Kriegers Flak Offshore Wind Farm

Technical Project Description for the large-scale offshore wind farm (600 MW) at Kriegers Flak

October 2015

1. Introduction

This document outlines the proposed technical aspects encompassed in the offshore-related development of the Kriegers Flak Offshore Wind Farm (OWF). This includes: wind turbines and foundations, internal site array cables and offshore sub-station platforms. Each technical component will be dealt with, with respect to construction (i.e. installation), operation, maintenance and decommissioning.

Substations and export cable to the shore are owned and installed by Energinet.dk. The current document only contains description of the substations. The wind farm developer/owner has not yet been assigned by the Danish Energy Agency (DEA). Therefore, parts of the technical solution within the wind farm are not finally developed and decided. However, to assess environmental aspects in the environmental impact assessment (EIA) and statement (EIS), 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 in the current document. Nevertheless, changes and substitutions of technicalities might occur prior to construction and the EIA will assess impacts from a worst-case scenario.

The document is not a design description for the final wind farm at Kriegers Flak. It is rather a realistic and best guess on how a future concessionaire will design the wind farm. The 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 sometime also from the framework. Whether deviations from the framework can be contained within the EIA permit/authorisation for establishment must be determined individually by the authorities on a case by case basis.

2. Kriegers Flak

The planned Kriegers Flak OWF (600 MW) is located app. 15 km east of the Danish coast in the southern part of the Baltic Sea close to the boundaries of the exclusive offshore economic zones (EEZ) of Sweden, Germany and Denmark (see appendix 1). At the neighboring German territory an OWF Baltic II is currently under construction, while pre-investigations for an OWF have already been carried out at Swedish territory, however further construction is currently on standby.

The area delineated as pre-investigation area covers an area of app. 250 km^2, and encircles the bathymetric high called "Kriegers Flak" which is a shallow region of approximately 150 km^2. Central in the pre-investigation there is a restriction area. Part of this where area (approx. 28 km^2) is reserved for sand extraction with no permission for technical OWF components to be installed. The remainder of the restriction area is reserved for installations and submarine cables. Hence, wind turbines will be separated in an Eastern (110 km^2) and Western (69 km^2) wind farm, allowing 200 MW on the western part, and 400 MW on the eastern part. According to the permission given by the DEA, a 200 MW wind farm must use up to 44 km^2. Along the EEZ border between Sweden and Denmark, and Germany and Denmark a safety zone of 500 meters will be established between the wind turbines on the Danish part of Kriegers Flak and the EEZ border.

To examine and document the general seabed and sub-seabed conditions at the Kriegers Flak 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 (Unexploded Ordnance) risk, have been used to carry out assessments of the environmental impacts on the seabed for the EIA as well as they can be used by the wind farm developer and other parties to evaluate the soil conditions to estimate limitations and opportunities related to the foundation of offshore wind turbines, substation and other installations.

Furthermore, a comprehensive site specific metocean analysis has been conducted. This study and the background data are available at Energinet.dk's webpage: [www.energinet.dk.](http://www.energinet.dk)

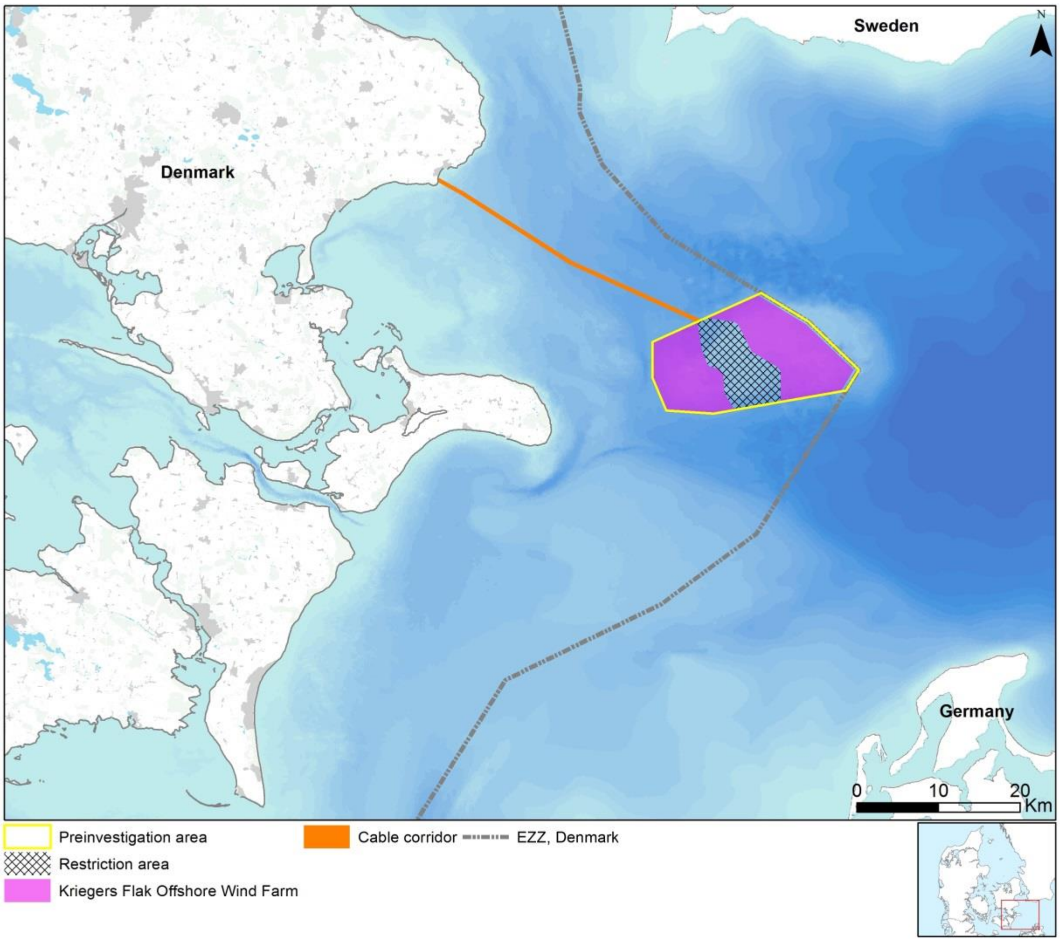


Figure 1: *The planned location of Kriegers Flak Offshore Wind Farm (600 MW) in the Danish territory. Approximately in the middle of the pre-investigation area there is a restriction area. Part of this area (approx. 28 km^2) is reserved for sand extraction with no permission for technical OWF components to be installed. The remainder of the restriction area is reserved for technical installations and submarine cables.*

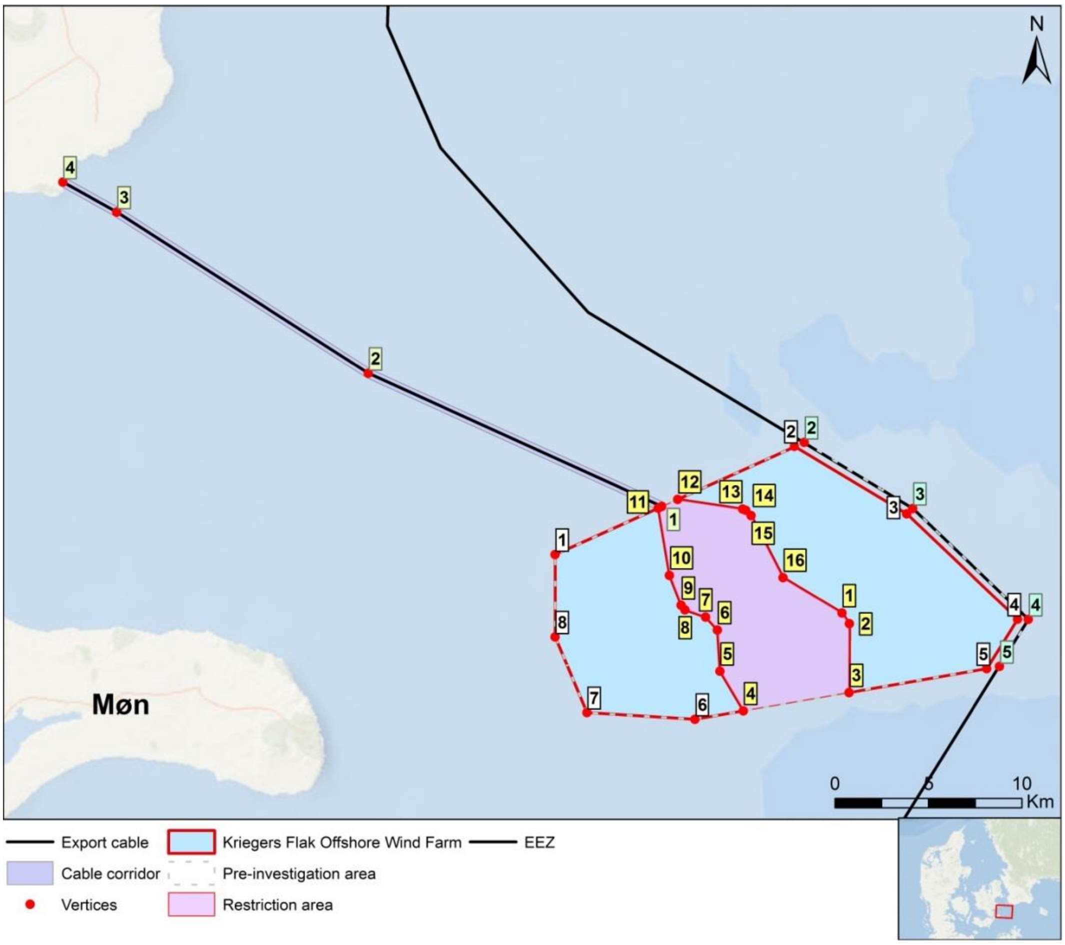


Figure 2: *The planned location of Kriegers Flak Offshore Wind Farm (600 MW) in the Danish territory. The numbers denote the coordinates of the polygons and vertices along the export cable corridor in Appendix 1. The export cable shown on the figure indicates two export cables. The final positions of the cables within the cable corridor have not yet been determined.*

2.1 Physical Characteristics

The water depth in the central part of the Kriegers Flak is generally between 16 and 20 m, while it is between 20 and 25 m along the periphery of the bank and more than 25-30 m deep waters along the northern, southern and western edges of the investigation area (Figure 3).

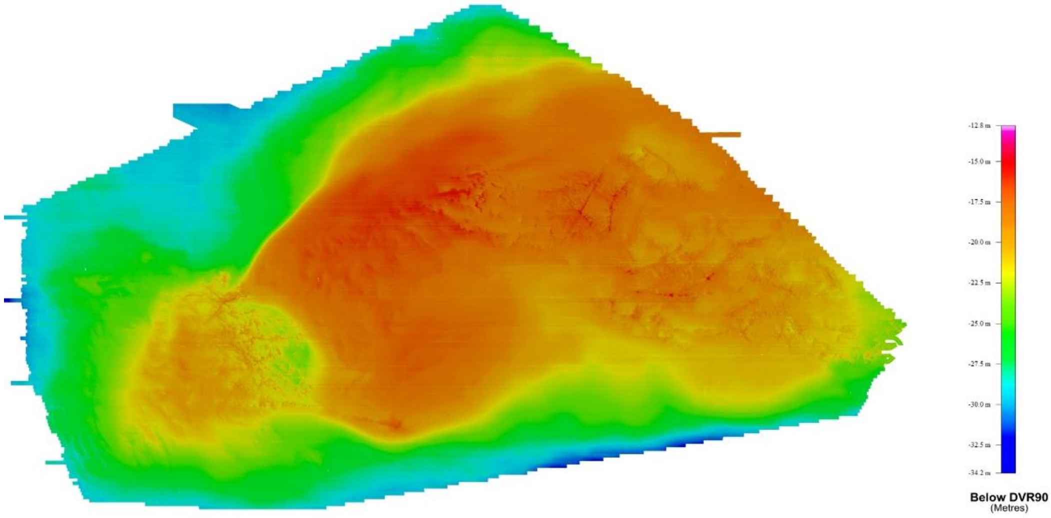


Figure 3: Overview of the Kriegers Flak area showing water depth variations by graded colour (based on the geophysical survey).

2.2 Met-ocean and geological characteristics

A comprehensive site-specific met-ocean analysis has been conducted for the Kriegers Flak project, including data covering salinity, density, water temperature, currents, waves, tides and wind. Furthermore geological and sedimentological settings of the survey area have been analysed.

Survey reports and data of the applied studies have been published by Energinet.dk: http://www.energinet.dk/EN/ANLAEG-OG-PROJEKTER/Anlaegsprojekter-el/Kriegers-Flak-havmoellepark/Sider/data.aspx (Energinet.dk, 2014).

3. Wind Farm Layout

As input for the Environmental Impact Assessment (EIA), possible and likely layouts of the offshore wind farm at Kriegers Flak have been assessed and realistic scenarios are used in the EIA. It must be emphasized that the layouts may be altered by the signed developer. Possible park layouts with a 3.0 MW wind turbine (Figure 4) and a 10.0 MW wind turbine (Figure 5) can be seen below.

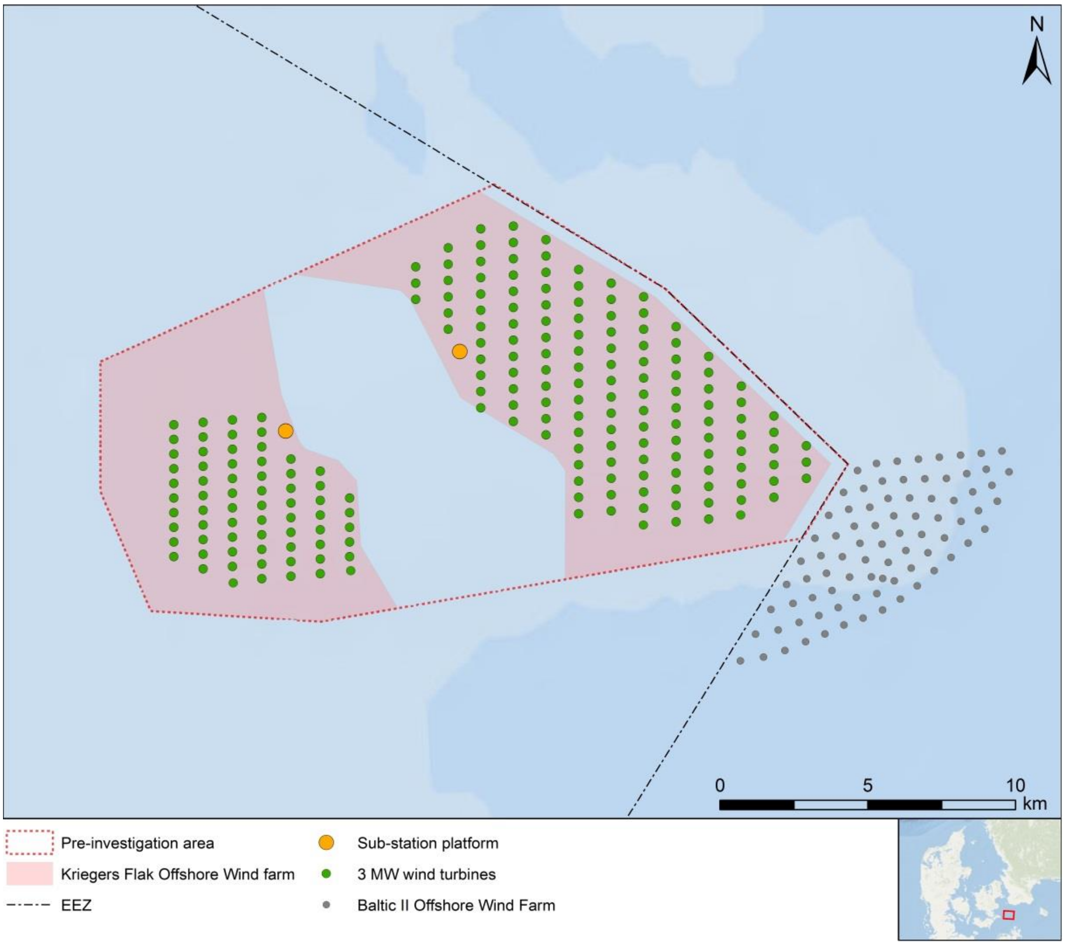


Figure 4: Suggested layout for 3.0 MW turbines at the eastern and western part of the planned wind farm (delineated by red polygons) at Kriegers Flak at Danish territory. The two orange symbols indicate the positions of the offshore sub-station platforms. The broken line delineates the pre-investigation area. In the south-eastern part of the map turbines within the German Baltic II OWF are shown.

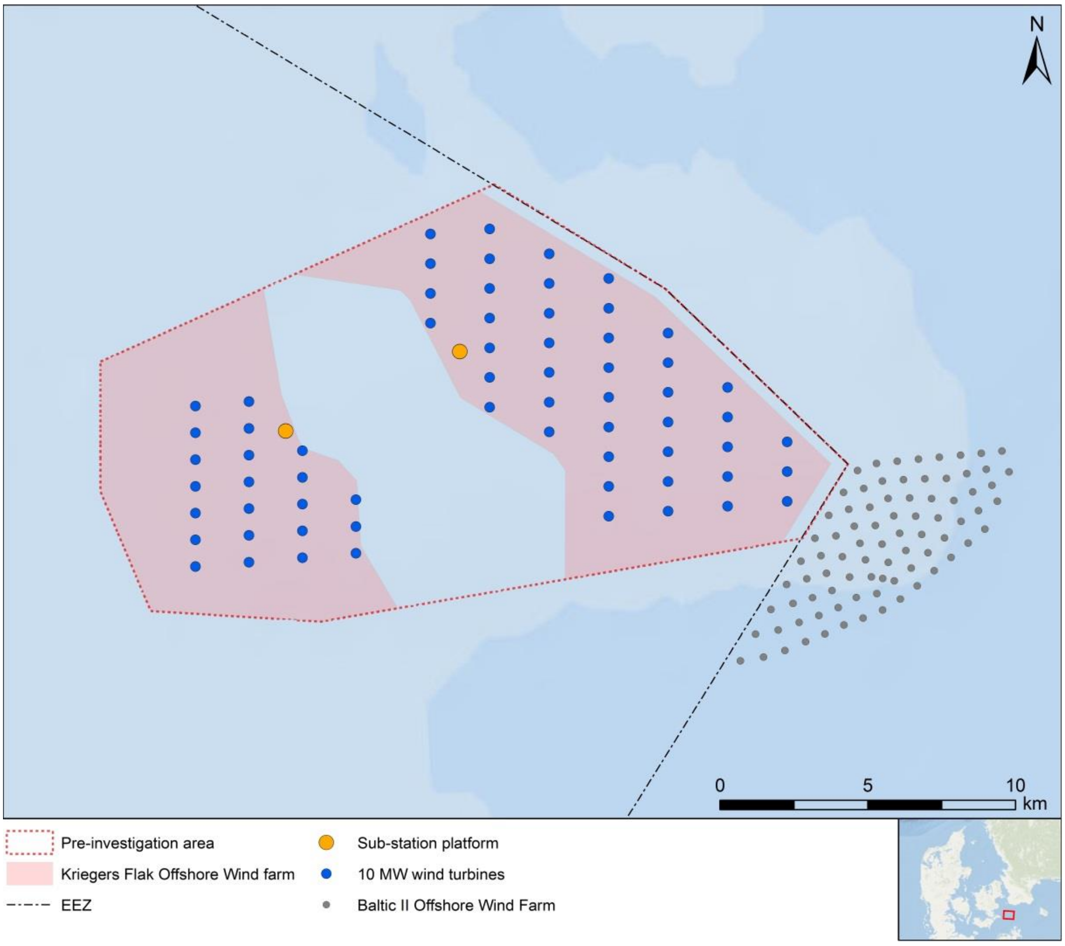


Figure 5: *Suggested layout for 10.0 MW turbines at the eastern and western part of the planned wind farm (delineated by red polygons) at Kriegers Flak at Danish territory. The two orange symbols indicate the positions of the offshore sub-station platforms. The broken line delineates the pre-investigation area. In the south-eastern part of the map turbines within the German Baltic II OWF are shown.*

4. Wind turbines at Kriegers Flak

4.1 Description

The installed capacity of the wind farm is limited to 600MW. The range for turbines at Kriegers Flak is 3.0 to 10.0 MW. Based on the span of individual turbine capacity (from 3.0 MW to 10.0 MW) the wind farm will feature from 60 (+4 additional turbines) to 200 (+3 additional turbines) turbines. 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 exact design and appearance of the wind turbine will depend on the manufactures. 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 Kriegers Flak, 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.

4.2 Dimensions

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

Outline properties of present day turbines are shown in Table 1.

Turbine Capacity	Rotor diameter	Total height	Hub height above MSL*	Swept area
3.0 MW	112 m	137 m	81 m	9,852 m²
3.6 MW	120 m	141.6 m	81.6 m	11,500 m²
4.0 MW	130 m	155 m	90 m	13,300 m²
6.0 MW	154 m	179 m	102 m	18,600 m²
8.0 MW	164 m	189 m	107 m	21,124 m²
10.0 MW	190 m	220 m	125 m	28,400 m²

*Table 1: Typical dimensions for offshore wind turbines between 3.0 MW and 10.0 MW. *MSL Mean Sea Level.*

The air gap between Mean Sea Level (MSL) and wing tip will be determined based on the actual project. However, a minimum of approximately 20 metres above HAT (Highest Astronomical Tide) is expected as used for most Danish offshore wind farms. The Danish Maritime Authority (Søfartsstyrelsen) will need to approve the detailed design and distance between the HAT and lower wing tip before construction of the Kriegers Flak OWF.

4.3 Materials

In Table 2 and Table 3 the raw materials including weight are specified for the 3.0 MW and the 8.0 MW turbines. The 10 MW turbines have never been produced and therefore there are no available data of use of raw material including weight for the 10.0 MW turbine. The GRP stands for Glass Reinforced Plastic.

3.0 MW	Material type	Weight
Nacelle	GRP	125.4 t
Hub	Cast iron	68.5 t (incl. blades)
Blade	GRP	-
Tower	Steel	150 t (61.8 m)

Table 2: Type and weight of materials for the 3.0 MW turbines.

8.0 MW	Material type	Weight
Nacelle	Steel/GRP	390 t +/- 10 % (incl. hub)
Hub	Cast iron	-
Blade	GRP	33 t per blade
Tower	Steel	340 t (84 m)

Table 3: Type and weight of materials for the 8.0 MW turbines.

4.4 Oils and fluids

Each wind turbine contains lubricants and hydraulic oils, and typical quantities for each turbine type are presented in Table 4. The wind turbine designs provide security for capturing a potential lubricant spill from a component in the wind turbine.

Oils and fluids	Quantity				
	3.0 MW	4.0 MW	6.0 MW	8.0 MW	10.0 MW*4
Gearbox Oil (mineral oil)	1,190 l*1	<600 l	NA*2	1,600 l*1	1,900 l
Hydraulic oil	250 l	<300 l	<300 l	700-800 l	1,200 l
Yaw/Pitch Motor Oil	Approx. 96 l	< 80 l	<100 l	Approx. 95 l	100 l
Transformer Oil	NA*3	< 1,450 l	<1,850 l	Approx. 4,000 l	6,000 l

Table 4: Typical quantities of oils and fluids for different types of turbines (3.0 – 10.0 MW).

*1Full synthetic oil
*2No gearbox.
*3NA because dry type trafo.
*4 Estimates of volumes since turbine specific data could not be acquired.

4.5 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 will be painted yellow, as in the case for Anholt OWF. The yellow colour will be initiated around 6m above high tide. The identification number of the turbine will be painted within the yellow colour band. The letters/numbers will be painted black and will be around 1m high and around 10cm wide.

The size of the yellow band and the identification number must be agreed with the Danish Maritime Authority and is typically 10-15 meters high.

4.6 Lighting and marking

The wind turbines will exhibit distinguishing markings visible for vessels and aircrafts in accordance with requirements by the Danish Maritime Authority and the Danish Transport Authority. Below is described the expected requirements for lights and markings.

Kriegers Flak will be marked on the appropriate aeronautical charts as requires 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.

Lightning 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.

Final requirements in relation to lightning will be determined by the Danish Maritime Authority and the Danish Transport Authority when the layout and the height of the turbines are known.

4.6.1 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 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 corresponding to approximately 75 candela. 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 Baltic II OWF. Indirect light should illuminate the part of the yellow painted section with the turbine identification number.

The marking of Kriegers Flak OWF must be expected to be synchronized with the Baltic II OWF.

Demand by the Danish Maritime Authority for Racon on the western side of Kriegers Flak OWF can be expected, depending on the exact location of the wind turbines.

The marking with light on the offshore sub-station platforms 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 offshore sub-station 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 off-shore sub-station 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. If cranes of 100-150 m height will be used during construction, these shall be marked with fixed red light of low intensity (10 candela as a minimum).

4.6.2 Aviation markings

Aviation markings will be agreed with the Danish Transport Authority. Regulations (Trafikstyrelsen, 2014a) and guidelines on aviation markings of wind turbines (Trafikstyrelsen, 2014b) provide details on the requirements to aviation markings. The requirements for aviation markings will differ between types of turbines due to differences in height.

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 on-going consultation with appropriate stakeholders as the design phase of Kriegers Flak 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.

For objects of 150 metres or more surveillance of the aviation marking and an associated emergency power system will be required.

4.7 Installation of wind turbines

4.7.1 Jack-up barges

Although offshore contractors use varying construction techniques, the installation of the wind turbines will typically require one or more jack-up barges. These vessels will be placed on the seabed and create a stable lifting platform by lifting themselves out of the water. The total area of each vessel's spud cans is approximately 350 m^2. The legs will penetrate 2 to 15 m into the seabed depending on seabed properties. These foot prints will be left to in-fill naturally.

4.7.2 Transportation of wind turbine components

The wind turbine components will either be stored at an adjacent port and transported to site by support barge or by the installation vessel itself, or transported directly from the manufacturer to the wind farm site by a barge or by the installation vessel. The wind turbines 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 due to unstable weather conditions. Following installation and grid connection, the wind turbines will be commissioned and the turbines will be available to generate electricity.

5. Foundations

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

5.1 Driven steel monopile

5.1.1 Description

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.

5.1.2 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. Grout (here: Ducorit®) consists of a binder which is mixed with quartz sand or bauxite in order to obtain the strength and stiffness of the product. Grout is similar to cement and according to CLP cement is classified as a danger substances to humans (H315/318/335). Cement is however not expected to cause environmental impacts. The grout which is expected to be used for turbines at Kriegers Flak OWF will 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. Grout is not considered as an environmental problem. 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 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 design for the proposed Kriegers Flak OWF, are presented in Table 5.

MONOPILE	**3.0 MW**	**3.6 MW**	**4.0 MW**	**8.0 MW**	**10.0 MW****
Outer Diameter at seabed level	4.5-6.0 m	4.5-6.0 m	5.0-7.0 m	6.0-8.0 m	7.0-10.0 m
Pile Length	50-60 m	50-60 m	50-60 m	50-70 m	60-80 m
Weight	300-700 t	300-800 t	400-900 t	700-1,000 t	900-1,400 t
Ground Penetration (below mud line)	25-32 m	25-32 m	26-33 m	28-35 m	30-40 m
Total pile weight (203/170/154/79/64 monopiles)	60,900-142,100 t	51,000-136,000 t	61,600-138,600 t	55,300-79,000 t	57,600-89,600 t
TRANSITION PIECE					
Length	10–20 m	10-20 m	10–20 m	15-25 m	15-25 m
Outer Diameter (based on a conical shaped monopile)	3.5-5.0 m	3.5-5.0 m	4.0-5.5 m	5.0-6.5 m	6.0-8.0 m
Weight	100-150 t	100-150 t	120-180 t	150-300 t	250-400 t
Volume of Grout per unit	15-35 m^3	15-35 m^3	20-40 m^3	25-60 m^3	30-70 m^3
Total weight (203/170/154/79/64 transition pieces)	20,300-30,450 t	17,000-25,500 t	18,480-27,720 t	11,850-23,700 t	16,000-25,600 t
Scour Protection					
Volume per foundation	2,100 m^3	2,100 m^3	2,500 m^3	3,000 m^3	3,800 m^3
Foot print area (per foundation)	1,500 m^2	1,500 m^2	1,575 m^2	1,650 m^2	2,000 m^2
Total Scour (203/170/154/79/64 mono piles)	426,300 m^3	357,000 m^3	385,000 m^3	237,000 m^3	243,200 m^3
Total foot print scour area (203/170/154/79/64 monopiles)	304,500 m^2	255,000 m^2	242,550 m^2	130,350 m^2	128,000 m^2

Table 5: Typical dimensions of monopiles and transitions pieces.

**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 6) .*
***Very rough estimate of quantities.*

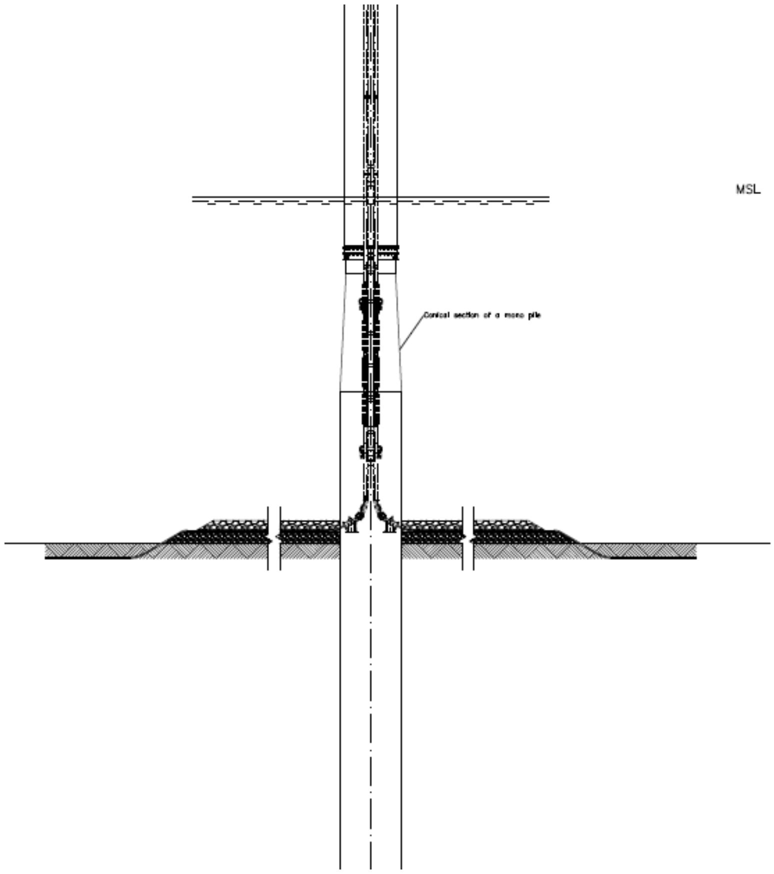


Figure 6: The conical part of a monopile.

The principal illustration above shows the conical part of the mono-pile (Figure 6). The mono-pile section above the conical part has a smaller outer diameter than the part of the monopile 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.

5.1.4 Installation of monopiles

5.1.4.1 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.

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.

Driving time and frequency
The expected time for driving each pile is between 4 and 6 hours. An optimistic estimate would be one pile installed and transition grouted at the rate of one per day.

An average monopile driving intensity will be around 200 impacts per meter monopile. Considering that the piles will be around 35 m 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.

5.2 Concrete gravity base

A concrete gravity base is a concrete structure, that rest on the seabed because of the force of gravity. These structures rely on their mass including ballast to withstand the loads generated by the offshore environment and the wind turbine.

5.2.1 Seabed preparation

The seabed will 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 local conditions:

- Removal of the upper seabed layer to a level where undisturbed soil is encountered, using a back-hoe excavator on a barge. The material will be loaded on split-hopper barges for disposal;
- Gravel is deposited in the hole to form a firm level base.

In Table 6 are given the quantities for an average excavation depth of 2 m, however large variations are foreseen, as soft bottom is expected in various parts of the area. Finally the gravity structure (and maybe nearby placed cables) will be protected against development of scour by installation of a filter layer and armour stones.

	3.0 MW	3.6 MW	4.0 MW	8.0 MW	10.0 MW**
Size of Excavation (approx.)	23-28 m	23-30 m	27-33 m	30-40 m	35-45 m
Material Excavation (per base)	900-1,300 m^3	1,000-1,500 m^3	1,200-1,800 m^3	1,500-2,500 m^3	2,000-3,200 m^3
Total Material Excavated (203/170/154/79/64 turbines)*	182,700-263,900 m^3	170,000-255,000 m^3	184,800-277,200 m^3	118,500-197,500 m^3	128,000-204,800 m^3
Stone Replaced into Excavation (per base) – stone bed	90-180 m^3	100-200 m^3	130-230 m^3	200-300 m^3	240-400 m^3
Total Stone Replaced (203/170/154/79/64 turbines)	18,270-36,540 m^3	17,000-34,000 m^3	20,020-35,420 m^3	15,800-23,700 m^3	15,360-25,600 m^3
Scour protection (per base)	600-800 m^3	700-1,000 m^3	800-1,100 m^3	1,000-1,300 m^3	1,100-1,400 m^3
Foot print area (per base)	800-1,100 m^2	900-1,200 m^2	1,000-1,400 m^2	1,200-1,900 m^2	1,500-2,300 m^2
Total scour protection (203/170/154/79/64 turbines)	121,800-162,400 m^3	119,000-170,000 m^3	123,200-169,400 m^3	79,000-102,700 m^3	70,400-89,600 m^3
Total foot print area (203/170/154/79/64 turbines)	162,400-223,300 m^2	153,000-204,000 m^2	154,000-215,600 m^2	94,800-150,100 m^2	96,000-147,200 m^2

Table 6: Quantities for an average excavation depth of 2 m (3.0 – 10.0 MW).

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

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

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 for the bucket foundation.

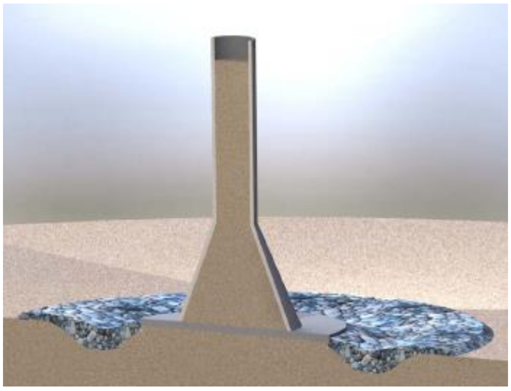


Figure 7: Example on scour protection of a concrete gravity base (drawing: Rambøll).

5.2.2 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 835 and 1,670 and 375 to 750 barge loads would be required for total numbers of respectively smaller and larger turbines. Should beneficial use not be feasible, the material would be disposed at sea at registered disposal site.

5.2.3 Ballast

The ballast material is typically sand, which is likely to be obtained from an off-shore 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.

The results of the preliminary gravity base design for the proposed Kriegers Flak OWF are presented below.

5.2.4 Dimensions

Table 7 gives estimated dimensions for five different sizes of turbines.

GRAVITY BASE	**3.0 MW**	**3.6 MW**	**4.0 MW**	**8.0 MW**	**10.0 MW***
Shaft Diameter	3.5-5.0 m	3.5-5.0 m	4.0-5.0 m	5.0-6.0 m	6.0-7.0 m
Width of Base	18-23 m	20-25 m	22-28 m	25-35 m	30-40 m
Concrete weight per unit	1,300-1,800 t	1500-2,000 t	1,800-2,200 t	2,500-3,000 t	3,000-4,000 t
Total concrete weight	263,000-364,000 t	254,000-338,000 t	274,000-335,000 t	193,000-230,000 t	186,000-248,000 t
BALLAST					
Type	Infill sand	Infill sands	Infill sands	Infill sands	Infill sands
Volume per unit	1,300-1,800 m³	1,500-2,000 m³	1,800-2,200 m³	2,000-2,500 m³	2,300-2,800 m³
Total volume (203/170/154/79/64 turbines)	263,900-365,400 m³	255,000-340,000 m³	277,200-338,800 m³	158,000-197,500 m³	147,720-179,200 m³

*Table 7: Estimated dimensions for different types of turbines. *Very rough quantity estimates. Depends of loads and actual geometry/layout of the concrete gravity foundation.*

5.2.5 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 approximate duration of installation one gravity base is 6 hours.

The bases will then be lowered from the barge onto the prepared stone bed and filled with ballast. This process which will take approximately 6 hours .

5.2.6 Physical discharge of sediment

There is likely to be some discharge of sediment to the sea water from the excavation process. A conservative estimate is 5 % sediment spill, i.e. up to 200 m^3 for each foundation over a period of 2 days per excavation.

5.3 Jacket foundations

5.3.1 Seabed preparation

Depending on the local conditions preparation of the seabed can be necessary prior to installation of jacket foundations, e.g. if the seabed is very soft due to sand banks.

5.3.2 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.

5.3.3 Installation

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 preinstalled piles and hereafter the jacket is fixed to the piles by grouting.

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 20 x 20 meters and 30 x 30 meters between the legs.

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. The same grounting material will be similar to the material described for seel monopiles in chapter 5.1.2. One pile will be used per jacket leg.

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 sea bed. Under normal conditions piling and placement of mudmats will be carried out from a jack-up barge in the wind farm area. Mudmats will be left on the seabed when the jackets have been installed 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 local wave and currents 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.

5.3.4 Dimensions

The dimensions of the jacket foundation will be specific to the particular location at which the foundation is to be installed, Table 8.

Jacket	**3.0 MW**	**3.6 MW**	**4.0 MW**	**8.0 MW**	**10.0 MW***
Distance between legs at seabed	18 x 18 m	20 x 20 m	22 x 22 m	30 x 30 m	40 x 40 m
Pile Length	40 – 50 m	40 – 50 m	40 – 50 m	50-60 m	60-70 m
Diameter of pile	1,200 – 1,500 mm	1,200 – 1,500 mm	1,300 – 1,600 mm	1,400 – 1,700 mm	1,500 – 1,800 mm
Scour protection volume (per foundation)	800 m^3	1,000 m^3	1,200 m^3	1,800 m^3	2,500 m^3
Foot print area (per foundation)	700 m^2	800 m^2	900 m^2	1,300 m^2	1,600 m^2
Total scour protection (203/170/154/79/64 turbines)	162,400 m^3	170,000 m^3	184,800 m^3	142,200 m^3	160,000 m^3
Total foot print area (203/170/154/79/64 turbines)	142,100 m^2	136,000 m^2	138,600 m^2	102,700 m^2	102,400 m^2

*Table 8: Dimensions for jacket foundations. *Very rough estimate of quantities.*

5.4 Suction Buckets

5.4.1 Description

The bucket foundation combines the main aspects of a gravity base foundation and a monopile.

5.4.2 Dimensions

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 than 1 m above sea bed. For this project the diameter of the bucket is expected 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 harbor site and transported by the jack-up supported by tugs to the position.

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

5.5.1 Access platform arrangements for crew access/equipment transfer

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.

Installation

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

5.5.2 Cable entry

Cables for gravitaty based foundations cable are normally placed inside the foundations whilst for monopiles the cables are places either inside or outside the foundations in tubes (I/J tubes)

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 would be determined during detailed design.

The protective paint should be of Class C5M or better according to ISO 12944. Some products in Class C5M, contain epoxy and isocyanates which is on the list of unwanted substances in Denmark. Further it can be necessary to use metal spray (for metallization) on exterior such as platforms or boat landings. The metal spray depending on product can be very toxic to aquatic organisms. It is recommended, that the use of protective paint and metal spray is assessed in relation to the usage and volume in order to evaluate if the substances will be of concern to the environment.

5.5.4 Scour protection

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 a detailed design.

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.

Monopile solution

Scour protection consists of a filter layer and an armour layer. Depending on the hydrodynamic environment the horizontal extent of the armour layer can be between 10 and 15 meter having thicknesses between 1 and 1.5 m. Filter layers are usually of 0.8 m thickness and reach up to 2.5 m further than the armour layer. Expected stone sizes range between d_{50} = 0.30 m to d_{50} = 0.5 m. The total diameter of the scour protection is assumed to be 5 times the pile diameter. Scour protection of a monopole can been seen at Figure 8.

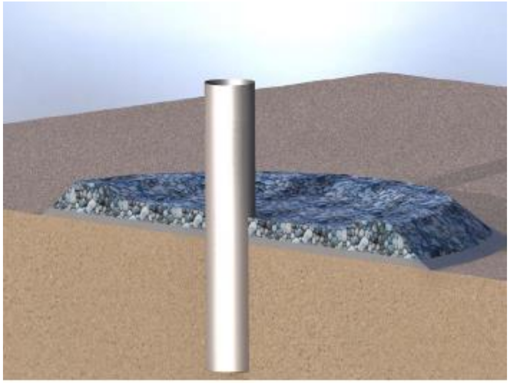


Figure 8: Example on scour protection (drawing: Rambøll).

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.

Jacket solution
The scour protection shall 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.

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.

Alternative scour protection measures
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 1.25 m. 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 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 1.25 t of sand. If this scour protection system is to be used at Kriegers Flak, it will add up to around 47,000 to 125,000t sand in geotextile bags for the 75/200 turbine foundations.

6. Offshore sub-station platforms at Kriegers Flak

6.1 Description

For the grid connection of the 600 MW offshore wind turbines on Kriegers Flak, 2-3 HVAC platforms will be installed. One (200 MW) on the western part of Kriegers Flak and one or two combined platforms (400 MW) on the eastern part of Kriegers Flak. The planned locations of the platforms are shown on Figure 4 and Figure 5.

The HVAC platforms are expected to have a length of 35-40 m, a width of 25-30 m and height of 15-20 m. The highest point is of a HVAC platform is expected to be 30-35 m above sea level.

The array cables from the wind turbines will be routed through J-tubes onto the HVAC platforms, where they are connected to a Medium Voltage (MV) switch gear (33kV) which also is connected to High Voltage (HV) transformers.

A 220 kV export cable will run between the two HVAC sub-station platforms.

The Kriegers Flak platforms will be placed on locations with a sea depth of 20-25 metres and approximately 25 -30 km east of the shore of Møn.

The platforms will be designed “collision friendly” way, meaning that minimum damages will occur on vessels in case of collision with the topside or foundation.

The platforms are designed with containers collecting oil or diesel in case of leakages. Their capacity are equivalent to or larger than the largest amount of oil or diesel contained at the platform.

The platforms will be without any light when no people are aboard except from required navigational lanterns which will be flashing synchronously with the wind turbines, having an effective reach of at least 5 nautical miles corresponding to an intensity of approximately 75 candela.

All platforms will be provided with helicopter landing platform and boat landing to make transport by helicopter or boat possible.

Figure 9: HVAC Offshore platforms at Anholt Offshore Wind Farm (400 MW) (photo Energinet.dk).

Regarding the Civil Aviation Administration – Denmark 'BL 3-5 Regulations of helidecks on offshore installations' pt. 9.1 the final location of offshore installation has the ensure a 210 degree zone with an obstacle free access to the platform out to a distance of 1,000 m due to security requirements of the helidecks on offshore installations (Civil Aviation Administration - Denmark, 2006).

6.2 Foundations for HVAC platforms

The foundation for the HVAC platforms will be either a jacket foundation consisting of four-legged steel structure or a gravity based structure (hybrid foundation) consisting of a concrete caisson with a four-legged steel structure on the top of the caisson.

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.

6.2.1 *Jacket foundation*

For installation purposes the jacket will be mounted with mud mats at the bottom of each leg. Mud mats ensure bottom stability during piling installation to temporary prevent the jacket from sinking into soft soils in the sea bed. The functional life span of these mud mats 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.

Figure 10: Jacket foundation.

The dimensions of the platform jacket foundations will be specific to the location at which the foundation is to be installed.

Jacket	**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 13 m
Pile length	35-40 m
Diameter of pile	1,700 – 1,900 mm
Weight of jacket	1,800 – 2,100 t
Scour protection area	600 – 1,000 m²

Table 9: Dimensions of the jacket foundations of the HVAC platforms.

6.2.2 *Gravity based structure*

The Gravity Based Structure is constructed as one or two caissons with an appropriate number of ballast chambers.

Two different designs can be predicted for the Kriegers Flak project:

- Hybrid foundation. One self-floating concrete caisson with a steel structure on tope, supporting the topside.
- (GBS) Steel foundation with two caissons integrated into the overall substation design.

The gravity based foundation will be placed on a stone bed prepared prior to the platform installation, i.e. the top layer of sea bed material is removed and replaced by a layer of crushed stones or gravel. After the gravity based foundation is placed on the store bed a layer of stones will be placed around the caisson as scour protection. The cables going to the platform may also be protected against scour.

Figure 11: Hybrid foundation.

The dimensions of the hybrid foundations will be specific to the location at which the foundation is to be installed.

Hybrid foundation	HVAC platform
Caisson length x width	21 x 24 m
Caisson height	15 – 16 m
Caisson weight	3,300 – 3,600 t
Distance between corner legs of steel structure	20 x 23 m
Location of interface caisson/steel structure	3-5 m below sea level
Height of steel structure	16 - 18 m
Diameter of structure legs	1,700 – 1,900 mm
Weight of steel structure	600-800 t
Ballast volume	1,600 – 1,800 m^3
Total weight of foundation incl. ballast	9,000 – 1,0000 t
Scour protection area	600 – 1,200 m^2

Table 10: Typical dimensions of hybrid foundations.

6.2.3 Installation

Jacket foundation

The installation of a platform with jacket foundation will be one campaign with a large crane vessel with a lifting capacity of minimum 2000 tons. The time needed for the installation of jacket plus topside will be 4 -6 days with activities ongoing day and night.

In case of an area with sand dunes dredging to stable seabed may be required. Minor sediment spill (a conservative estimate is 5 %) may be expected during these operations.

Gravity based foundation

The seabed preparation will start with removal by an excavator aboard a vessel or by a dredger of the top surface of the seabed to a level where undisturbed soil is encountered. The excavated material is loaded aboard a split-hopper barge for disposal at appointed disposal area.

After the top soil has been removed crushed stones or gravel is deposited into the excavated area to form a firm level base. In Table 11 are given the quantities for an average excavation depth of 2 m. Finally the foundation is protected against development of scour holes by installation of filter and armour stones.

	HVAC platform
Size of Excavation (approx.)	30 x 40 m
Material Excavation	2,400 m^3
Stone Replaced into Excavation (approx.)	2,000 m^3
Scour protection	1,800-3,000 m^3

Table 11: Approximate quantities of excavated material, stones, gravel and scour protection at installation of a gravity based foundation at 2 m depth (HVAC platform).

When the seabed preparation has finished the hybrid foundation or the Gravity Based Substation will be tugged from the yard and immersed onto the prepared seabed. This operation is expected to take 18 - 24 hours.

When the hybrid foundation is in place it will be ballasted by sand, the ballasting process is expected to take 8 – 12 days.

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 offshore sub-station platform.

Inter-array cables will be installed at the HVAC platform in J-tubes which lead the cables to the platforms where the medium voltage cables will be connected to the high voltage part of the platform.

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.

7.1.1 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 placed 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 – sub-station platform
- Pull in – wind turbines

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 fall down in the bottom of the trench.

Cable installation

The array cables will be buried to provide protection from fishing activity, dragging of anchors etc.

A burial depth of approximately one meter is expected. The final depth of burial will be determined at a later date and may vary depending on a more detailed soil condition survey and the equipment selected.

The submarine cables are likely to be buried using a combination of two techniques:

- Pre-trenching the cable route using a suitable excavator.
- Post lay jetting by either Remote Operated Vehicle (ROV) or manual trencher that utilises high-pressure water jets to fluidise a narrow trench into which the cable is located.

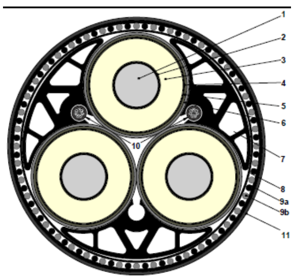
After the cables are installed, the sediments will naturally settle back into the trench assisted by water currents.

7.2 Export cables

Two 220 kV export submarine cables will be installed from the offshore sub-station platforms to the landfall at Rødvig, in addition to the two export cables to shore, a 220 kV submarine cable will be installed between the platforms. The total length of the export cables and the cables between the sub-station platforms will be approx. 100 km.

The export cables from the platforms to the landing at Rødvig will on the main part of the route be aligned in parallel with a distance of 100-300 m. Close to the shore (approx. the last 500 m), the distance between the cables will be approx. 30-50 m.

The export cable will be a three core 220 kV (max. voltage 245 kV) XPLE submarine cable.



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 12: Illustration of a typical export cable.

The transmission cable will have conductors of aluminum. The export cable will be with XLPE insulation (Cross linked PE).

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

It is the intention that the transmission cable is to be installed with a minimum number of offshore joints. In the actual case it is planed two off-shore joints, on each cable

7.2.1 Export cable installation

The Kriegers Flak area where the cables are to be installed is partly consisting of soft (sand) and hard (clay and chalk) sediments.

It is expected that the export cables are installed in one length on the seabed and after trenching the cable is protected to the depth of one meter.

To prevent the cables from getting exposed as a result of sediment mitigation in near shore zone, the protection of the cables are done by installing them in PE ducts , possibly done via an HDD (Horizontal Directional Drilling). The exact type of installation will be based on the actual conditions.

When the cable is laid it will be buried via so called jetting. The jetting will be conducted in one operation and independent of the operation were the cables are laid on the seabed. It is expected that the route can be planned around possible big boulders. If boulders are to be moved they will be placed just outside the cable route, but inside the area of the geophysical survey.

It is expected that a significant amount of hard soil conditions are present along the trace – up to 50 %. Here the pre-excavated trench will have depth of approx. 1-2 meter with a width of approx. 0.7-1.5 meters.

The excavation may be conducted by and excavator placed upon a vessel or a barge or by cutting or by ploughing. The soil will be deposited near the trench. The pre trenching will be aimed to be conducted one year prior to the cable installation.

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 have been deposited in the period after trenching or clearing. The trench will thereafter be covered with the deposited material from the trenching operation.

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 Kriegers Flak project it is estimated that the jetting will last for approximately 3-4 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 can here be lowered to a range of below 1 meter coverage, exact coverage is subject to the specific situation and the surrounding seabed conditions.

8. Noise emissions from installation and operation

8.1 Noise emissions from installation of monopiles

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.

Noise emissions during installation of concrete gravity foundations are considered to be small.

8.2 Operational airborne noise emissions

There are two types of noise associated with operation of wind turbines; aerodynamic 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 at the source 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 Kriegers Flak 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 (BEK nr 1284 af 15/12/2011) are:

- 44 and 42 dB (A) for outdoor areas in relation to neighbours (up to 15 m away) in the open land, at 8 m/sec and 6 m/sec wind speed respectively.
- 39 and 37 dB (A) for outdoor areas in residential areas and other noise sensitive areas, at 8 m/sec and 6 m/sec wind speed respectively.

In relation to construction noise, the most extensive noise is normally generated from piling of offshore 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.

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.

9. Offshore construction

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

9.1 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 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. 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.

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.

9.1.1 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.

9.2 Lighting and markings during construction

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 and the Danish Civil Aviation Administration

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 Danish Maritime Authority. 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). The use of cranes which are of more than 150 metres high requires prior notice and approval by the Danish Transport and Construction Agency.

9.3 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.

Any other waste from the offshore constructions will be collected and disposed according to the requirements for onshore waste management.

Prior to the decommissioning a plan for identification, separation and handling of hazardous substances will be prepared. Furthermore a detailed plan for recycling and handling of materials from the wind turbines will be prepared. Finally a detailed plan for the disposal methods for the remaining materials from the wind farm will be worked out (also described in section 11.7).

10. Wind farm operations and maintenance

Operation and maintenance of the Kriegers Flak OWF 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. It is expected that maintenance check of the turbines will be carried out every 6 month.

10.1 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.

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 on the extent of potential safety zones.

For all turbines and for the offshore sub-station platform a prohibited entry zone of minimum 50m radius of the foundations is foreseen for non-project vessels. For the actual project the decision will be taken by Danish Maritime Authority.

10.2 Wind farm inspection and maintenance

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

Maintenance schedules of the wind farm depend on the turbine type installed, but is normally separated into two different categories:

- Periodic overhauls
- Scheduled maintenance
- Un-scheduled maintenance

10.2.1 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.

10.2.2 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.

10.2.3 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.

10.2.4 Offshore sub-station platforms

The strategy for maintenance of the offshore substation platforms will be similar to the wind farm, normally one visit during day time per month is planned for planned maintenance.

In case of the need for unexpected maintenance of substations necessary transportation can be arranged either by helicopter or be vessel, similar to the unexpected maintenance of the wind farm.

10.3 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.

For the substations it is expected that each platform will have 18 – 30 service visits per year. The number of visits 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 50 % of the service visits is expected to be by helicopter.

10.4 Surveys during operation of the wind farm

Regular surveys to inspect the foundations, scour protection and inter-array cables will also be required during the operation of the wind farm.

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.

10.5 Emissions and discharge

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.

Wind turbines

No solid discharges are anticipated into the marine environment during normal operation of the wind turbines. 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 turbines.

Offshore sub-station platforms

During the operation phase very little emissions is exposed to the environment.

Relevant emissions will be exhaust gas from the diesel generators on platforms. As the generators are only in operation in emergency situation or shortly on a monthly basis for testing purpose, the emission is very limited.

At the unmanned platforms minor discharge of the sewage water directly to the sea will take place. The sewage system for toilets is equipped with shredders and the sewage pipes lead to below the sea surface in order to reduce the environmental impact.

11. Wind farm decommissioning

The lifetime of the wind farm is expected to be around 30 years. It is expected that two years in advance of the expiry of the production time the developer shall submit a decommissioning plan. The method for decommissioning will 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 competent authorities before the work is being initiated.

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.

11.1 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.
- Inter array 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.
- Scour protection – to be left in situ.

11.2 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.

11.3 Decommissioning of offshore sub-station platform

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

- Disconnection of the wind turbines and associated hardware.
- Removal of all fluids, substances on the platform, including oils, lubricants and gasses.
- 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.

11.4 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 skips or open containers on board the vessel for later disposal through appropriate routes for material reuse, recycle or disposal.

11.5 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.

11.6 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.

11.7 Disposal and 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.

12. References

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13. Appendix

13.1Appendix 1

Overview of coordinates delineating the restriction area for sand extraction and installation of technical elements and submarine cables, the wind farm area and the pre-investigation area at Kriegers Flak. ID refers to locations visualized in Figure 2. P1 and P2 are coordinates of the offshore substation platforms shown on Figure 4 and Figure 5 (WGS84 (UTM 32N).

	Restriction area		**Wind farm area**		**Pre-investigation area**		**Export cable corridor**		**Offshore substation platforms**		
ID	**East**	**North**	**East**	**North**	**East**	**North**	**East**	**North**	**ID**	**East**	**North**
1	755172	6103830	739829	6106961	739829	6106961	745533	6109532	P1	746103	6104602
2	755568	6103263	752625	6112752	753157	6112962	729840	6116651	P2	751999	6107300
3	755554	6099575	758629	6109142	758952	6109422	716397	6125279			
4	749900	6098597	764565	6103504	765136	6103492	713509	6126882			
5	748647	6100719	762915	6100856	763597	6100973					
6	748509	6102922	747313	6098148	747313	6098148					
7	747876	6103610	741529	6098509	741529	6098509					
8	746775	6103995	739829	6102553	739829	6102553					
9	746568	6104243									
10	745949	6105854									
11	745344	6109440									
12	746387	6109914									
13	749862	6109393									
14	750029	6109332									
15	750313	6109047									
16	752020	6105730									