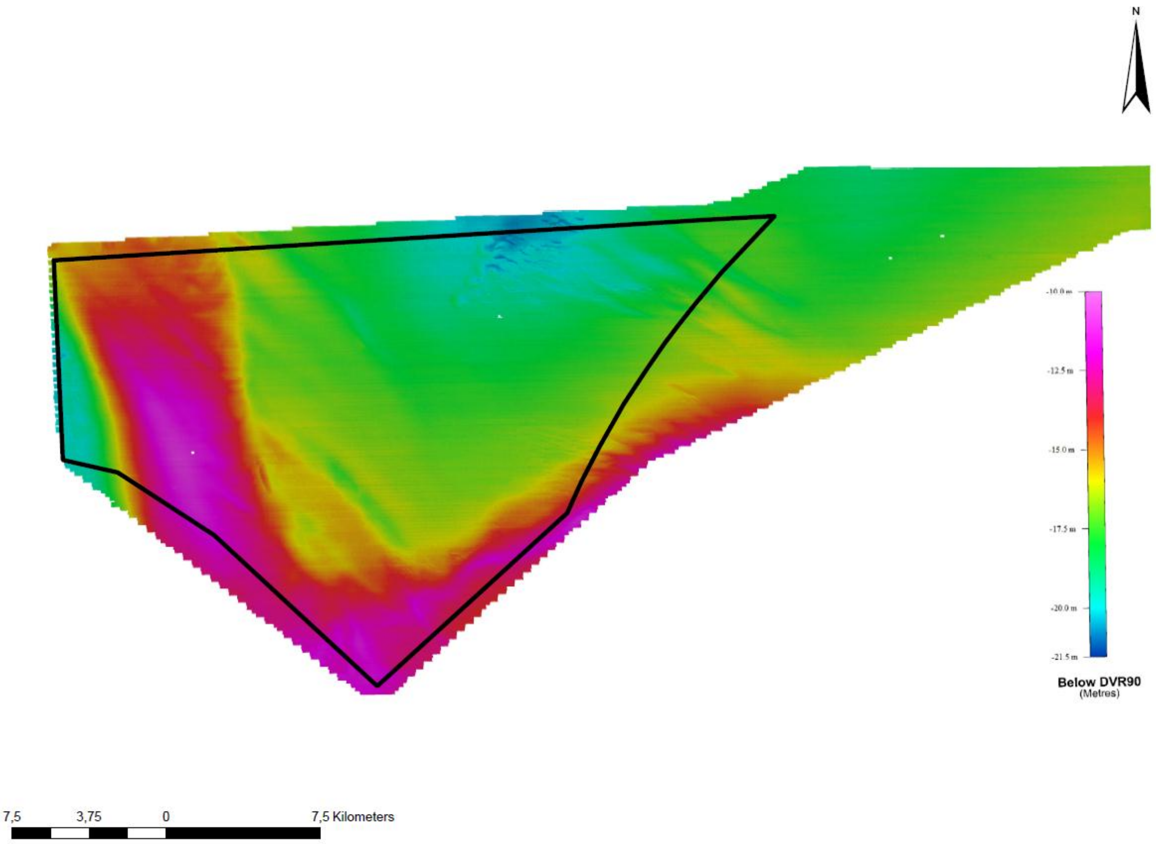


Figure 2. Bathymetric map of the Horns Rev 3 area showing depths below DVR90 as graded colour. The map is based upon the Geophysical survey in 2012. The black line encircles the pre-investigation area of 160km^2.

2.2 Metocean characteristics

A comprehensive site specific metocean analysis is currently being conducted, but no preliminary data is yet available. Hence, the description below is based on existing information about site specific metocean characteristics. The metocean study will be published late 2013.

2.2.1 Salinity and density

In general, the salinity in this part of the North Sea is app. 32-35 PSU (3.2-3.5%) with only minor spatial and temporal variations.

2.2.2 Currents

The area is subject to tide-induced, wind-induced and wave-induced currents, which of course vary in direction and magnitude according to time of the day and seasonal variations. During meteorologically calm periods the tide-induced currents dominate with a magnitude of up to 0.5 m/s. The strongest currents naturally occur during storms causing currents considerably larger than the tide-induced.

Directions of the currents vary significantly in the area, but the net directions are north-south or vice versa.

There is a net sedimentation accumulation in the Blåvands Huk-Horns Rev area.

2.2.3 Wave size

In Figure 3 directional wave height distribution is shown (wave roses) at an offshore point at / immediately north of Horns Rev and a point app. 5 km off the coast, both places at app. 10 m water depth.

The wave sizes in the area are in general significantly influenced by the shallow water at Horns Rev, the waves break on the reef and no waves higher than about Hs = 0.6 m times the local water depth can pass over the reef. This means that Horns Rev significantly limits the near shore wave condition in the lee area of the reef, especially with the waves coming in from south and south-westerly directions.

However, in the Horns Rev 3 area, the reef must be expected to have little to no influence when the wind direction is from the north, north-west and directly from west.

2.2.4 Tides

The tidal amphidromy along the Danish West Coast is anti-clockwise. The hydrographical effect of Horns Rev is a dampening of the northward travelling tidal wave, which has a drastic effect on the tidal ranges in the region where e.g. Spring Tidal Ranges vary between 0.8 m in Hvide Sande north of Horns Rev, to 1.8 m around Blåvands Huk, and 1.5-1.8 m in Esbjerg south of the Horns Rev area.

2.2.5 Wind

The winds at Horns Rev are predominantly westerly throughout the year (Figure 4). The wind and wave climate can be rough during both summer and winter, but especially during fall and winter.

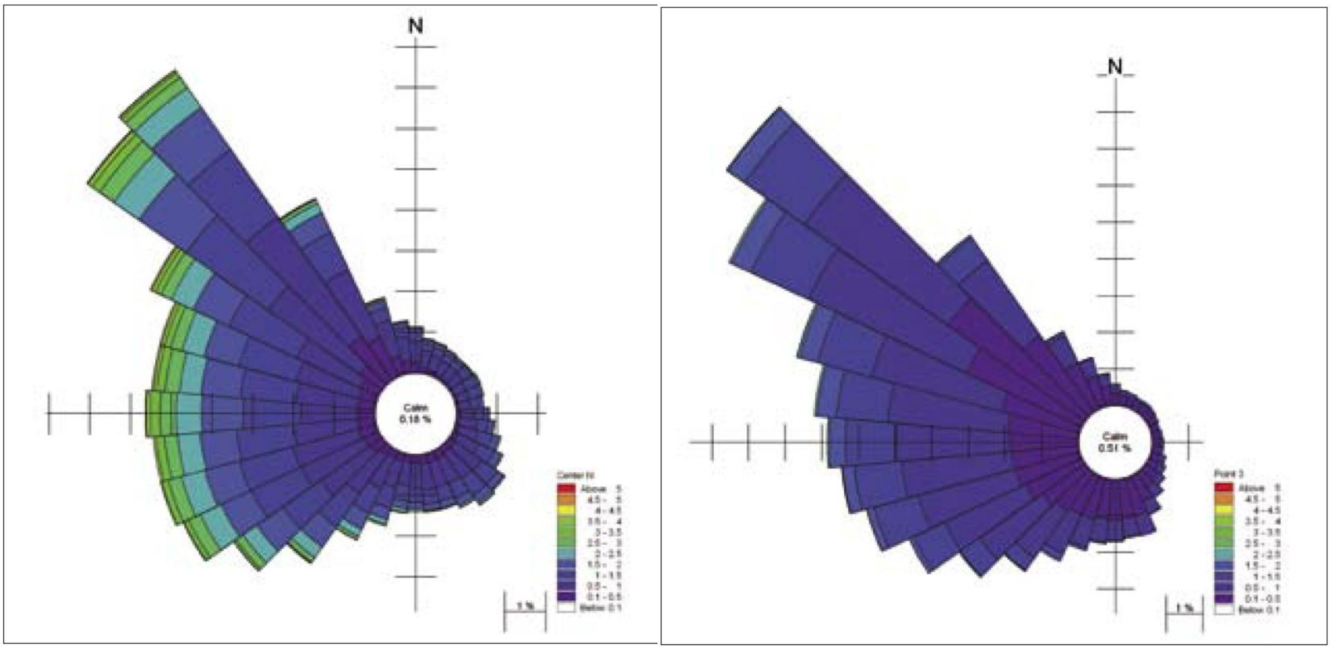


Figure 3. Directional wave height distribution (wave roses) at an offshore point north of Horns Rev 2 and a point app. 5 km off the coast, both places at app. 10 m water depth (from EIA Horns Rev 2, Dong Energy 2006). The inner white circle represents the rare occasion Calm, the inner dark blue represent wave heights between 0.1-0.5 m – hereafter every colour change represents an increase of 0.5 m (e.g. the light blue represents wave height 2 m-2.5 m).

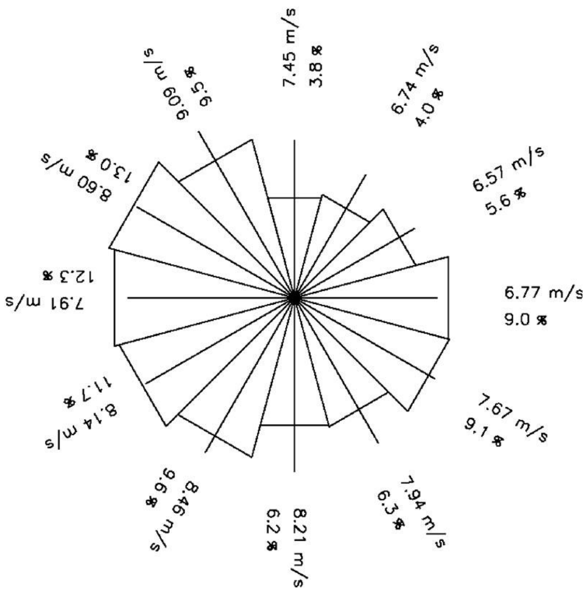


Figure 4. Wind rose from the Horns Rev (from NASA/Risø).

2.3 Geological Characteristics

Based on the combined results of the Horns Rev 3 geo-investigations, it can be concluded that the seabed and the upper geological layers in the Horns Rev 3 area exhibits marine postglacial sediments deposited during the Holocene with a total thickness up to app. 40 m in the central-eastern part of the site to below c. 10 m in the western part.

The seabed surface sediments vary from combinations of coarse sand to the west to combinations of fine and medium sand in the eastern part of the site.

Just below the Holocene deposits that vary from organic sil/clay to fine sand, sandy glaciiofluvial (Weichselian and Saalian) meltwater deposits overlay Saale, and older, glacial sediments. The latter are interpreted to truncate deep into the pre-Quaternary sediments along buried valleys in the Horns Rev 3 area and region (Figure 5).

The geological layers down to a target depth of c. 100 m below seabed have been divided into 9 units in an updated digital 3D geological model based upon an integrated geophysical, geological and geotechnical evaluation and interpretation with ages ranging from Pre-Quaternary to Holocene.

Large variation in thickness and depths are seen at the HR3 site. Deep channels with glacial and post-glacial deposits trends north-south and is deeply eroded in the pre-quaternary units Figure 6.

Figure 6 shows the depth to the base of the post-glacial units. The deepest part is found centrally and to south of the site. In contrast to the generally sandy sediments that are found and/or interpreted to dominate most of the layers within the expected maximum depth of interest (c. 100m below seabed), cohesive silt and clay, occasionally with organic content, are found to dominate the post-glacial layers Post_2 and Post_5, and show significant variation in geotechnical parameters throughout the site. It is consequently described as a soft to very stiff clay. It is found as part of 3 of the post-glacial units in the model and show accumulated thickness up to 20 m centrally at the site. In the glacial and pre-quaternary units cohesive soils are found as well but more locally.

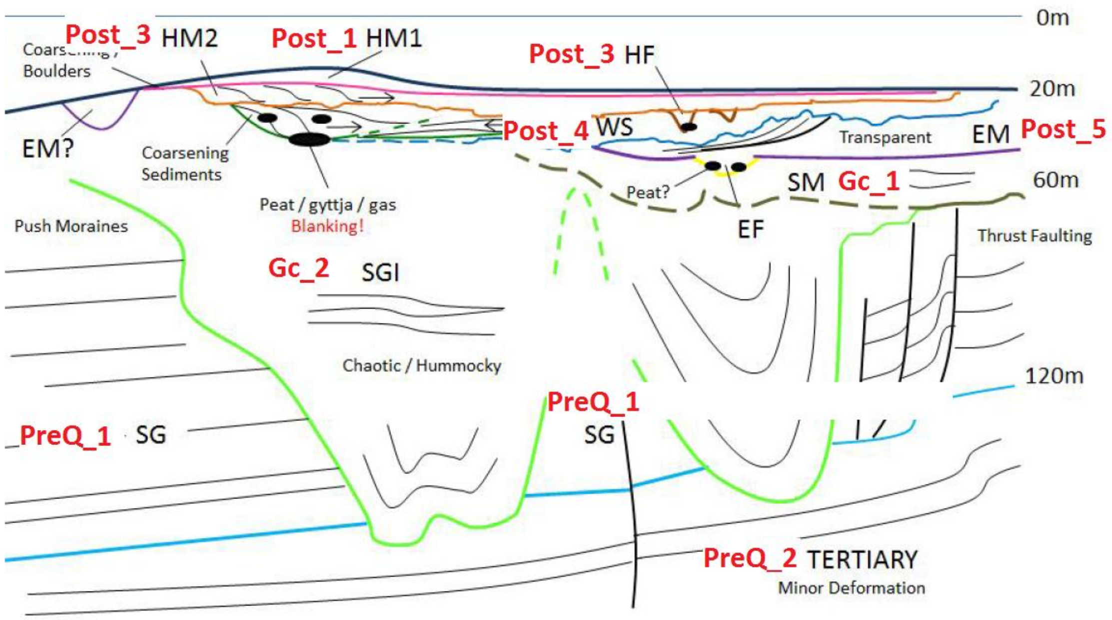
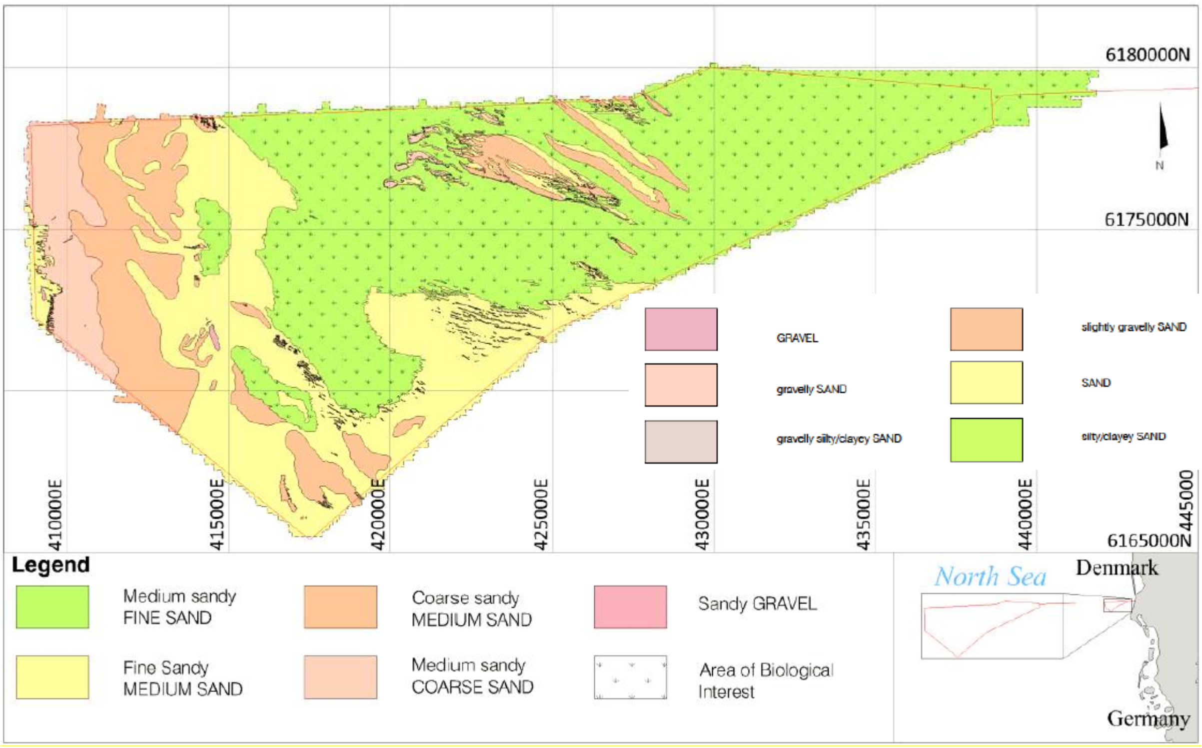


Figure 5. Horns Rev 3 Geological Model (COWI February 2014)



Units	Unit in geologi-cal model	Geotechnical soil units	Sedimentology	Depth to Base Below seabed
Post-Glacial	Post_1 (pink)	Pg1	Post glacial sand	0 - 35 m
	Post_2 (red)	Pg1, Pg2, Pg2_sand	Post glacial sand and/or clay/silt	
	Post_3 (orange)	Pg2, Pg2_sand, Pg2_peat, Pg_1	Post glacial clay/silt with layers of sand/gytja/peat	
	Post_4 (dark blue)	Pg2_Sand	Post glacial sand	
	Post_5 (purple)	Pg2	Post glacial silt/clay/ organic material	
Glacial	Gc_1 (olive-green)	Gc_Mw_sand, Gc_Mw_clay	Melt water sand (Weichsel/Saale)	10 – 50 m
	Gc_2 (green)	Gc_Mw_sand, Gc_Mw_clay, GcGl_till, GcFl_clay	Till and melt wa-ter deposits, subglacial (Saale/Elster)	20 – 275 m
Pre-Quatena-ry	PreQ_1 (blue)	PreQ_sand, PreQ_silt, PreQ_clay, PreQ_charcoal	Pre-Quaternary (internal bounda-ry) Mio-cene/Oligocene/E ocene	100 - 300+ m
	PreQ_2 (light blue)	-	Pre-Quaternary Mio-cene/Oligocene/E ocene	Depth not en-countered

Figure 6. Seabed Surface Map. The map is based upon the Geophysical survey in 2012.

3. Wind Farm Layout

As input for the environmental impact assessment for Horns Rev 3 OWF and grid connection, possible and likely wind turbine layouts for Horns Rev 3 have been assessed.

It must be emphasized that the wind turbine layout may be altered by the signed developer. The layout will eventually emerge as a result of an optimization involving detailed assessments of hundreds or even thousands of layouts.

This process has been mimicked with the aim of producing realistic scenarios, but without going into too much detail and using fewer layouts. The following outlines the key-aspects. The study was conducted by DTU Wind Energy in 2013 for Energinet.dk and is considered as confidential.

3.1 Approach to assess wind farm layout

The optimal design depends on several factors including choice of turbine type, cost of cables, the variation of cost of foundations with water depth, and wake losses due to internal shadowing within the wind farm as well as shadow effects from neighbouring farms. All these factors have been included in the layout analysis through a simplified economic model developed to cope with dependences of energy production costs on farm layout, bathymetry and spatial variations in the wind climate. A model fed with wind climate input generated from simulations with mesoscale climate model (Weather Research & Forecasting Model, WRF) was used to simulate wake induced losses and annual energy production. Based on these plausible layouts for the smallest (3.0MW) and the largest (10.0MW) turbine type was found. Also, layouts for the 8.0MW turbine have been produced.

In the economic model calculations were based on scaling of the costs of a reference wind farm. Based on the required total installed power and the turbine type (either 3.0MW or 10.0MW), it was assumed that much of the costs will be independent of farm layout including operation and maintenance costs. Cable costs were assumed to be scaled linear according to farm size and foundation costs to be scaled exponentially with water depth.

For the power density, the analysis indicated only week dependence of the energy production cost on wind farm area, which means, that the power density could be markedly increased without seriously affecting the profitability. A power density of 5.6 MW per km^2 was used in this analysis corresponding to 71.4 km^2 for 400 MW.

3.2 Layouts

Several different layouts were tested in terms of derived annual energy production accounting for shade effects from neighbouring wind farms and wind regimes across the pre-investigation area. It was concluded, that the effect of the variation in wind climate across the area appears to be just as important as the shading effects from Horns Rev 2. The available bathymetry data included in the analysis showed fairly constant water depths; therefore bathymetry had little impact on energy production costs apart from the advantage of including the shallower area in the western part next to Horns Rev 2 and avoidance of the deep area extending about 1km from the western edge. Suggested layouts for different scenarios are presented in the figures below. The layouts are made for 3.0MW and 10.0MW, respectively – and for three different locations of the turbines; closest to the shore (easterly in pre-investigation area), in the centre of the pre-investigation area, and in the western part of the pre-investigation area.

The planned capacity of Horns Rev 3 is 400 MW. For 3.0MW and 10.0MW, respectively, this gives 134 and 40 turbines. Two extra turbines can be allowed (independent of the capacity of the turbine), in order to secure adequate production even in periods when one or two turbines are out of service due to repair. The illustrated park-layouts on figure 6-14 include the two extra turbines, as well as the two extra turbines are included in the modelling and evaluations during the EIA-process.

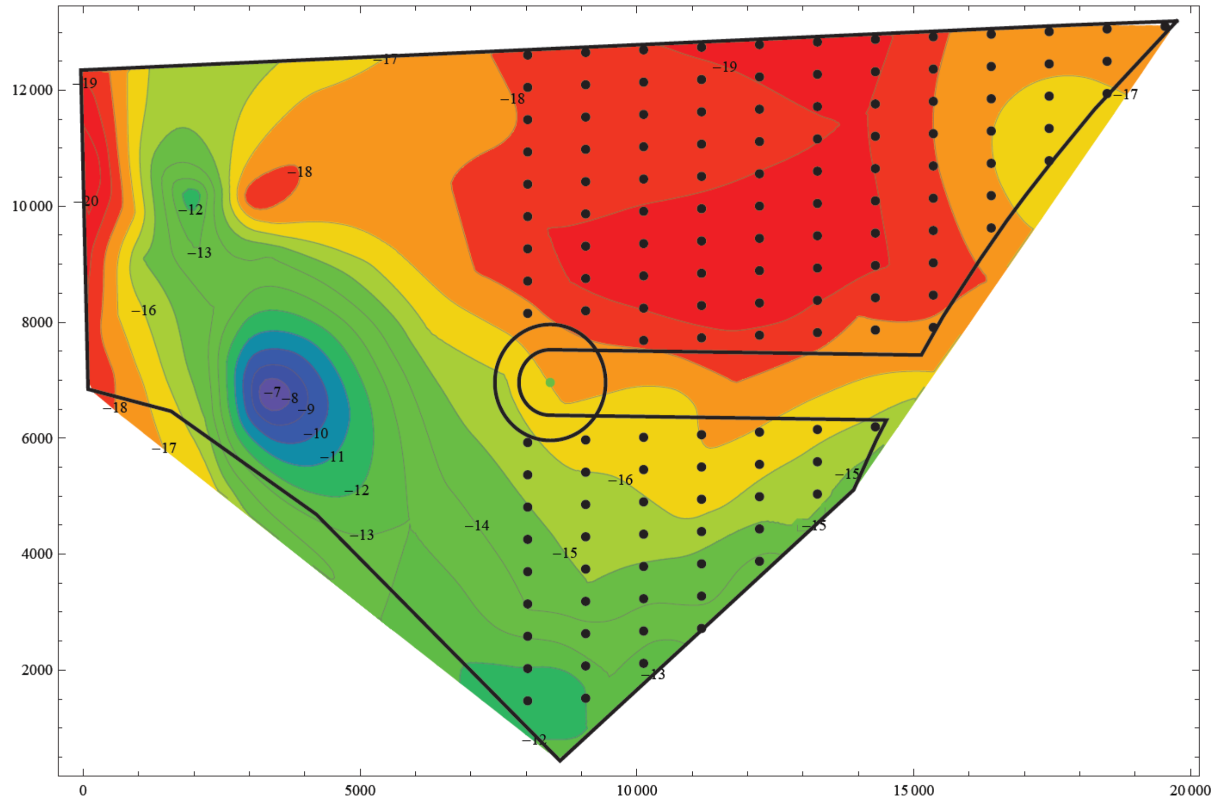


Figure 5. Suggested layout for the 3.0MW turbine at Horns Rev 3, closest to shore.

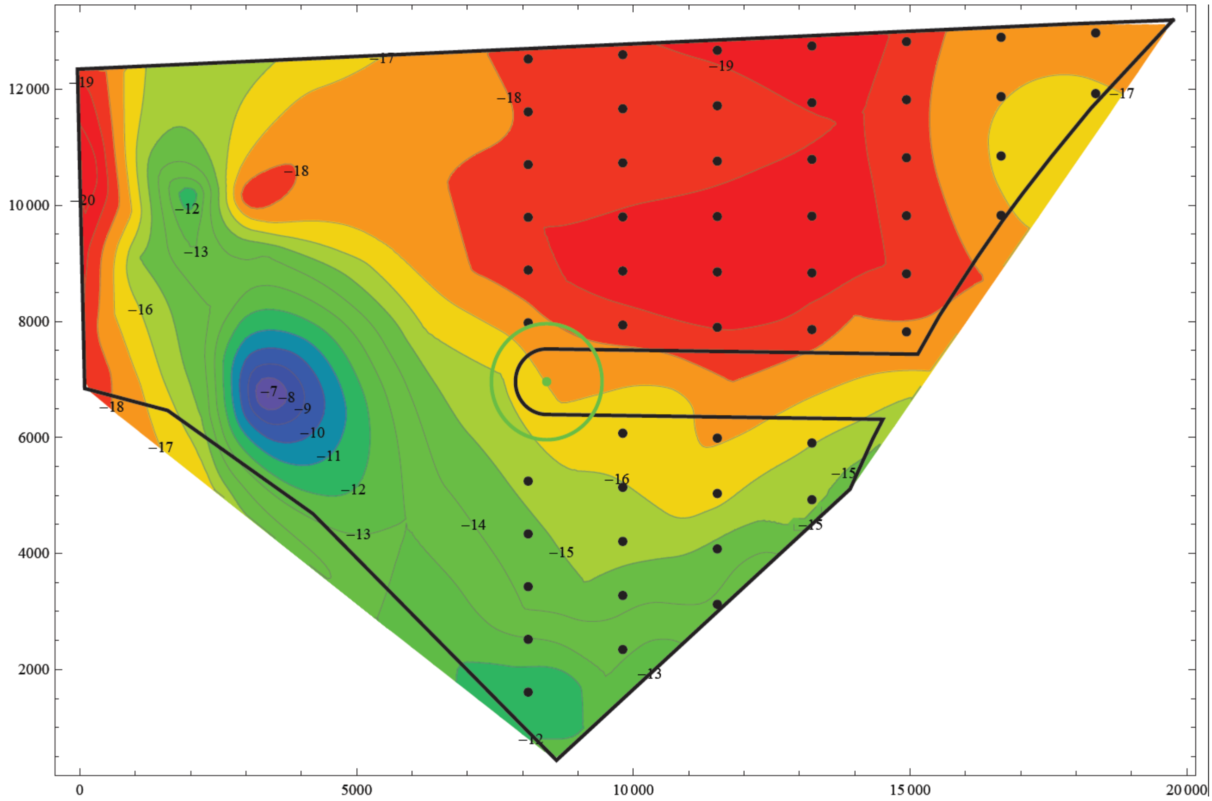


Figure 6. Suggested layout for the 8.0MW turbine at Horns Rev 3, closest to shore.

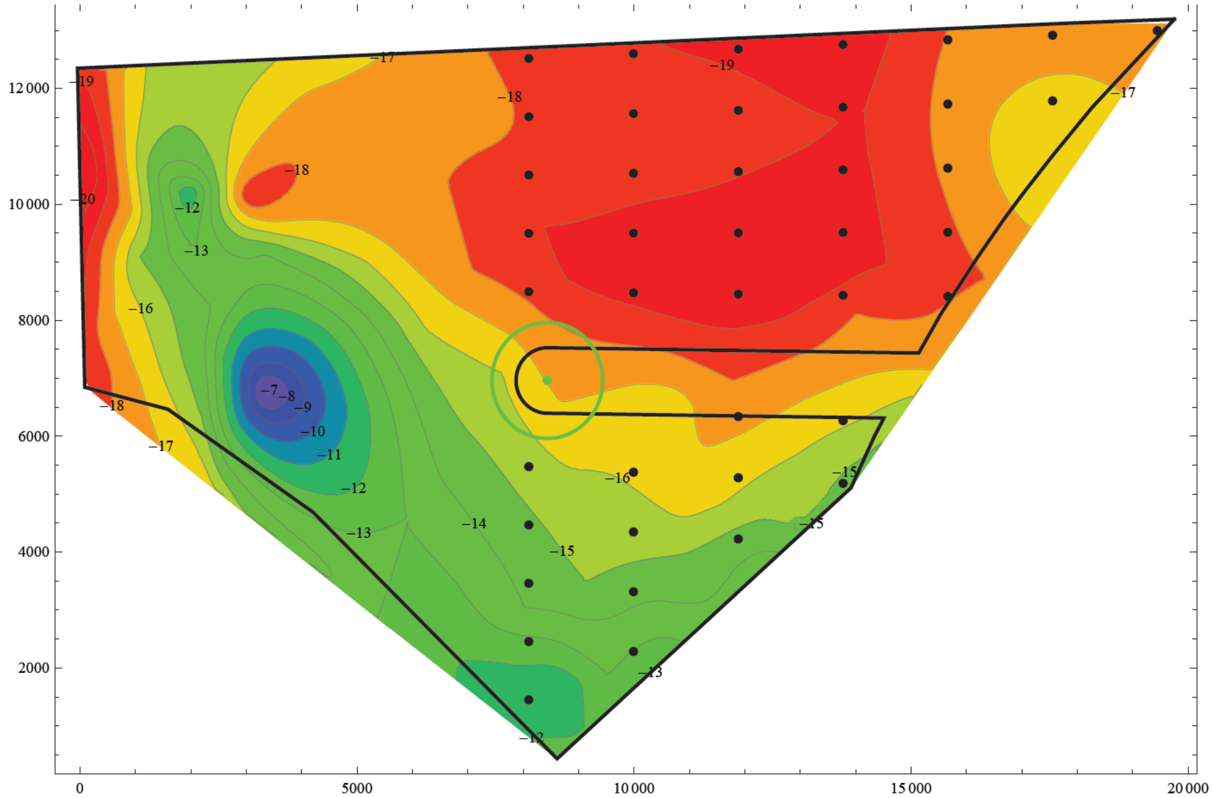


Figure 7. Suggested layout for the 10.0MW turbine at Horns Rev 3, closest to shore.

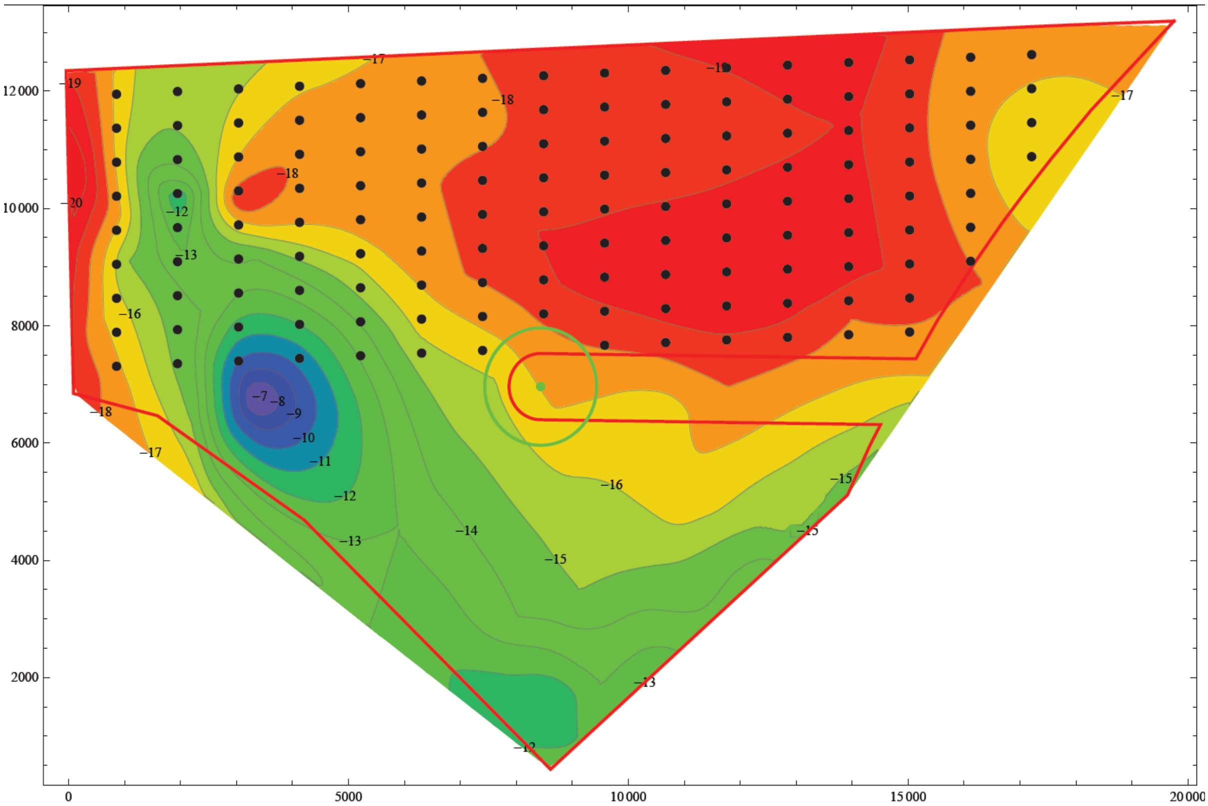


Figure 8. Suggested layout for the 3.0MW turbine at Horns Rev 3, located in the centre of the area.

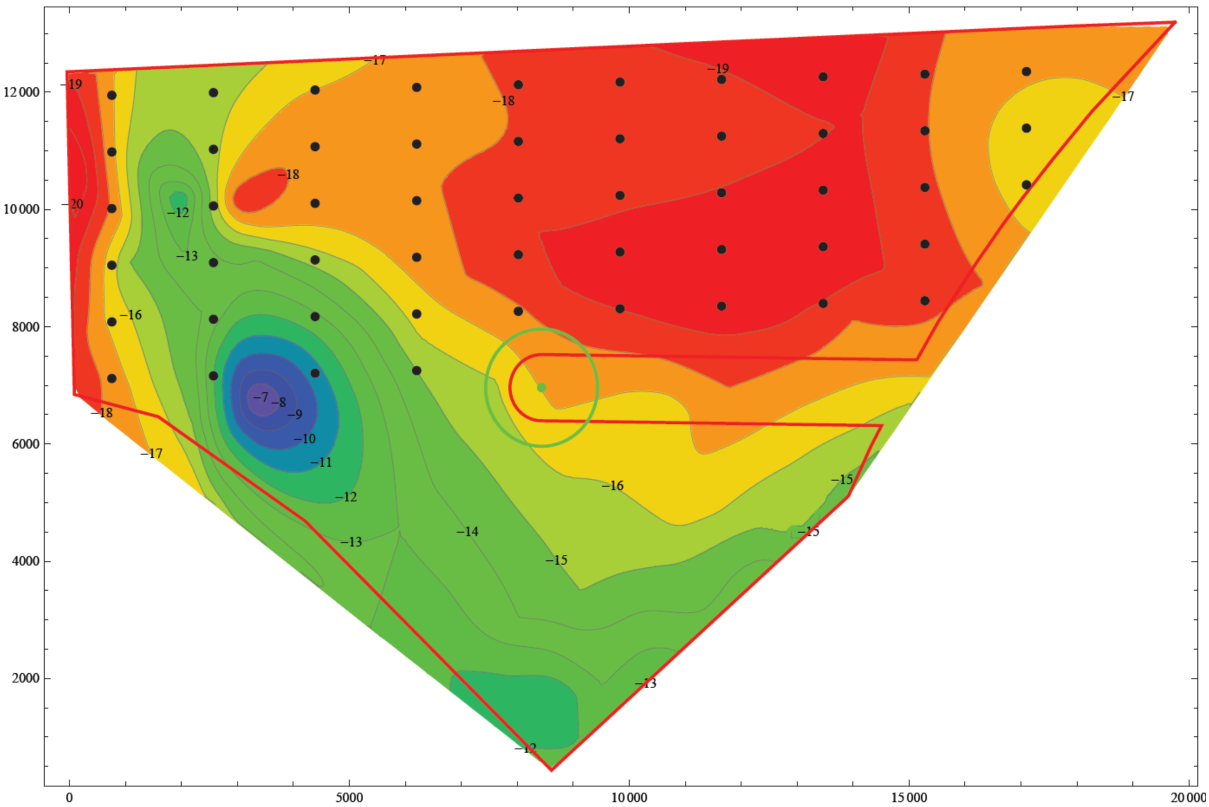


Figure 9. Suggested layout for the 8.0MW turbine at Horns Rev 3, located in the centre of the area.

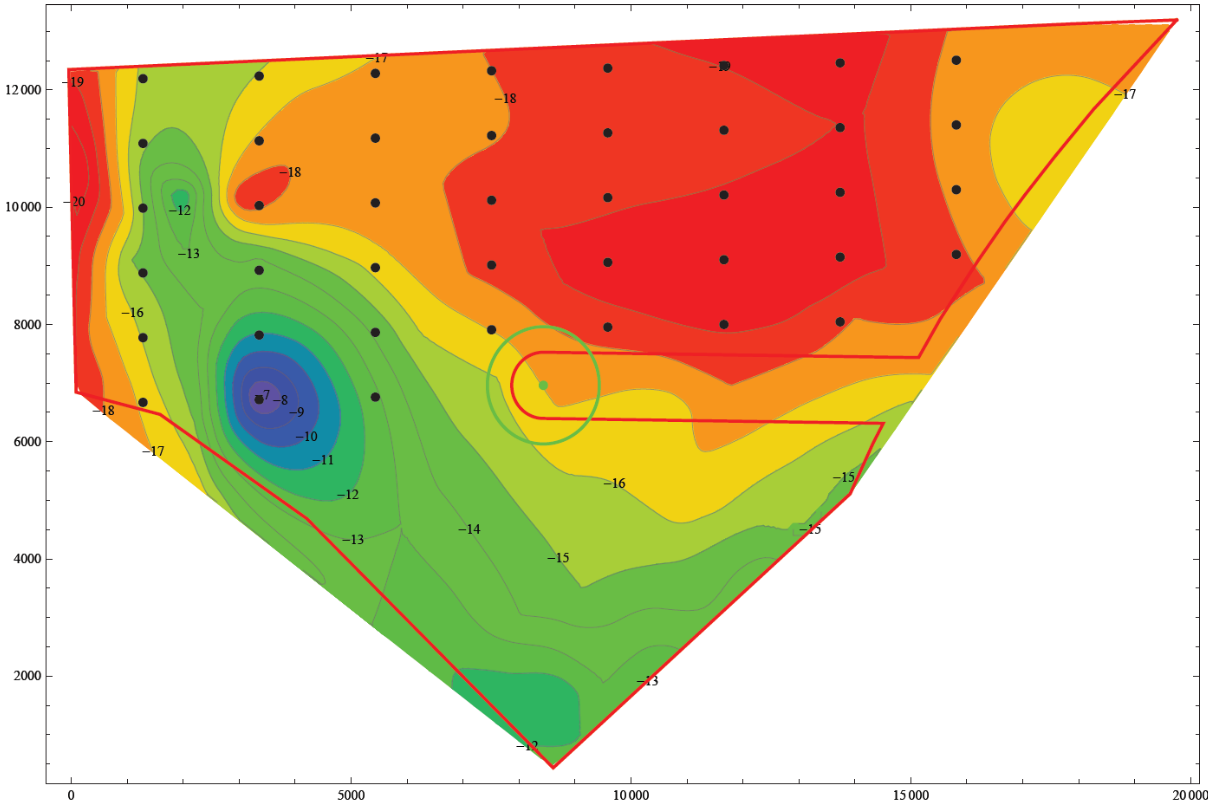


Figure 10. Suggested layout for the 10.0MW turbine at Horns Rev 3, located in the centre of the area.

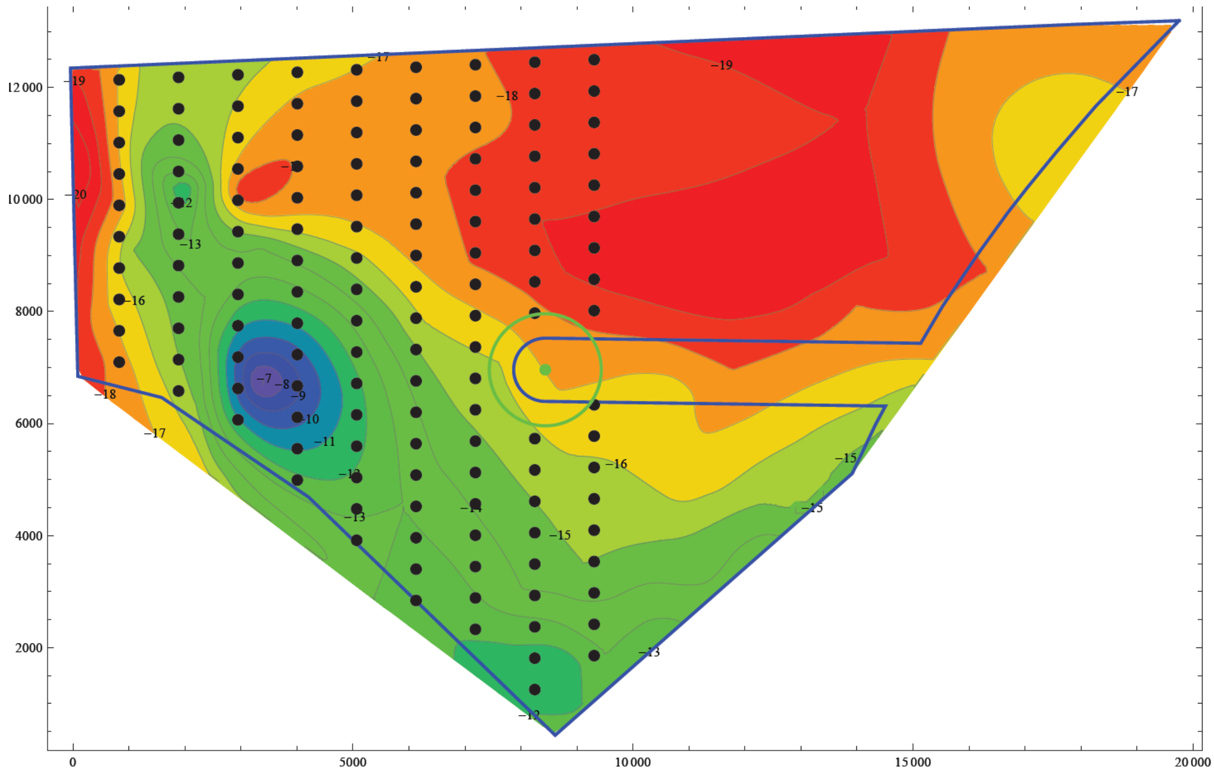


Figure 11. Suggested layout for the 3.0MW turbine at Horns Rev 3, located most westerly in the area.

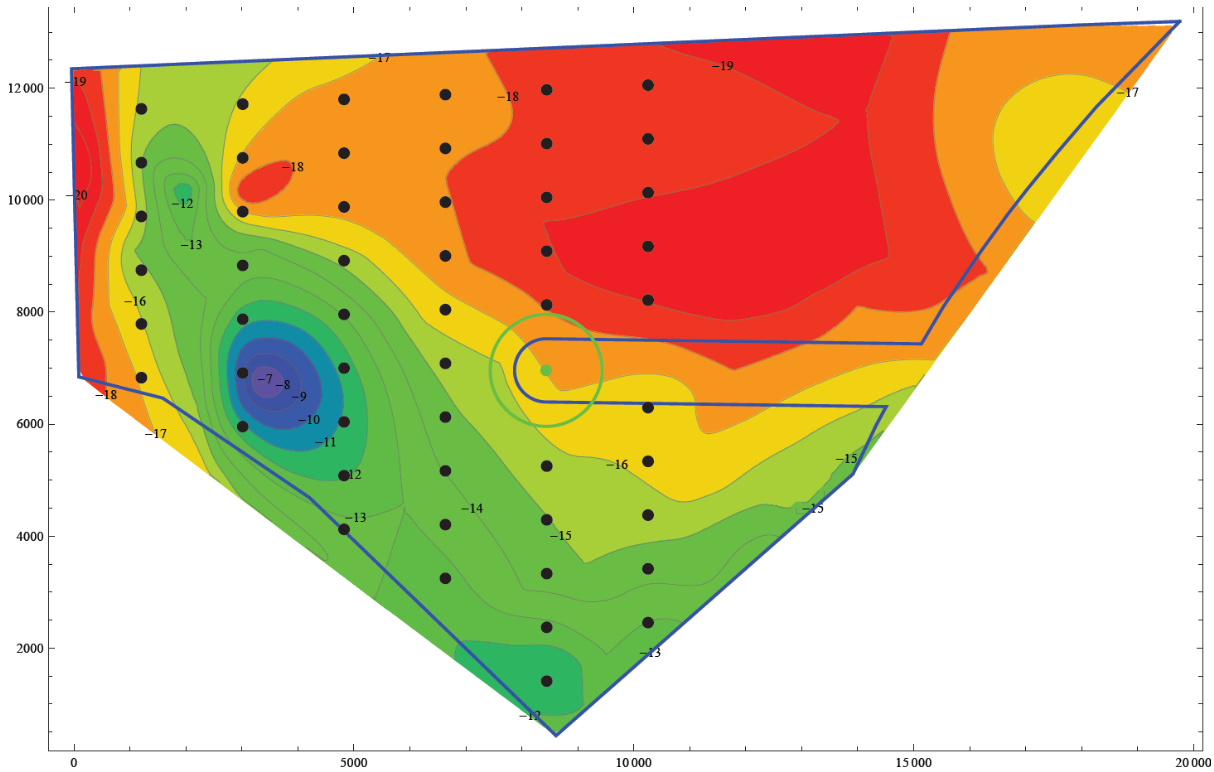


Figure 12. Suggested layout for the 8.0MW wind turbine at Horns Rev 3, located most westerly in the area.

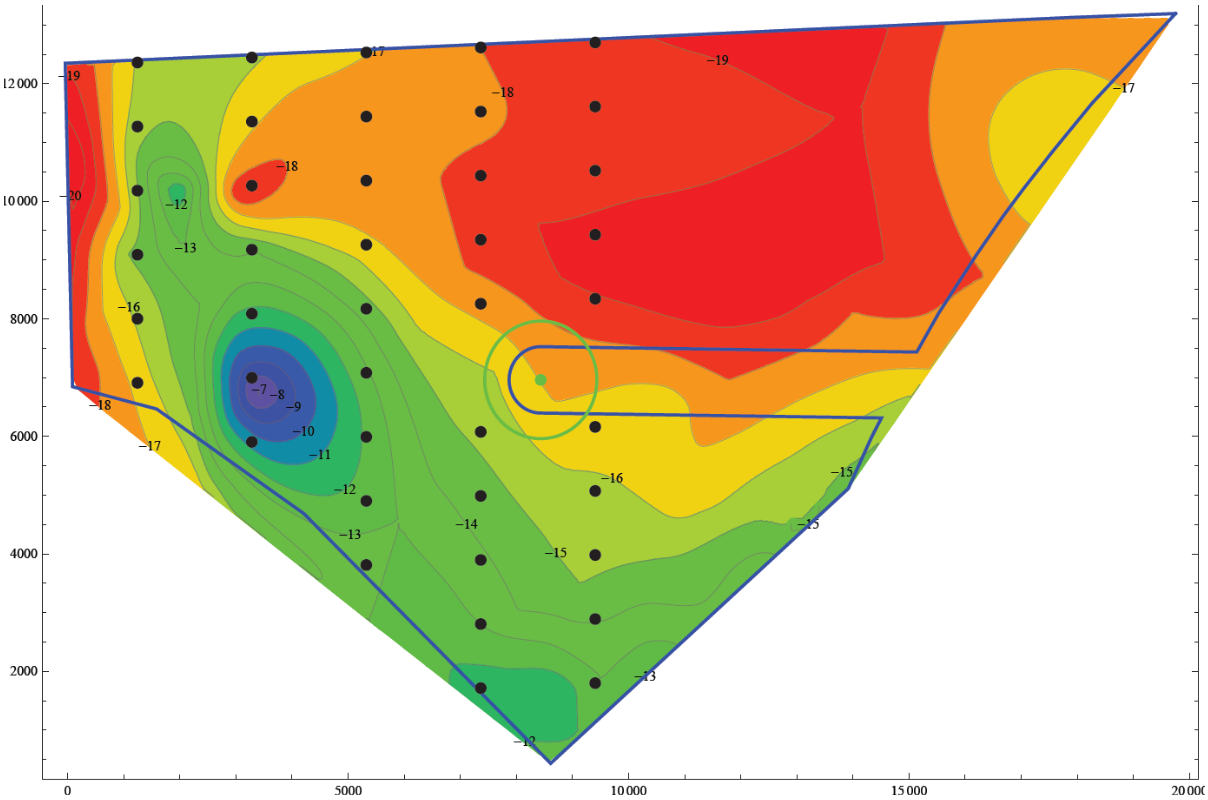


Figure 13. Suggested layout for the 10.0MW wind turbine at Horns Rev 3, located most westerly in the area.

4. Wind Turbines at Horns Rev 3

4.1 Description

The maximum rated capacity of the wind farm is limited to 400MW. The farm will feature from 40 to 136 turbines depending on the rated energy of the selected turbines corresponding to the range of 3.0MW to 10.0MW. The 3.0MW turbine was launched in 2009 and is planned to be installed at the Belgium Northwind project during 2013 and 2014. The 3.6MW turbine was released in 2009 and has since been installed at various wind farms, e.g. Anholt OWF. The 4.0MW turbines are gradually taking over from the 3.6MW on coming OWF installations. The 6.0MW was launched in 2011 and the 8.0MW was launched in late 2012, both turbines are being tested and may be relevant for Horns Rev 3 OWF. A 10 MW turbine is under development which may also be relevant for Horns Rev 3 OWF. These turbine types shall be considered in the Environmental Impact Assessment for Horns Rev 3.

The offshore Platform, and related onshore grid connection, will be designed for at maximum power capacity of 400 MW at the 33 kV side of the 33/220 kV transformer, with an energy capacity equal to production from 405 MW installed turbines with an average turbine availability of 95%.

As part of this technical description information has been gathered on the different turbines from different manufactures. It should be stated that it is the range that is important; other sizes and capacities from different manufactures can be established at Horns Rev 3, as long as it is within the range presented in this technical description.

The wind turbine comprises tubular towers and three blades attached to a nacelle housing containing the generator, gearbox and other operating equipment. Blades will turn clockwise, when viewed from the windward direction.

The wind turbines will begin generating power when the wind speed at hub height is between 3 and 5 m/s. The turbine power output increases with increasing wind speed and the wind turbines typically achieve their rated output at wind speeds between 12 and 14 m/s at hub height. The design of the turbines ensures safe operation, such that if the average wind speed exceeds 25 m/s to 30 m/s for extended periods, the turbines shut down automatically.

4.1.1 Dimensions

Preliminary dimensions of the turbines are not expected to exceed a maximum tip height of 230m above mean sea level for the largest turbine size (10.0MW).

Outline properties of present day turbines are shown in the table below. Included are also data from Horns Rev 2, Rødsand 2 and Anholt OWFs.

Turbine Capacity (MW)	**Rotor Diameter (m)**	**Total Height (m)**	**Hub Height above MSL (m)**	**Swept area (m^2)**	**Wind farms**
3.0MW	112m	135m or site specific	79m or site specific	9,852 m^2	Northwind
3.6MW	120m	141,6m or site specific	81,6m or site specific	11,500m^2	Anholt OWF
4.0MW	130m	153m or site specific	88m or site specific	13,300m^2	-
6.0MW	154m	177m or site	100m or site	18,600	-

		specific	specific	m^2	
8.0MW	164m	187m or site specific	105m or site specific	21,124m^2	-
10.0MW	190m	220m or site specific	125m or site specific	28,400 m^2	-

The air gap between Mean Sea Level (MSL) and wing tip will be determined based on the actual project. However a minimum of approximately 20m above MSL is expected as used for most wind farms including the Horns Rev 2, Rødsand 2 and Anholt OWFs. The Danish Maritime Authority (Søfartsstyrelsen) will need to approve the detailed design and distance between the MSL and lower wing tip before construction of Horns Rev 3 OWF.

4.2 Material

In the tables below the raw material including weight is specified for each turbine capacity. The GRP stands for Glass Reinforced Plastic. No information has been found in relation to the 10MW turbine.

3.0 MW	**Material type**	**Weight**
Nacelle	Steel/GRP	125.4 t
Hub	Cast iron	68.5 t (incl. blades)
Blade	GRP	-
Tower	Steel	150 t (61.8m)
Helipad	None	None

3.6 MW	**Material type**	**Weight (ton)**
Nacelle	Steel/GRP	140 t
Hub	Casted steel/GRP	100 t (incl. Blades)
Blade	GRP	-
Tower	Steel	180t for 60 m tower
Helipad	Steel/GRP	N/A

4.0 MW	**Material type**	**Weight (ton)**
Nacelle	Steel/GRP	140 t
Hub	Casted steel/GRP	100 t (incl. blades)
Blade	GRP	-
Tower	Steel	210t for 68 m tower
Helipad	Steel/GRP	N/A

6.0 MW	**Material type**	**Weight (ton)**
Nacelle	Steel/GRP	360 t incl. rotor
Hub	Casted steel/GRP	No available weights
Blade	GRP	No available weights
Tower	Steel	No available weights
Helipad	Steel/GRP	N/A

8.0 MW	Material type	Weight (ton)
Nacelle	Stell/GRP	390 t ± 10% (incl hub)
Hub	Cast iron	-
Blade	GRP	33 t per blade
Tower	Steel	340 t (84 m)
Helipad	Galvanised steel or alloy	Weight included on the Nacelle and Hub.

4.2.1 Oils and fluids

Each wind turbine contains lubricants and hydraulic oils, and typical quantities for each turbine type are presented in the table below. The wind turbine designs provide security for capturing a potential lubricant spill from a component in the wind turbine.

Fluid	Approximately Quantity			
	3.0 MW	4.0 MW	6.0 MW	8.0 MW
Gearbox Oil (mineral oil)	1190 l*	<600 l	NA**	1,600 l*
Hydraulic oil	250 l	<300 l	<300 l	700-800 l
Yaw/Pitch Motor Oil	Approx. 96 l	< 80 l	<100 l	Approx. 95 l
Transformer Oil	NA***	< 1,450 l	<1,850 l	Approx. 4,000 l

*Full synthetic oil
**No gearbox.
***NA because dry type transformer.

No information has been found in relation to the 10MW turbine.

4.2.2 Colour

A typical colour of the turbine towers and blades will be light grey (RAL 1035, RAL 7035 or similar). The colours must follow the CIE-norms (iCAO annex 14, volume 1, appendix 1) and the BL 3-11 from the Danish Transport Authority. Transition pieces may be used in the connection between the foundation and the turbine towers. The transition pieces are often painted yellow, as in the case for Anholt OWF. The size of the yellow colour must be agreed with the Danish Maritime Authority (Søfartsstyrelsen) and is typically 10-15 m high. The identification number of the turbine will be painted within the yellow colour band. The letters/numbers must be painted in black and the size must be agreed with the Danish Maritime Authority.

4.3 Lightning and marking

The wind turbines will exhibit distinguishing markings visible for vessels and aircrafts in accordance with requirements by the Danish Maritime Authority (Søfartsstyrelsen) and the Danish Transport Authority (Trafikstyrelsen).

Horns Rev 3 will be marked on the appropriate aeronautical charts as required by the Danish Transport Authority. It will also be lit in a way that meets the requirements of both aviation (civilian and military) and marine stakeholders. Lighting will be required to make the development visible to both aircrew and mariners. It is likely that two separate systems will be required to meet aviation standards and marine safety hazard marking requirements.

The light markings for aviation as well as the shipping and navigation will probably be required to work synchronously. Whether the lightning for Horns Rev 3 OWF will be required to work synchronously with Horns Rev 2 and Horns Rev 1 OWFs, should be agreed with the Danish Maritime Authority and the Danish Transport Authority.

The final requirements in relation to lighting will be determined by the Danish Maritime Authority (Søfartsstyrelsen) and the Danish Transport Authority (Trafikstyrelsen) when the layout and height of the wind farm has been finally agreed.

4.3.1 Marking for ship and navigation

The marking with light on the turbines in relation to shipping and navigation is expected to comply with the following description, but must be negotiated between the concessionaire and the Danish Maritime Authority (Søfartsstyrelsen) when the final park layout has been decided, and in due time before construction.

- All turbines placed in the corners and at sharp bends along the peripheral (significant peripheral structures = SPS) of the wind farm, shall be marked with a yellow light. Additional turbines along the peripheral shall be marked, so that there will be a maximum distance between SPS defined turbines on 2 nautical miles.

- The yellow light shall be visible for 180 degrees along the peripheral and for 210-270 degrees for the corner turbines (typically located around 5-10m up on the transition piece). The light shall be flashing synchronously with 3 flashes per 10 second and with an effective reach of at least 5 nautical miles. Within the wind farm the individual turbines will not be marked.

- The top part of the foundation (the transition piece) must be painted yellow. Each turbine should be numbered (identification number) using of black number on a yellow background. The identification numbers should differ from the numbers used in Horns Rev 2 OWF. Indirect light should illuminate the part of the yellow painted section with the turbine identification number.

- The marking of Horns Rev 3 OWF is not expected to be synchronized with Horns Rev 2 OWF.

- Demand by the Danish Maritime Authority for Racon on the north side of Horns Rev 3 OWF must be expected.

- The marking with light on the transformer station will depends on where the platform is located in connection with the turbines. The position of the platform is fixed, whereas the layout of the wind farm will be determined by the coming developer. The platform can be situated within the wind farm, respecting the corridor for export cable etc., or outside the wind turbine array. If the transformer platform is located outside the wind farm area it will most likely be requested to be marked by white flashing lanterns, and an effective reach of 10 nautical miles. The exact specifications of the marking will be agreed with the Danish Maritime Authority in due time before construction.

- There must be a 500 m safety zone around the wind farm and around the transformer platform, if the platform is not located as an integral part of the wind farm.

- During construction the complete construction area shall be marked with yellow lighted buoys with a reach of at least 2 nautical miles. Details on the requirements for the positions and number of buoys shall be agreed with the Danish Maritime Authority (Søfartsstyrelsen). If cranes of 100-150m height will be used during construction, these shall be marked with fixed red light of low intensity (10 candela as a minimum).

4.3.2 Aviation markings

Aviation markings will be agreed with the Danish Transport Authority (Trafikstyrelsen). Regulations on aviation markings of wind turbines (BL 3-11 af 21/03/2013) provide some details on the requirements to aviation markings. The requirements for aviation markings of wind turbines will differ from different types of wind turbines depending on the height of the wind turbine.

Danish regulation and guidance specifies that all turbines in an offshore wind farm with tip heights in excess of 100 m, and not in the vicinity of an airfield, shall be marked with two fixed aviation warning lights at the top of the nacelle. The colour of the lights shall be red with a low-intensity of 10 cd in accordance with type A as detailed in the ICAO guidance. The aviation lights shall be visible horizontally in all directions (360 degrees) regardless of the position of the blades. Besides turbine towers, flashing obstacle warning lights must be placed on turbine nacelles every 900 m along the perimeter, and in all corners and bends of the wind farm. For offshore wind farms with turbine heights between 100 m and 150 m the colour of the lights must be red with a medium-intensity of 2,000 cd (type B) as specified by ICAO. Alternative aviation markings can be negotiated.

Offshore wind farms with turbines whose tip heights are greater than 150 m shall be equipped with obstacle warning lights in accordance with the regulations or based on an individual risk assessment. Alternative markings in accordance with the regulations can be negotiated during ongoing consultation with appropriate stakeholders as the design phase of Horns Rev 3 progresses.

Towers on the perimeter, corners and bends will be marked by three fixed red obstacle warning lights (type B with a light intensity of 32 cd) placed at an intermediate level of the turbine tower as well as two flashing obstacle lights on top of the nacelle. The colour of the obstacle warning lights during daylight will be white with a medium-intensity of 20,000 cd (type A). At night they will be red with a medium intensity of 2,000 cd (type B). Furthermore the perimeter of the nacelles of these turbines shall be marked by three fixed low intensity red warning lightings each of 32 cd. The distance between the unmarked part of the turbines or tip of the blades and the top of the obstacle markings must not exceed 120 m.

4.3.3 Operational airborne noise emissions

There are two types of noise associated with wind turbines; aerodynamic noise and mechanical noise.

Aerodynamic noise is broad-band in nature, relatively unobtrusive and is strongly influenced by incident conditions, wind speed and turbulence intensity. An operational Sound Power Level is expected in the order of 95dB(A) to 112dB(A), depending on the selected turbine type and the wind speed.

Mechanical noise is generated by components inside the turbine nacelle and can be radiated by the shell of the nacelle, blades and the tower structure. Such noise emissions are not considered significant for the present generation of turbines to be considered for the Horns Rev 3 OWF.

Noise levels on land during the operation of the wind farm are expected to be well below allowed limits. The overall limits for operational noise on land according to the Danish legislation are:

- 44 dB for outdoor areas in relation to neighbours (up to 15m away) in the open land, and
- 39 dB for outdoors areas in residential areas and other noise sensitive areas.

In relation construction noise, the most extensive noise is normally generated from piling of off-shore foundations. A typical range that can be expected from piling at the source level, is normally within a range of LWA: 125-135 dB(A) LWA re 1pW.

4.3.4 Installation

Although offshore contractors have varying construction techniques, the installation of the wind turbines will typically require one or more jack-up barges. These vessels stand on the seabed and create a stable lifting platform by lifting themselves out of the water. The area of seabed taken by a vessels spud cans is approximately 350m^2 (in total), with leg penetrations of up to 2 to 15m (depending on seabed properties). These foot prints will be left to in-fill naturally.

The wind turbine components will either be stored at an adjacent port and transported to site by support barge or the installation vessel itself, or transported directly from the manufacturer to the wind farm site by barge or by the installation vessel. The wind turbine will typically be installed using multiple lifts. A number of support vessels for equipment and personnel jack-up barges may also be required.

It is expected that turbines will be installed at a rate of one every one to two days. The works would be planned for 24 hours per day, with lighting of barges at night, and accommodation for crew on board. The installation is weather dependent so installation time may be prolonged in unstable weather conditions.

Following installation and grid connection, the wind turbines are commissioned and are available to generate electricity.

5. Foundations - wind turbines

The wind turbines will be supported by foundations fixed to the seabed. It is expected that the foundations will comprise one of the following options:

- Driven steel monopile
- Concrete gravity base
- Jacket foundations
- Suction buckets

It shall be noted that floating foundation structures supporting smaller wind turbines have been installed outside the coast of Portugal and Norway as tests. The concept has been developed for deeper waters as the cost of a traditional foundation structure will much too costly for these sites. Concepts of floating foundations for more shallow water may be developed in the future, but is not be considered feasible at this stage for Horns Rev 3 OWF as the costs exceeds those for more traditional foundation types as mentioned above.

Until today, no floating foundation concepts has been designed to sustain larger turbines like the 3.0MW, which is expected to be the minimum turbine size for Horns Rev 3 OWF.

The existing OWFs, Horns Rev 1 and 2, have both used monopiles for the turbines and jackets for the offshore platforms.

Horns Rev 3 is rated for a capacity of 400MW. In addition; within each of the individual wtg groups two additional turbines shall be encountered so the total capacity can be expected to be more than 400MW.

5.1 Driven steel monopile

5.1.1 Description

Monopiles have been installed at a large number of wind farms in the UK and in Denmark in e.g. Horns Rev 1, Horns Rev 2 and Anholt OWFs.

This solution comprises driving a hollow steel pile into the seabed. Pile driving may be limited by deep layers of coarse gravel or boulders, and in these circumstances the obstruction may be drilled out. A transition piece is installed to make the connection with the wind turbine tower. This transition piece is generally fabricated from steel, and is subsequently attached to the pile head using grout. The grouting process is discussed later in this document. Recent studies have proven the conventional grout connection to be failing on several wind parks, thus, alternatives as e.g. conical transitions piece, shear keys and elastomeric bearings will be considered in the design. Alternatively to the grout connection a bolted connection may also be introduced. The foundation structures are normally protected by use of painting and sacrificial anodes.

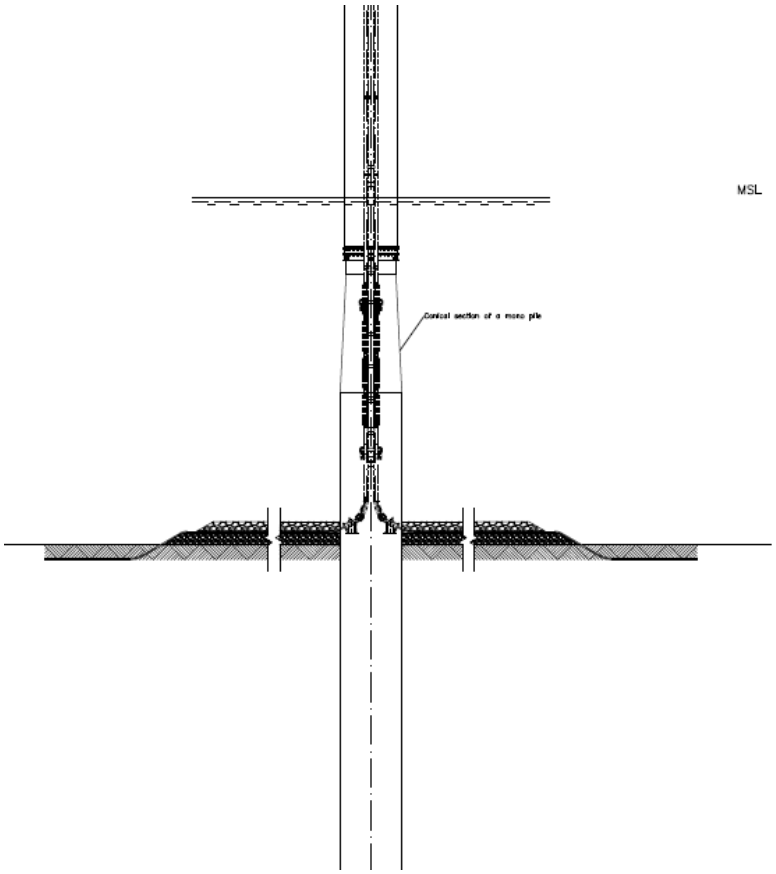
5.1.2 Dimensions

The dimensions of the monopile will be specific to the particular location at which the monopile is to be installed. The results of some very preliminary monopile and transition piece designs for the proposed Horns Rev 3 OWF, are presented below:

MONOPILE	3MW Turbine	3.6MW Turbine	4MW Turbine	8MW Turbine	10MW** Turbine
Outer Diameter	4.5-6.0m	4.5-6.0m	5.0-7.0m	6.0-8.0m	7.0-10.0
Pile Length	50-60m	50-60m	50-60m	50-70m	60-80m
Weight	300-700t	300-800t	400-900t	700-1000t	900-1400t
Ground Penetration (below mud line)	25-32m	25-32m	26-33m	28-35m	30 – 40m
Total pile weight (136/114/102/52/42 monopiles)	41,000-95,000t	34,000-91,000t	41,000-92,000t	36,500-52,000t	38,000-60,000t
TRANSITION PIECE					
Length	10-20m	10-20m	10 – 20m	15-25m	15 – 25m
Outer Diameter	3.5-5.0m (if pile not conical up to 6.2 m)	3.5-5.0m (if pile not conical up to 6.2 m)	4.0-5.5m (if pile not conical up to 7,2 m)	5.0-6.0m (if pile not conical up to 8.2 m)	6.0-8.0 m (if pile not conical up to 10.2m)
Weight	100-150t	100-150t	120-180t	150-300t	250–400t
Volume of Grout per unit	15-35 m³	15-35 m³	20-40 m³	25-60 m³	30-70 m³
Total weight (136/114/102/ 52/42) transition piece	14,000-21,000t	1,000-17,000t	12,500-18,500t	8,000-16,000t	10,500-17,000t
Scour Protection					
Volume per foundation	2,100m³	2,100 m³	2,500 m³	3,000m³	3,800 m³
Foot print area (per foundation)	1,500m²	1,500m²	1,575m²	1,650m²	2,000 m²
Total Scour (136/114/102/52/420 mono piles)	286,000m³	240,000m³	255,000m³	156,000m³	160,000m³
Total foot print scour area (136/114/102/52/42 mono piles)	204,000m²	171,000m²	161,000m²	86,000m²	84,000m²

*Outer diameter at and below the seabed level. Above the seabed the diameter normally decrease resulting in a conical shape of the mono-pile (see figure below).

**Very rough estimate of quantities.



The principal illustration above shows the conical part of the mono-pile. The mono-pile section above the conical part has a smaller outer diameter than the part of the mono- pile below the conical part. The outer diameter of the pile above the conical part then allows for a transition piece with an inner diameter smaller than the outer diameter of the imbedded pile – taken the length of the pile section above the conical part into account compared to the length of the transition piece.

5.1.3 Installation

The construction of the driven monopile support structure is discussed below.

5.1.3.1 Seabed preparation

The monopile concept is not expected to require much preparation works, but some removal of seabed obstructions may be necessary. Scour protection filter layer may be installed prior to pile driving, and after installation of the pile a second layer of scour protection may be installed (armour layer). Scour protection of nearby cables may also be necessary.

5.1.3.2 Installation sequence

The installation of the driven monopile will take place from either a jack-up platform or floating vessel, equipped with 1-2 mounted marine cranes, a piling frame, and pile tilting equipment. In addition, a small drilling spread, may be adopted if driving difficulties are experienced. A support jack-up barge, support barge, tug, safety vessel and personnel transfer vessel may also be required.

The installation sequence, which can vary according to pile size and vessel characteristics, is typically as follows:

- Load pile (or piles) onto support barge at the onshore support base, sea-fasten, and transport to site. Alternatively tow floated piles to the site from the manufacturing base;
- Anchor handling (installation of anchors) at the turbine location (if required);
- Jack-up barge arrives at the installation location, extends the lifting jacks and performs stability tests prior to lifting;
- Pile is transferred from the barge to the jack-up and then lifted into a vertical position;
- The pile is then driven until target penetration is achieved;
- Remove hammer;
- Installation of transition piece;
- Jack-up barge moves to next installation location to meet barge with next pile;
- Anchor handling, removal and re-deployment of anchors (if required).

5.1.3.3 Driving time

The expected time for driving each pile is between 4 and 6 hours. Drivability analysis shall be part of the proposed design. A time estimate would be one to two days for one pile installed and transition grouted. Horizontal fixing cylinders for fixation of transition piece during curing are foreseen.

A monopile driving intensity will be around 200 impacts per meter monopile. Considering that the piles will be around 35m each, this will be around 7,000 impacts per monopile. When this is divided regularly over the 6 hours pile driving activity, this leads to approximately 20 impacts per minute during the 6 hours pile driving activity.

An estimate of the expected maximum driving intensity will be around 400 impacts per meter monopile. If the monopile is 35m each, this will lead to around 14,000 impacts per monopile. When this is divided regularly over the 6 hours pile driving activity, this leads to approximately 40 impacts per minute during the 6 hours pile driving activity.

5.1.3.4 Grouting Process

Grouting is used to fix transition pieces to the piled support structure. Grout is a cement based product, used extensively for pile grouting operations worldwide. The grout used for the proposed Horns Rev 3 OWF would conform to the relevant environmental standards. The grout will either be mixed in large tanks aboard the jack-up platform, or mixed ashore and transported to site. The grout is likely to be pumped through a series of grout tubes previously installed in the pile, so that the grout is introduced directly between the pile and the walls of the transition piece.

Methods will be adopted to ensure that the release of grout into the surrounding environment is minimized; however some grout may be released as a fugitive emission during the process. A worst-case conservative estimate of 5%, (up to 160 t) is assumed for the complete project.

5.1.3.5 Noise Emissions

The underwater noise generated by pile driving during installation has been measured and assessed during construction of wind farms in Denmark, Sweden and England. The noise level and emissions will depend among other things of the pile diameter and seabed conditions. An indicative source level of the pile driving operation would be in the range of 220 to 260dB re 1µPa @1metre.

5.2 Concrete gravity base

5.2.1 Description

These structures rely on their mass including ballast to withstand the loads generated by the off-shore environment and the wind turbine.

The gravity base concept has been used successfully at operating wind farms such as Middelgrunden, Nysted, Rødsand II and Sprogø in Denmark, Lillgrund in Sweden and Thornton Bank in Belgium.

Normally the seabed preparation is needed prior to installation, i.e. the top layer of material upon the seafloor is removed and replaced by a stone bed. When the foundation is placed on the seabed, the foundation base is filled with a suitable ballast material, and a steel "skirt" may be installed around the base to penetrate into the seabed and to constrain the seabed underneath the base.

The results of the preliminary gravity base design for the proposed Horns Rev 3 OWF are presented below.

5.2.2 Dimensions

The dimensions of the concrete gravity foundation will be specific to the particular location at which the foundation is to be installed. The table below gives estimated dimensions for four different sizes of turbines.

GRAVITY BASE	**3MW Turbine**	**3.6MW Turbine**	**4MW Turbine**	**8MW Turbine**	**10MW* Turbine**
Shaft Diameter	3.5-5.0m	3.5-5.0m	4.0-5.0m	5.0-6.0m	6.0-7.0m
Width of Base	18-23m	20-25m	22-28m	25-35m	30-40m
Concrete weight per unit	1300-1800t	1500-2000t	1800-2200t	2500-3000t	3000-4000t
Total Concrete weight (t), (136/114/102/52/42 turbines)	177,000-245,000t	171,000-228,000t	184,000-225,000t	130,000-156,000t	126,000-168,000t
BALLAST					
Type	Infill sands	Infill sands	Infill sands	Infill sands	Infill sands
Mass per unit (m^3)	1300-1800m³	1500-2000m³	1800-2200m³	2000-2500m³	2300 – 2800m³
Total mass (m^3) , (136/114/102/52/42 turbines)	177,000-245,000m³	171,000-228,000m³	184,000-225,000m³	104,000-130,000m³	97,000-118,000m³

*Very rough estimate of quantities. Depends of loads and actual geometry/layout of GBS. The GBS may en general be design with a conical section and not a straight shaft.

5.2.3 Ballast

The ballast material is typically sand, which is likely to be obtained from an offshore source. An alternative to sand could be heavy ballast material (minerals) like Olivine, Norit (non- toxic materials). Heavy ballast material has a higher weight (density) that natural sand and thus a reduction in foundation size could be selected since this may be an advantage for the project. Installation of ballast material can be conducted by pumping or by the use of excavators, conveyers etc. into the ballast chambers/shaft/conical section(s). The ballast material is most often transported to the site by a barge.

5.2.4 Seabed preparation

The seabed will normally require preparation prior to the installation of the concrete gravity base. This is expected to be performed as described in the following sequence, depending on ground conditions, and available plant:

- The top surface of the seabed is removed to a level where undisturbed soil is encountered, using a back-hoe excavator aboard a barge, with the material loaded aboard split-hopper barges for disposal;
- Gravel is deposited into the hole to form a firm level base.

The quantities for the seabed preparation depend on the ground conditions. Below is given the quantities for an average excavation depth of 2m, however large variations are foreseen, as soft ground is expected in various parts of the area. Finally the gravity structure (and maybe nearby placed cables) will be protected against development of scour holes by installation of a filter layer and armour stones.

	3MW Turbine	**3,6MW Turbine**	**4MW Turbine**	**8MW Turbine**	**10MW** Turbine**
Size of Excavation (approx.)	23-28	25-30m	27-33m	30-40m	35-45m
Material Excavation (per base)	900-1,300m³	1,000-1,500m³	1,200-1,800m³	1,500-2,500m³	2,000-3,200m³
Total Material Excavated (136/114/102/52/42 turbines)*	123,000-177,000m³	114,000-171,000m³	123,000-184,000m³	78,000-130,000m³	84,000-135,000m³
Stone Replaced into Excavation (per base) – stone bed	90-180m³-	100-200m³	130-230m³	200-300m³	240-400m³
Total Stone Replaced (136/114/102/52/42 turbines)	12,500-25000m³	11,500-23, 000m³	13,500-23,500m³	10,500-16,000m³	10,000-17,000m³
Scour protection (per base)	600-800m³	700-1,000m³	800-1,100m³	1,000-1,300m³	1,100-1,400m³
Foot print area (per base)	800-1,100m²	900-1,200m²	1,000-1,400m²	1,200-1,900m²	1,500-2,300m²
Total scour protection (136/114/102/52/42 turbines)	95,000m³	97,000m³	97,000m³	60,000m³	53,000m³
Total foot print area (136/114/102/52/42 turbines)	129,000m²	120,000m²	123,000m²	81,000m²	80,000m²

(*) For excavation depths of further 4 to 8m at 20% of the turbine locations, the total excavated material would by increased by around 100%.

**Very rough estimate of quantities. Depending on loads and actual geometry/layout of GBS. The GBS may en general be design with a conical section and not a straight shaft.

The approximate duration of each excavation of average 2m is expected to be 3 days, with a further 3 days for placement of stone. The excavation can be done by a dredger or by excavator placed on barge or other floating vessels.

5.2.5 Disposal of excavated materials

The material excavated during the seabed preparation works will be loaded onto split-hopper barges for disposal. Each excavation is expected to produce 5-10 barge loads, hence up to between 550 and 1,200 and 250 to 500 barge loads would be required for total numbers of respectively smaller and larger turbines. The Client will determine the possible range of beneficial uses of the spoil material, including using the material as ballast within the structure or as scour protection material or for port construction. If beneficial use is not feasible, the material would be disposed at sea at a registered disposal site.

5.2.6 Installation sequence

The installation of the concrete gravity base will likely take place using a floating crane barge, with attendant tugs and support craft. The bases will either be floated and towed to site or transported to site on a flat-top barge or a semi-submergible barge. The bases will then be lowered from the barge onto the prepared stone bed and filled with ballast.

5.2.7 Physical discharges of water

There is likely to be some discharge to water from the material excavation process. A conservative estimate is 5% material spill, i.e. up to 200 m^3 for each base, over a period of 3 days per excavation.

5.2.8 Noise emissions

Noise emissions during construction are considered to be small.

5.3 Jacket foundations

Depending on the seabed conditions it might be necessary to do pre-dredging before installation of jacket foundations e.g. due to very soft soil and/or due to sand dunes.

5.3.1 Description

Basically the jacket foundation structure is a three or four-legged steel lattice construction with a shape of a square tower. The jacket structure is supported by piles in each corner of the foundation construction.

The jacket foundation has been used successfully at operating wind farms such as in the East Irish Sea, The North Sea and in The Baltic Sea.

The construction is built up of steel tubes in the lattice structure and with varying diameters depending of their location in the lattice structure. The three or four legs of the jacket are connected to each other by cross bonds which provide the construction with sufficient rigidity.

On top of the jacket a transition piece constructed in steel is mounted on a platform. The transition piece connects the jacket to the wind turbine generator. The platform itself is assumed to have a dimension of approximately 10 x 10 meters and the bottom of the jacket between 18 x 18 meters and 30 x 30 meters between the legs.

The jacket foundation together with the transition piece (excluding the piles) can weigh between 400 and 600 tonnes.

Fastening the jacket with piles in the seabed can be done in several ways:

- Piling inside the legs
- Piling through pile sleeves attached to the legs at the bottom of the foundation structure
- Pre-piling by use of a pile template

The jacket legs are then attached to the piles by grouting with well-known and well-defined grouting material used in the offshore industry. One pile will be used per jacket leg. The type of grouting material will be the same as for the monopiles.

For installation purposes the jacket may be mounted with mudmats at the bottom of each leg. Mudmats ensure bottom stability during piling installation. Mudmats are large structures normally made out of steel and are used to temporary prevent offshore platforms like jackets from sinking into soft soils in the seabed. Normally the pile driving and location of the mudmats will take place by means of a jack-up-vessel which has been transported to the area of the wind turbines. The mudmats will be left at the seabed after installation of the jacktes. The functional life span of these mudmats is limited, as they are essentially redundant after installation of the foundation piles. The size of the mudmats depends on the weight of the jacket, the soil load bearing and the environmental conditions.

Scour protection at the foundation piles and cables may be applied depending on the soil conditions. In sandy soils scour protection is necessary for preventing the construction from bearing failure. Scour protection consists of natural well graded stones or blasted rock.

5.3.2 Dimensions

The dimensions of the jacket foundation will be specific to the particular location at which the foundation is to be installed:

Jacket	**3MW Turbine**	**3,6MW Turbine**	**4MW Turbines**	**8MW Turbine**	**10MW Turbine**
Distance between legs at seabed	18 x 18m	20 x 20m	22 x 22m	30 x 30 m	40 x 40m
Distance between legs at wtg interface	11 x 11m	12 x 12m	13 x 13m	15 x 15m	18x18m
Platform size at interface	10 x 10m	10 x 10m	10 x 10m	12 x 12m	10x10m
Pile Length	40 – 50m	40 - 50m	40 – 50m	50-60m	60-70m
Diameter of pile	1200 – 1500mm	1200 – 1500mm	1,300-1,600mm	1400 – 1700mm	1500-1800mm
Weight	400t	400t	450t	600t	800t
Total weight (136/114/102/52/42 turbines)	54,500t	46,000t	46,000t	31,500t	34,000t
Scour protection volume (per foundation)	800m^3	1,000m^3	1,200m^3	1,800m^3	2,500 m^3
Foot print area (per foundation)	700m^2	800m^2	900m^2	1,300m^2	1,600m^2

Total scour protection (136/114/102/52/42 turbines)	109,000m^3	112,000m^3	123,000m^3	94,000m^3	105,000m^3
Total foot print area in m^2 (136/114/102/52/42 turbines)	95,000m^2	91,000m^2	92,000m^2	68,000m^2	67,000m^2

5.3.3 Installation
Depending of the seabed pre-dredging maybe considered necessary due to very soft soil and/or due to sand dunes. In case of an area with sand dunes dredging to stable seabed may be required. Dredging can be done by trailing suction hoper dredger or from an excavator place on a stable plat form (a jack-up) or from a floating vessel with an excavator onboard. The dredged material can be transported away from the actual offshore site by a vessel or barge for deposit. Minor sediment spill may be expected during these operations.

Normally a jack-up rig will be tugged to the site for doing the piling. The jack-up also place mud-mats/pile template as appropriate. After placing the pile template the piling will commence through the piling sleeves. The piles can be up-ended from an assisting jack-up, an offshore barge or from a floating condition. Alternative a floating shear leg can be used.

The jacket construction itself is transported to the position by a large offshore barge. At the position a heavy floating crane vessel lifts the jacket from the barge and lowers it down to the pre-installed piles and hereafter the jacket is fixed to the piles by grouting.

The jacket construction can also be transported on an offshore barge in upright position with pre-installed piles either in the pile sleeves or in the jacket legs. A heavy floating crane vessel lifts the jacket from the barges and down to the seabed and leave hereafter the position. A jack-up tugged to the position will take over and commence the piling and the jacket will be fixed to the piles by grouting.

5.4 Suction buckets
5.4.1 Description
'The bucket foundation' is a new concept and quality proven hybrid design which combines the main recognized aspects of a gravity base foundation, a monopile and a suction bucket. 'The Bucket foundation' is said to be "universal", thus it can be applied to and designed for various site conditions. Homogeneous deposits of sand and silts, as well as clays, are ideal for the feasible foundation concept. Layered soils are likewise suitable strata for the bucket foundation.

However, installation in hard clays and tills may prove to be challenging and will rely on a meticulous penetration analysis, while rocks are not ideal soil conditions when installing the bucket foundation.

The concept has been used offshore for supporting met masts at Horns Rev 2 and Dogger Bank. The bucket is target for 2015/2016 in relation to wind turbines.

5.4.2 Dimensions
The most "common" design of a bucket foundation is to have a relation between the diameter (D) of the bucket and the skirt height (H) of the bucket as H/D = 0.5.

The plate diameter from the gravity based structure will be used as foundation area. It is further anticipated that the maximum height of the bucket including the lid will be less that 1 m above seabed. The diameter of the bucket is anticipated to be the same as for the gravity based foundation structures.

5.4.3 Installation

The foundations can be tugged in floated position directly to its position by two tugs where it is upended by a crane positioned on a Jack-Up

The concept can also be installed on the jack-up directly at the harbour site and transported by the jack-up supported by tugs to the position.

Before the foundation is lowered into the water, it is fitted with an advanced click-on system combining a pump unit and a superior control method. This system ensures secure operation and installation of the bucket using jet and suction. The further installation process ensures that the penetration is kept within the predicted installation parameters with respect to maximum amount of suction pressure, penetration speed and inclination.

The suction installation process is controlled by two measures; one being the overall suction within the bucket chamber allowing a downward force on the structure. The rim of the skirt is equipped with a large number of sectional divided nozzles for injection of water. The bucket structure will by these means be steered vertically allowing precise installation within the inclination tolerances, specified by the topside requirements
Installation of the bucket foundation’ does not require seabed preparations and divers. Additionally, there are reduced or no need for scour protecting depending on the particular case.

5.5 Offshore foundation ancillary features

The foundations will require the following ancillary features for safety and operational protection of equipment:

- Access platform arrangements for crew access/equipment transfer;
- Cable entry;
- Corrosion protection;
- Scour protection materials description.

5.5.1 Access platform arrangements to the wind turbines

5.5.1.1 Description

The access platform comprises one or more ladders, enabling access to the foundation at any water level. In addition, a platform at the top of the ladder is necessary for crew safety. Both these features will be constructed from steel. The structures will have provisions for personnel safety, e.g. life-rings.

5.5.1.2 Installation

The access platform will be lifted into place by the jack-up barge during the main construction works.

5.5.2 Cable entry

The steel tube is normally placed in site the foundation structure of the gravity base concept. The cables to the momopiles go either directly into the foundation or in a steel tube (I/J-tube) outside the foundation.

5.5.2.1 Description

The wind turbines in the array will be inter-connected by subsea cables to provide both power and telemetry links. Provision is made for the entry and protection of the cables.

The cables are most likely to be installed in a "J/I-tube" arrangement, a steel tube of approximately 250-400mm diameter attached to the side of the turbine support structure extending from above the high water level to the seabed (or fixed internal). Each structure will have between two and four J-tubes. J-tubes will be installed prior to concrete pouring of the foundation structure. Further attachments, like extensions or Bellmouth must be bolted onto J-tube.

5.5.2.2 Installation

For the gravity base options, the cable entry and protection provisions will be pre-installed (most likely welded) onto the support structure at the quayside. For driven piles, where there is the likelihood of the cable entry feature being vibrated off the structure by the driving procedure, the features will be subsequently secured onto the structure by bolting.

5.5.3 Corrosion protection

Corrosion protection on the steel structure will be achieved by a combination of a protective paint coating and installation of sacrificial anodes on the subsea structure.

The anodes are standard products for offshore structures and are welded onto the steel structures. Anodes will also be implemented in the gravity based foundation design. The number and size of anodes will be determined during detailed design.

5.5.4 Scour protection materials description

Scour is the term used for the localized removal of sediment from the area around the base of support structures located in moving water. If the seabed is erodible and the flow is sufficiently high a scour hole forms around the structure.

There are two different ways to address the scour problem; either to allow for scour in the design of the foundation (thereby assuming a corresponding larger water depth at the foundation), or to install scour protection around the structure such as rock dumping or fronded mattresses.

The decision on whether to install scour protection, in the form of rock, gravel or frond mats, will be made during the design phase.

The design of scour protection with stone depends on the type of the foundation and bed condition.

5.5.4.1 Installation

If scour protection is required the protection system normally adopted consists of rock placement. The rocks will be graded and loaded onto a suitable rock-dumping vessel at a port and deployed from the host vessel either directly onto the seabed from the barge, via a bucket grab or via a telescopic tube.

5.5.4.1.1 Monopile solution

The scour protection may consist of a filter layer and an armour layer. Depending on the hydrodynamic environment the horizontal extent of the armour layer can be seen according to experiences from former projects in ranges between 10 and 15 meter having thicknesses between 1 and 1.5m. Filter layers are usually of 0.8m thickness and reach up to 2.5m further than the armour layer. Expected stone sizes range between d_{50} = 0.30m to d_{50} = 0.5m. The total diameter of the scour protection is assumed to be five times the pile diameter.

5.5.4.1.2 Gravity base solution

Scour protection may be necessary, depending on the soil properties at the installation location. The envisaged design for scour protection may include a ring of rocks around the structure.

5.5.4.1.3 Jacket solution

Scour protection may be installed as appropriate by a Dynamically Positioned Fall Pipe Vessel and/or a Side Dumping vessel. The scour protection may consist of a two layer system comprising filter stones and armour stones. Nearby cables may also be protected with filter and armour stones. The effect of scour may also be a part of the foundation design so scour protection can be neglected.

5.5.4.1.4 Bucket Foundation

Scour protection may be necessary, depending on the soil properties at the installation location. The envisaged design for scour protection may include a ring of rocks around the structure. During detailed foundation design scour protection may not be needed.

5.5.4.2 Alternative Scour Protection Methods

Alternative scour protection systems such as the use of mats may be introduced by the contractor. The mats are attached in continuous rows with a standard frond height of 1.25m. The installation of mats will require the use of standard lifting equipment.

Another alternative scour protection system is the use of sand filled geotextile bags around the foundations. This system is planned to be installed at the Amrumbank West OWF during 2013, where some 50,000t of sand filled bags will be used around the 80 foundations. Each bag will contain around 1.25t of sand. If this scour protection system is to be used at Horns Rev 3, it will add up to around 31,000 to 84,000t sand for the 50/133 turbine foundations.

6. Offshore substation platform at Horns Rev 3

6.1 Description

Energinet.dk will build and operate the transformer platform (named Horns Rev C) and the high voltage cables to the shore.

The cables (array cables) from the wind turbines will be routed through J-tubes onto the transformer platform, where they are connected to medium voltage switchgear which via three 33/220 kV transformers is connected to the 220 kV export cable.

The 220 kV export cables will run from the transformer platform to the shore and further on to the existing substation Endrup where the connection to the electrical transmission network will take place via a 400/220 kV transformer.

The location of the Horns Rev C platform is illustrated on figure 15. The coordinates for the platform in WGS84, UTM zone 32 N are: Easting (m) 414.400; Northing (m) 6.172.300 (7° 41,163' E and 55° 41,421' N).

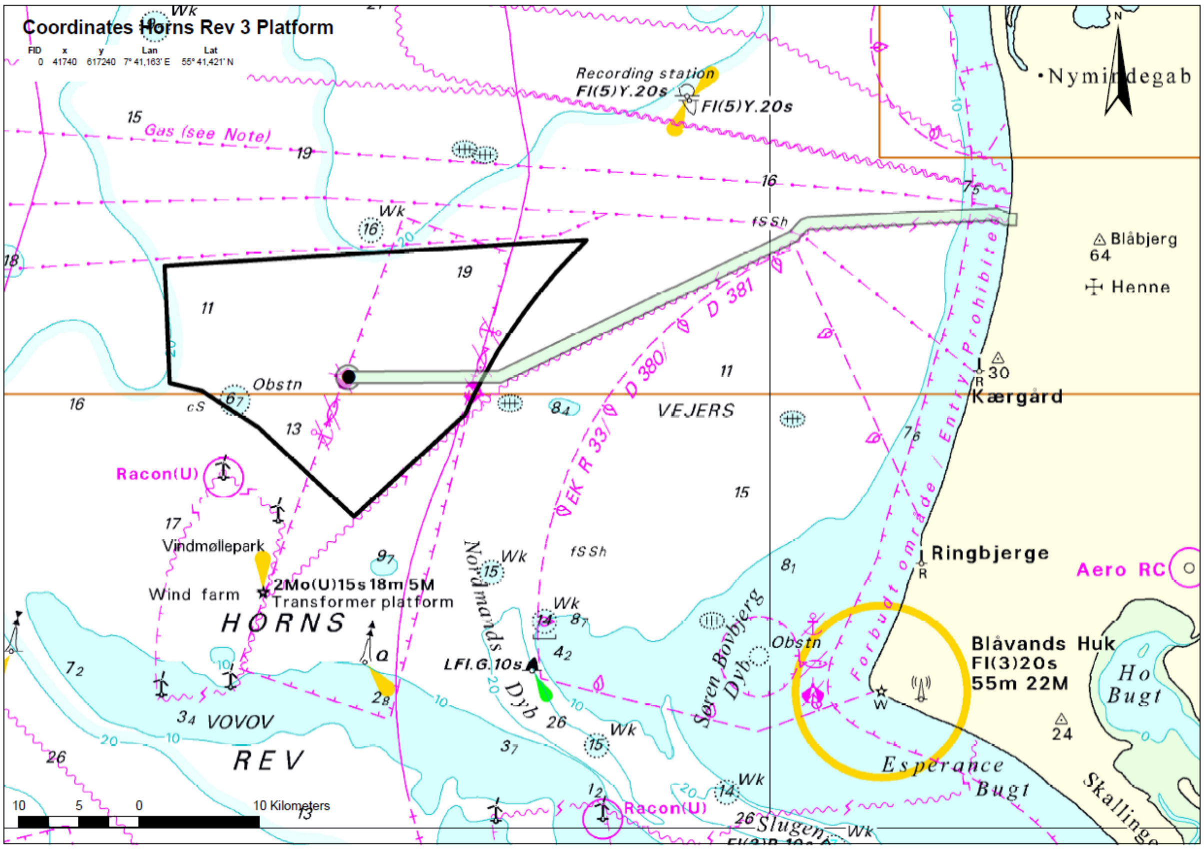


Figure 14. Location of the Horns Rec C Platform

Energinet.dk allows that the Horns Rev 3 platform is sourrounded by wind turbines if a cone around the platform and a coorridor along the export cable is kept free of turbines, in order to minimize the risk of damages to the export cable during construction activities inside the wind farm area. Around the platform a zone of 1000 m shall be kept free of obstacles. The export cable coorridor shall be 500 m on each side of the cable.

The platforms will be designed "collision friendly", meaning that minimum damages will occur on vessels in case of collision with the platform or the foundation. The detailed measures concerning collision risk will be coordinated with the Danish Maritime Authority (Søfartsstyrelsen) prior to construction.

The platform will be equipped with a heli-platform and boat landings meaning that access can be carried out by helicopter and/or boat. During the installation and commissioning phases, service vessels will approach the platform on a daily basis and can be up to 4- 8 times by helicopter during the installation and commissioning phases. When the platform is in operation a total of 18 – 20 service visits per year is expected. Though this may vary depending on the need for service and maintenance, it is expected that most frequent visits will be required during the first year of operation. Approximately 14 – 16 of these service visits will be by helicopter visits. During the summer period service vessels will primarily be used.

Because of the helicopter platform it is a requirement that the transformer platform is to be located so that an obstacle free zone of 1000 m (i.e. to any wind turbine) in an angle of 210 degrees is obtained.

The platform will be designed unmanned, but 8-10 persons will be able to accommodate in case of bad weather.

6.1.1 Dimensions

The transformer platform will be placed up to approximately 32km from the coast in a designated area on approximately 100x100m. The platform will consist of a foundation structure and a topside. The dimensions of the foundations are expected to be 24m long and 20m wide, with a height of app. 13m above sea level.

The topside of the platform will have a layout similar to the Anholt Platform with 4 decks for equipment; cable deck, main deck, mezzanine deck, roof deck and a helicopter landing platform on the top.

It is expected that the topside will have length of 40m, a width of 30m and a height of 30 – 35m above sea level. The lower deck (cable deck) is expected at a level of 13 m above sea level.

The top side will – when unmanned – have no light switched on except for the required lanterns. The light can be switched on/off from the control centre and via radio communication from crew vessels and helicopters arriving/leaving the platform.

The required lanterns will be two synchronized flashing lights installed on the top side's corners diagonally opposite each other. The lanterns light ability, visual angle and flash sequence will be in accordance with the requirements of the Danish Maritime Authority (Søfartsstyrelsen).

On the topside a crane with the lifting capacity of approximately 3.500 kg and an operation range of 15m will be installed. On all decks lay-downs areas are established for storage of goods/equipment operated by the crane.

On the cable deck the following is placed:

- Oil/water separator tank
- Oil spill tank
- Manifold distributer with valves for transformers fire fighting system
- Rescue and safety equipment (life rafts)

Cable Hang-off flanges for array cables from the wind farm and flanges for fire pumps are mounted on the cable deckle. The Hang-offs for the 220 kV transmission cable are placed approximately 1m under the cable deck due to the required bending radius of the 220 kV cable. The 220 kV and 33 kV cables will be routed on cable latters suspended from the soffit of the main deck.

The main deck will be placed 4.5m above the lower deck corresponding to approximately 17.5m above sea level. On the main deck the following is placed:

- Three 33/220 kV transformers
- 220 kV GIS switch gear
- 33kV switch gear (33 kV)
- Three 33/0.4kV auxiliary power transformers
- Back-up diesel generators
- Repair shop and storage area

The mezzanine deck is placed 5m above the main deck corresponding to approximately 22.5m above the sea level. On the mezzanine deck is the control room, auxiliary power distribution systems, batteries, battery chargers and personal room placed.

The roof deck is placed 4m above the mezzanine deck corresponding to approximately 26.5m above the sea level. On the roof deck the following is placed:

- Coolers for ventilation
- Fuel tank
- Antennas
- Metrological mast etc.
- Fire fighting equipment for the helicopter deck and diesel tank.

The fire fighting equipment for the 33/220kV transformers and auxiliary power transformers will consist of a heavy water spray system (deluge plant). The deluge plant will be supplied with seawater from two 100% submersible pumps, which are placed in a protective tube (caisson) mounted on the foundation. Fire-fighting equipment in the vital rooms will be an inert gas system. Press bottles with inert gas will be located on either the lower decks or mezzanine deck.

On the transformer station the array cables will be connected to a 33 switch gear. The voltage will be converted from 33kV to 220kV by 3 transformers. The 220 kV part of the transformer will be connected to gas-insulated switch gear which again is connected to the 220kV cable. Three minor transformers will be connected to the 33kV switch gear to ensure power supply to the transformer station. Diesel generators will be installed as back-up power suppliers.

Transformer oil of type Nytro 10 XN or Shell Diala S3 will be used for cooling the transformers down. The total transformer oil quantity will be 115- 130 m^3 will be used for cooling the transformers down. To avoid oil spillage into the sea any potential oil spill be collected by oil drip trays and led to a drainage system and passed through an oil / water separator where the oil will go to a storage tank with a capacity equal to the oil quantity of a 220/33 kV transformer (app. 40 m^3).

The oil spill will be transported to shore for disposal or re-use. The oil spill system will be designed to store all the oil from one of the largest transformers. Underneath the 20 m^3 diesel tank there will in addition also be an oil drip tray which also is connected to the drainage system so a potential spill can be collected.

6.1.2 Foundations

The foundation structure will be a jacket construction.

The foundation will have J-tubes for both array cables with diameter of 300-400 mm and export cables where the steel tubing may have a diameter up to 700-800 mm.

6.1.2.1 Jacket foundation

The construction is built up of steel tubes in the lattice structure and with varying diameters depending of their location in the lattice structure. The four legs of the jacket are connected to each other by cross bonds which provide the construction with sufficient rigidity. The jacket supported by piles in the four main legs. The piles will be pilled to an expected depth of 20-40m into the seabed.

For installation purposes the jacket will be mounted with mudmats at the bottom of each leg to ensure bottom stability during the piling installation to temporary prevent the jacket from sinking into soft soils in the sea bed. The functional life span of these mudmats is limited, as they are essentially redundant after installation of the foundation piles. The size of the mudmats depends on the weight of the jacket, the soil load bearing and the seabed conditions.

Scour protection at the foundation piles and cables may be applied depending of the soil conditions. In sandy soils scour protection is necessary for preventing the construction in from bearing failure. Scour protection consists of natural well graded stones.

Figure 15. Jacket foundation

6.1.2.1 Dimensions

The dimensions of the platform jacket foundations will be specific to the location at which the foundation is to be installed. Seabed conditions and water depth determines the dimensions of the foundation, so the specified dimensions is expected values, since the precise location of the platform is not yet known.

Jacket (expected values)	HVAC platform
Distance between corner legs at seabed	20 x 23 m
Distance between legs at platform interface	20 x 23 m
Height of jacket	depth of the sea plus 13m
Pile length	35-40 m
Diameter of pile	1700 – 1900mm
Weight of jacket	1800 - 2100t
Scour protection area	600 - 1000 m2

6.1.3 Installation of platform with jacket foundation

The installation time of the transformer platform will be around a 1 week for a jacket foundation and up to 3-4 months for a hybrid foundation.

In case of jacket foundation, all installation operations will be carried out by crane vessel with a lifting capacity of minimum 2000 tons.

Seabed preparation is not expected to be necessary before the installation of the jacket foundation. The jacket and topside will arrive to the location on a barge from the construction site. The jacket will be lifted from the barge and placed on the sea bottom. When the jacket is placed the piles will be installed by the crane vessel inside the main legs of the jacket and driven down in the seabed by a hydraulic hammer until target penetrations is achieved.

After the piles are installed the piles and jacket will be grouted together. The grouting materials will be mixed on board the crane vessel and pumped through preinstalled tubes to ensure injection directly between the jacket legs and the piles a preinstalled gasket will insure that the grouting is kept in place in the grouting zone. The piling and grouting processes are expected to take 48 to 72 hours. Methods will be adopted to ensure that the release of grout into the surrounding environment is minimized; however some grout may be released as a fugitive emission during the process. A worst-case conservative estimate of 5% (up to 5 t) is assumed.

24 hours after the grouting has finished the topside will be lifted by the crane vessel from the barge and placed onto the jacket. The lifting operation is expected to take 8-14 hours.

The installation of the topside and the jacket can also be done in two stages. First the jacket and piles are transported by barge to the location and is placed by a minor floating crane vessel and fastened to the seabed by pilling and grouting. Following a heavy floating crane vessel can transport the topside from the production site to its location offshore and place it upon the jacket.

Scour protection with stones are hereafter placed. The amount will depend on the site conditions and the jacket design.

6.1.3.1 Scour protection

Where the seabed consists of erodible sediments there will be a risk for the development of scour holes around the foundation structure(s) due to impact from waves and current. Development of scour holes can cause an impact on the foundation structures stability. To prevent serious damages the seabed can be secured and stabilized by installation of scour protection (stones, mats, sand backs etc.).

The design of the scour protection depends upon the type of foundation design and seabed conditions. For a piled foundation structure the scour protection will be installed around the piles. Often the scour protection may cover an area on the seabed to a distance of 4 - 5 times the diameter of the mono pile. The scour protection may consist of a two layer system comprising a filter layer and an armour layer. The thickness of the filter layer can be anticipated to be in the area of 700 – 900mm and the armour layer in the area of 700 – 1200mm.

A scour protection design for a single pile is shown below.

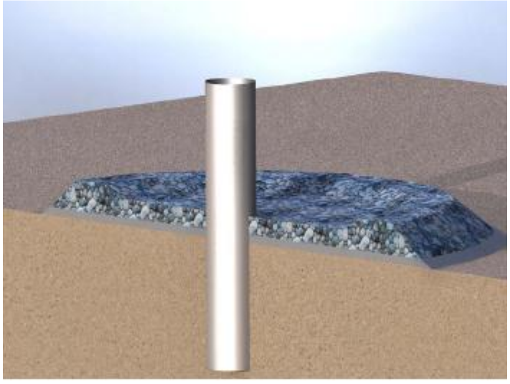


Figure 16. Example of scour protection

The gravity based foundation structure is placed in an excavation on a layer of gravels tones for primary secure a horizontal level. The required depth of the excavation is a result of the foundation design. After placing of the foundation, scour protection is installed around the foundation slab and up to sea bed level. In the design phase it will be determined if a part of the existing sea bed also needs to be protection for preventing scour.

The extend of excavation at foundation level might be out to 2m from the edge of the foundation structure and from here a natural slope up to existing sea bed level. A scour protection design for a gravity based foundation structure is shown in the figure below. The quantities to be used will be determined in the design phase. The design can also be adopted to the bucket foundation.

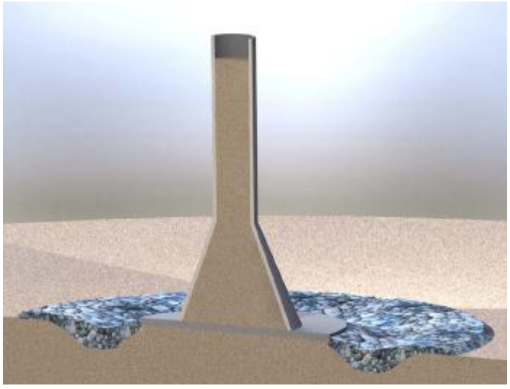


Figure 17. Example of scour protection

6.1.4 Operational airborne noise emissions

Some mechanical noise may be generated from equipment on the platform (transformers, diesel generators etc. These noise contributions are not deemed significant for the overall noise picture from the offshore wind farm.

Noise levels on land during the operation of platform will be well below allowed limits. The overall limits for operational noise on land according to the Danish legislation are:

- 44 dB for outdoor areas in relation to neighbours (up to 15m away) in the open land, and
- 39 dB for outdoors areas in residential areas and other noise sensitive areas.

In relation construction noise, the most extensive noise is normally generated from piling of off-shore foundations. A typical range that can be expected from piling at the source level, is normally within a range of LWA: 125-135 dB(A) LWA re 1pW.

7. Submarine cables

7.1 Inter-array cables

A medium voltage inter-array cable will be connected to each of the wind turbines and for each row of 8-10 wind turbines a medium voltage cable is connected to the transformer station.
The inter array cables will properly be with three core type with a common steel armour. The three cores will each consist of a conductor of Aluminium or Copper with XLPE insulation, and an outer protection consisting of polyethylene, possibly with a radial water barrier of lead underneath. The outer diameter of the cable independent of the chosen voltage will be in the area of 100 - 160 mm and with a weight around 15 - 50 kg/m (weight in air) but shall not be taken as a limitation. The will have an integrated optical fibre cable with 6-12 fibres for communication with the control system in each wind turbine (a part of the SCADA system for the wind farm).

The length of the individual cables between the wind turbines are depending of the size of the turbines or the configuration of the site. It is expected that the larger turbine / rotor diameter the larger the distance is between the wind turbines.

After pulling the cable into the J-tubes on the foundation structure of the wind turbine the cables are fixed to a hang-off flange. At the transformer station the cables are fixed to a cable deck or likely.

The inter-array cables may be protected with bending restrictors at each J-tube. Scour protection shall also be considered for protecting the cables,

7.1.1 Typical installation of Inter-Array Cables

The inter array cables are transported to the site after cable loading in the load-out harbour. The cables will be place on turn-tables on the cable vessel/barge (flat top pontoon or anchor barge). The vessel is assisted by tugs or can be self-propelling.

The installation of the array cables are divided into the following main operations:

- Installation between the turbines
- Pull in - transformer station
- Pull in – wind turbines

The CLV (Cable Laying Vessel) will approach the first turbine and secure its position with anchors.

The first pull-in of the cable will be performed directly from the turntable, over the Shute, through the bent restrictor system and up through the J-tube, and finally secured with the temporary hang off on the cable deck.

When the first pull-in is finalized the CLV will pull itself towards the second turbine using the anchors. During the move the cable will simultaneously be laid on the seabed.

On arrival at the second turbine the CLV will secure its position with anchors. The cable will be cut in the correct length and put on a quadrant. The cable will be lowered in to the water using the quadrant. The cable will be pulled through the bend restrictor system and up through the J-tube. The cable is finally secured with the temporary hang off on the cable deck.

The quadrant will be recovered and the integrated fibre in the power cable is tested (OTDR - Optical Time-Domain Reflection) to discover possible damage during the transport and installation of the cable.

Depending on the seabed condition the cable will be jetted or rock covered for protection. Jetting is done by a ROV (Remote Operate Vessel) placed over the cable. As the jetting is conducted the ROV moves forwards and the cable falls down in the bottom of the trench.

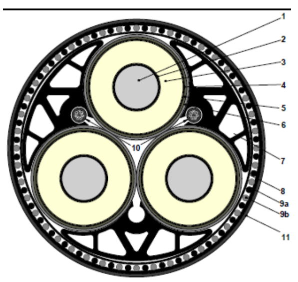
Finally, cables in the area around the turbines will be scour protected if exposed.

7.2 Export cable

A 220 kV (maximum voltage is 245 kV) transmission cable will be installed from the offshore transformer station and to the connection point on land – landfall - at Blåbjerg Substation. The length of the transmission cable will be app. 34 km.

The transmission cable will be aligned in parallel with the existing transmission cable from Horns Rev 2, with a distance of approximately 300 m. The Horns Rev 3 cable will be placed north of the Horns Rev 2 cable. Close to shore, the distance between the cables is expected to be app. 40-50 m.

The transmission cable will be a 220 kV (max. voltage 245 kV) XPLE cable with three conductors.



1 Conductor (here Aluminium)
2 Inner conductive layer
3 XLPE Insulation
4 Outer conductive layer
5 Lead sheath, for radial watertightening
6 Outer PE sheath, semiconducting
7 Filler
8 Bedding, PP yarn
9 Armouring,
10 Fibre optic cable
11 Outer sheath, Bitumen, PP yarn

Figure 18. Illustration of a typical export cable. To the left the cross section, and the cable to the right.

It is expected that the transmission cable will have conductors of Aluminium with a size of 3x2000 mm^2. As an alternative a cobber conductor can be used. The manufacturing possibilities and the actual price will decide which type to be chosen.

As the transmission cable will be designed specifically for the actual site it is most likely that a type testing of the cable including accessories will be conducted before delivery.

The transmission cable shall have 24 optical fibres integrated for communication and for temperature measurements as appropriate.

It is the intention that the transmission cable is to be installed without joints. But; the decision will be taken in the final design phase and based upon proposals from the tenders.

7.2.1 Geophysical Investigations

In 2012 a geophysical cable route survey was conducted for the offshore parts of the cable route (water depths >c. 10 m). A combined geophysical and geotechnical cable route survey is planned to be carried out during 2013 for the remaining part of the planned export cable route. The geophysical investigations for the offshore part include multibeam (MBES), side scan sonar (SSS), magnetometer (Gradiometer), high resolution sub-bottom profiler (Pinger) and multichannel reflection seismics (Sparker) where the latter is replaced by single-channel sub-bottom profiler (Sparker) for the near shore part. The widths of the geophysical surveys, that is the side scan sonar coverage, is between c. 900 m for the offshore part to c. 200-500 m for the near shore part, and consist of one centreline plus a number of wing lines spaced 100m plus appropriate MBES and SSS infill including Gradiometer lines.

The geological and geotechnical investigations along the cable route from the planned substations till near the shore will include samples of the seabed sediments (grab samples), sampling of the sub-seabed (vibrocores), and CPT tests on the same locations. The positions of the geotechnical seabed testing and sampling to a max depth of 6 meters below seabed will be based on analysis of the results of the geophysical surveys. In addition to the field work comes geological descriptions of all samples, and geotechnical laboratory analyses of selected samples, including thermal resistivity.

The overall objective of the marine cable route surveying between the planned sub-stations and the corresponding landfall is to assist in planning the exact sea cable route plus to provide input to environmental, biological, archaeological and UXO evaluations, as well as to provide information to be used for design of the cables and the installation operations (e.g. to identify the location, extent and nature of impediments to laying and burying of the cables).

The detailed mapping of the seabed and the upper layers below to c. 5-10 m depth along the cable route has been / will be carried out in order to:

- Provide accurate bathymetric charts of the cable route corridors
- Chart surfaces and objects of biological relevance (e.g. possible stone reefs, bubble reefs, areas with high coverage of macro-algae and/or eelgrass).
- Chart surfaces and objects of marine archaeological relevance (e.g. historical shipwrecks including anchors and related items, possible relics of ancient settlements).
- Chart possible man-made obstructions (e.g. un-exploded ordnance (UXO), lost fishing gear, waste of any kind left on the sea bottom, possible uncharted cables and pipelines).
- Chart natural seabed features, morphology and types (e.g. rocks, sand ripples, loose and mobile material, sandy surfaces, till surfaces, etc.).
- Locate structural complexities or geo-hazards within the shallow geological succession such as faulting, accumulations of shallow gas, buried channels, soft sediments, etc.
- Measure in situ geotechnical parameters, and to describe and analyse samples of seabed materials at the same locations as the testing is performed.
- Correlate the geotechnical and geological results with interpreted geophysical results for detailed delineation of seabed and sub-seabed sediment types and layers, with special focus on mapping differences in sediment hardness in the upper relevant layers along the routes, in order to carry out a detailed Burial Assessment Study (BAS).
- Based upon the geophysical investigations and prior to installation of cables a clearance of the seabed in the cable corridors will take place. A corridor width of 50m shall be consid-

ered. Clearance can be conducted as pre-lay grapnel runs and boulder clearance (by trawling).

7.2.2 Export cable installation

The North Sea coast is relatively rushy/choppy and some sedimentation with sand is expected. It is expected that the export cable is installed in one piece on the seabed and after trenching the cable is jetted to the depth of one meter. For hindering the cable getting exposed the cable is jetted to the depth of maximum 3-5 meters in the near shore zone. The exact depth will be based on the actual conditions. The jetting will be conducted in one operation and independent of the operation were the cable is placed upon the seabed.

It is not expected that jetting will be a problem as the seabed consists of sand.

It is expected that there can be limited areas where it may be necessary to pre-excavate a cable trench prior to jetting the cable down due to firm soil conditions. The depth of the trench will be approximately 0.7 – 1.5m and the width 1 – 2m. The excavation may be conducted by and excavator placed upon a vessel or a barge or by cutting or by ploughing. The soil can be deposited near the trench.

After trenching the export cable will be installed by a cable laying vessel or barge, self-propelled or operated by anchors or tugs. It may then be necessary to clear up the trench just before the cable is installed, still, after installation the cable will often have to be jetted down in the sediments, that has been deposited in a period after trenching or clearing. The trench will hereafter be covered with the trenched material, thus some of the soil may have vanished.

During jetting very fine grained seabed material will tend to get washed away and have an impact on the degree of volume back filling. A re-filling may be applied as appropriate with natural seabed friction materials. Basically the jetting will be conducted in one continuing process; thus there can be areas where the jetting may be conducted more than one time due to the soil conditions. On Horns Rev it is estimated that the jetting will last for approximately 3 months excluding weather stand-by.

It shall be noted that the jetting also can be conducted by hand/diver in case of special conditions (environmental etc.). The depth of the jetting will may here be lowered to a range of 30 – 50cm.

8. Offshore construction

The construction and installation of the OWF components is described in the chapters above, reference is made to these paragraphs on detail in the installation methodology of the power plants. The Chapter 4 contains information on the installation of the turbines and blades, including the individual selected turbine types. Chapter 5 contains information on the installation of the foundations for the turbines, including the relevant foundation designs. Chapter 6 includes information on the transformer platform(s) construction, and finally Chapter 7 details the installation of inter-array and export cables.

In the paragraphs below additional general information on the offshore construction works are provided.

8.1 Access to site and safety zones

The construction of the proposed OWF is scheduled to take place throughout the year. Construction activity is expected for 24 hours per day until construction is complete.

A safety zone of 500m is expected to be established around the main construction sites in order to protect the project, personnel, and the safety of third parties during the construction and commissioning phases of the wind farm. The safety zones may include the entire construction area or a rolling safety zone may be selected. The exact safety zone will be agreed with the Danish Maritime Authority (Søfartsstyrelsen) prior to construction.

It is intended that third parties will be excluded from any safety zone during the construction period, and that the zone(s) will be marked in accordance with the requirements from the Danish Maritime Authority (Søfartsstyrelsen). The temporary markings will include yellow light buoys with an effective reach of at least 2 nautical miles. All buoys will further be equipped with yellow cross sign, radar reflector and reflector strips. Regular Notice to Mariners will be issued as construction progresses.

The same safety procedures will apply for laying of the export cables.

8.2 Construction vessels

The types of construction vessels will be selected by the nominated contractor, however an overview of the main types of vessels for each task is presented below:

Task	**Likely Type of Construction Vessel**
Pile Installation	Jack-up rig, floating crane and barge
Gravity Base Installation	Floating crane and barge, excavators
Suction Bucket	Jack-up rig
Wind Turbines	Jack-up rig
Scour Protection	Construction barge or dedicated barge
Cable Installation	Dedicated cable lay vessel
Offshore Transformer Station	Floating crane and barge
Crew Transfer	Workboat
Assisting vessels	Tugs, MultiCats etc.

To optimize the construction programme, it is likely that installation of wind turbines, foundations and cables will be undertaken on the site at the same time, although not necessarily within the same part of the site. Therefore it is likely that around 20-30 vessels (including support craft) may be on site at any time during the construction phase. Work will be carried out 24 hours a day when the conditions are optimal, and can be carried out throughout the year.

8.2.1 Helicopter

Helicopters will also to a certain extend be used in the construction works. Helicopters may be used during the installation of the substation(s) and may also be used in relation to installation of the turbine towers. In addition helicopters may be used to transport personnel if required.

During the construction and commissioning of the substation(s) helicopters may work up to 2-4 times per day. For the installation of turbine towers and transport of personnel this transport may add up to a mean of 1-2 travel times per day during the construction and commissioning period.

8.3 Lighting and markings

The status of the construction area including markings and lighting will be disseminated through the Notice to Mariners procedure.

The construction area and incomplete structures will be lit and marked in accordance with the protocol recommended by the Danish Maritime Authority (Søfartsstyrelsen) and the DanishTransport Authority (Trafikstyrelsen).

8.4 Construction programme

Energinet.dk is responsible for construction of the platform and the subsea cable. The concessionaire for the wind farm has not yet been identified, so the detailed plan for construction in the wind farm area (foundations, WTG and inter-array cabling) is not present at this time.

An indicative construction program is presented below. Activities with the responsibility within Energinet.dk are marked in blue, whereas activities where the responsibility is within the Danish Energy Agency and/or the concessionaire are marked in red.

Time Schedule	2013				2014				2015				2016				2017				2018				2019			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Investiga-tions/surveys for EIA	■	■	■	■	■																							
Internal hearing of authorities						■																						
EIA in public hearing						■	■																					
Concession winner appointed										■																		
Permission for off-shore work								■																				
Installation of WTG foundations															■	■	■	■	■	■	■	■						
Installation of 220 kV export cable										■	■	■	■	■	■													
Installation of trans-former station														■	■	■												
Energizing of trans-former station																■												
Installation of WTG																	■	■	■	■	■	■	■	■	■	■	■	■
Energizing of WTG (finalized by January 2020)																					■	■	■	■	■	■	■	■

8.5 Emissions and discharges (environmental)

During construction (and decommissioning) some emissions to the atmosphere will be emitted from the marine vessels and helicopters. These emissions are not considered to be significant.

In addition, there is a minor risk of accidental discharges or spill from the turbines or marine vessels associated with construction and decommissioning.

There are not anticipated solid discharges into the marine environment during the construction phase. All waste generated during construction will be collected and disposed of by licensed waste management contractors to licensed waste management facilities onshore.

Daily work will be conducted on the platform during construction. This generates waste water and toilet waste. Waste water from kitchen and bath will be discharged through a drain approximately 4-5 meters below surface. Toilet waste will before discharge pass through a grinder.

A comprehensive Environmental Management System is expected to be implemented prior to construction in consultation with statutory authorities, with a suite of complementary management plans corresponding to different aspects related to the construction activities. The Environmental Management System would form a component part of the construction contract for the development.

9. Wind farm operations and maintenance

Operation and maintenance of the offshore wind farm will continue 24 hours per day, 365 days per year, and access to site will be required at any time. The harbour to be used during construction and maintenance has not yet been decided.

9.1 Access to site and safety zones

Safety zones can be applied for the wind farm area or parts hereof. The specific safety zones will be determined by the Danish Maritime Authority (Søfartsstyrelsen).

A 200m safety zone around all cables will be expected. The safety zone of 200m on either site of the cables will normally include restriction for anchoring and e.g. bottom trawling that may be intrusive into the seabed. The project needs to comply with the law act nr. 939 from 27/11/1992 on offshore cable laying, specifying these protection zones and agree with the Danish Maritime Authority (Søfartsstyrelsen) on the extent of potential safety zones.

For all turbines and for the offshore transformer station a prohibited entry zone of minimum 50m radius of the foundations is foreseen for non-project vessels.
On Nysted and Rødsand 2 "restriction in practices" zones have been applied for the entire parks for trawling, aggregate extraction and dredging or anchoring (for non-project vessels). For the actual project the decision will be taken by the Danish Maritime Authority (Søfartstyrelsen).

9.2 Wind farm control

The wind turbines are configured so that they operate with a minimum of supervisory input. The turbines are monitored and controlled by micro-processors installed within the turbine tower. Should a turbine develop a fault, the status of the fault is diagnosed, and if necessary the turbine is automatically shut down for safety purposes.

All information relating to on-site conditions (wind speed, direction, wave height, etc.), turbine status and generated output is held within a central like Supervisory Control And Data Acquisition (SCADA) system linked to each individual turbine micro-processor. The supervision system is controlled from an operations base ashore, and allows for the remote control and shutting down of any individual turbine (or a number of turbines) should circumstances dictate.

9.3 Wind farm inspection and maintenance

The wind farm will be serviced and maintained throughout the life of the wind farm from a local port in the vicinity to the OWF. Following the commissioning period of the wind farm, it is expected that the servic-ing interval for the turbines will be approximately 6 months.

Maintenance of the wind farm is normally separated into three different categories:

1. Periodic overhauls
2. Scheduled maintenance
3. Un-scheduled maintenance

9.3.1 Periodic overhauls

Periodic overhauls will be carried out in accordance with the turbine manufacturer's warranty. These overhaul campaigns will be planned for execution in the periods of the year with the best access conditions, preferably in summer.

The periodic overhauls will be carried out according to the supplier's specifications. The work scope typically includes function and safety tests, visual inspections, analysis of oil samples, change of filters, lubrication, check of bolts, replacement of brake pads, oil change on gear box or hydraulic systems.

9.3.2 Scheduled maintenance

Scheduled maintenance applies primarily to inspections and work on wear parts susceptible to failure or deterioration in between the periodic overhauls. A scheduled inspection of each turbine is likely to take place every six months. The tasks will typically be inspection on faults and minor fault rectification.

Scheduled maintenance will be performed using small personnel craft operated from the local harbour.

9.3.3 Unscheduled maintenance

Unscheduled maintenance applies to any sudden defects. The scope of such maintenance would range from small defects to complete failure or breakdown of main components. Such maintenance would require the intervention of construction vessels similar to those involved in the construction of the wind farm.

Inspections of support structures and subsea cables will be performed on a regular basis as will ad-hoc visits for surveillance purposes.

9.4 Helicopters during operation

Helicopters may also be used in combination with the vessels, especially during unscheduled maintenance of the turbines or the substation. It is expected that the turbine towers will be constructed with a landing platform for personnel.

9.5 Surveys during operation of the wind farm

Regular surveys to inspect the foundations, scour protection, inter-array and export cables will also be required during the operation of the wind farm. The requirements to the survey program cannot be foreseen at this stage as it will depend on the installed foundation types and the local conditions. Though it may be required to follow up with some targeted geophysical surveys along the cable routes, this will be expected shortly after commissioning of the wind farm to monitor the conditions on the laid cables.

Around the scour protection and foundations targeted video drop down or diver surveys may be expected. Some maintenance work may in addition be required during the lifetime of the wind farm as needed.

In addition, a few environmental monitoring surveys post construction and during the first year/few years of operation can in some cases be required by the authorities. This may be to follow up on potential environmental concerns in the wind farm area or along the cable routes.

9.6 Health and safety

During the offshore works Operation and Maintenance standards will be required. It will be required that all offshore works comply with a high degree of HSSE (Health, Safety, Security and Environmental) standards. These standards will comply with the national legislation and with the standards applied by the developed for the wind farm site.

9.7 Emissions and discharge (environmental)

During operation only minor emissions can be expected to be emitted from the maintenance operations. Maintenance may be carried out by vessels or in some cases when required with helicopters.

No solid discharges are anticipated into the marine environment during normal operation of the turbine array. All waste generated during operation, for example associated with maintenance, will be collected and disposed of by licensed waste management contractors to licensed waste management facilities onshore.

There are no anticipated direct aqueous discharges to the marine environment during normal operation of the turbine array.

10. Wind Farm Decommissioning

The lifetime of the wind farm is expected to be around 25 years. It is expected that two years in advance of the expiry of the production time the developer shall submit a decommissioning plan. A part of this decommissioning program an EIA will be required to be completed. The method for decommissioning will be to follow best practice and the legislation at that time.

It is unknown at this stage how the wind farm may be decommissioned; this will have to be agreed with the regulators before the work is being initiated.

It may be an option that the wind farm can be repowered, that is turbines and potential foundations may be exchanged with larger and more efficient turbines at that time.

The following sections provide a description of the current intentions with respect to decommissioning, with the intention to review the statements over time as industry practices and regulatory controls evolve.

10.1 Extent of decommissioning

The objectives of the decommissioning process are to minimize both the short and long term effects on the environment whilst making the sea safe for others to navigate. Based on current available technology, it is anticipated that the following level of decommissioning on the wind farm will be performed:

- Wind turbines – to be removed completely.
- Structures and substructures – to be removed to the natural seabed level or to be partly left in situ.
- Infield cables – to be either removed (in the event they have become unburied) or to be left safely in-situ, buried to below the natural seabed level or protected by rock-dump.
- Export cables – to be left safely in-situ, buried to below the natural seabed level or protected by rock-dump.
- Cable shore landing – to be either safely removed or left in-situ, with particular respect to the natural sediment movement along the shore.
- Scour protection – to be left in-situ.

10.2 Decommissioning of wind turbines

The wind turbines would be dismantled using similar craft and methods as deployed during the construction phase. However the operations would be carried out in reverse order.

10.3 Decommissioning of offshore sub-station platform

The decommissioning of the offshore sub-station platforms is anticipated in the following sequence:

1. Disconnection of the wind turbines and associated hardware.
2. Removal of all fluids, substances on the platform, including oils, lubricants and gasses.
3. Removal of the sub-station from the foundation using a single lift and featuring a similar vessel to that used for construction.

The foundation would be decommissioned according to the agreed method for that option.

10.4 Decommissioning of buried cables

Should cables be required to be decommissioned, the cable recovery process would essentially be the reverse of a cable laying operation, with the cable handling equipment working in reverse gear and the cable either being coiled into tanks on the vessel or guillotined into sections approximately 1.5m long immediately as it is recovered. These short sections of cable would be then stored in ships or open containers on board the vessel for later disposal through appropriate routes for material reuse, recycle or disposal.

10.5 Decommissioning of foundations

Foundations may potentially be reused for repowering of the wind farm. More likely the foundations may be decommissioned through partial of complete removal. For monopoles it is unlikely that the foundations will be removed completely, it may be that the monopole may be removed to the level of the natural seabed. For gravity foundations it may be that these can be left in situ. At the stage of decommissioning natural reef structures may have evolved around the structures and the environmental impact of removal therefore may be larger than leaving the foundations in place. The reuse or removal of foundations will be agreed with the regulators at the time of decommissioning. The suction bucket can fully be removed by adding pressure inside the bucket.

10.6 Decommissioning of scour protection

The scour protection will most likely be left in situ and not be removed as part of the decommissioning. It will not be possible to remove all scour protection as major parts of the material are expected to have sunk into the seabed. Also it is expected that the scour protection will function as a natural stony reef. The removal of this stony reef is expected to be more damaging to the environment in the area than if left in situ. It is therefore considered most likely that the regulators at the time of decommissioning will require the scour protection left in situ.

10.7 Disposal / re-use of components

It is likely that legislation and custom will dictate the practices adopted for the decommissioning of the proposed OWF. The decommissioned materials could have the following disposal methods:

- All steel components sold for scrap to be recycled.
- The turbine blades (fibre-glass) to be disposed of in accordance with the relevant regulations in force at the time of decommissioning. One potential disposal method identified is to break down the fibre-glass into a pulp for use as cavity insulation in buildings.
- Reuse of concrete from foundations.
- All heavy metals and toxic components (likely to be small in total) disposed of in accordance with relevant regulations.

10.8 Access to site

It is envisaged that the requirements for access to site during the decommissioning phase will be similar to those required during the construction phase.

10.9 Decommissioning program

A decommissioning program will be established by the nominated contractor as part of the concession.

10.10 On-going monitoring

The scope and duration of the monitoring requirements post decommissioning will be agreed between the operator of the wind farm and the owner in consultation with other Government Departments and details will be included in the decommissioning program. The operator will implement the arrangements for monitoring, maintenance and management of the decommissioned site and any remains of installations or cables that have been left in-situ in accordance with the agreement.