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Anholt Offshore Wind Farm

Air Emissions

November 2009

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Background Memo
Air Emissions

November 2009

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Abbreviations

CO_2	Carbon dioxide
HFO	Heavy fuel oil
MGO	Marine gas oil
NO_X	Nitrogen oxides
SO_2	Sulphur dioxide

1. Summaries

1.1 Dansk resumé

I denne rapport er udledningen af forurenende stoffer til atmosfæren fra etablering og drift af Anholt Havmøllepark estimeret.

Løsningen med monopælfundamenter giver anledning til færre emissioner for begge mølletyper (33-41 % lavere end løsningen med gravitationsfundamenter).

På grund af de færre enheder, der skal installeres giver 5,0 MW møllerne anledning til det laveste emissionsbidrag for begge fundamentløsninger (49-54 % lavere end 2,3 MW møllerne).

Uanset mølle og fundamenttype er emissionerne fra anlægsfasen meget lave (<< 1 % af de årlige nationale emissioner).

1.2 English summary

This report presents an estimation of the air emissions that will be caused by the construction and operation of Anholt Offshore Wind Farm.

The solution with the monopole foundations will give rise to fewer emissions for both turbine types (33-41% lower than the solution with gravity based foundations).

Because of the fewer units to be installed the 5.0 MW turbines give rise to the lowest emission contribution of both foundation types (49-54% lower than the 2.3 MW turbines).

Regardless of the turbine size and type of foundation the emissions from the construction phase is very low (<<1% of annual national emissions).

2. Introduction

2.1 Background

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

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

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

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

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

- Technical Description
- Geotechnical Investigations
- Geophysical Investigations
- Metocean data for design and operational conditions
- Hydrography including sediment spill, water quality, geomorphology and coastal morphology
- Benthic Fauna
- Birds
- Marine mammals
- Fish
- Substrates and benthic communities
- Benthic habitat
- Maritime archaeology
- Visualization

- Commercial fishery
- Tourism and Recreational Activities
- Risk to ship traffic
- Noise calculations
- Air emissions

2.2 Content of specific memo

This technical background report calculates the emissions to air that will arise from the construction and operation of Anholt Offshore Wind Farm.

3. Offshore wind farm

3.1 Project description

This chapter describes the technical aspects of the Anholt Offshore Wind Farm. For a full project description reference is made to /1/. The following description is based on expected conditions for the technical project; however, the detailed design will not be done until a developer of the Anholt Offshore Wind Farm has been awarded.

3.1.1 Site location

The designated investigation area for the Anholt Offshore Wind Farm is located in Kattegat between the headland Djursland of Jutland and the island Anholt - see Figure 3.1. The investigation area is 144 km^2, but the planned wind turbines must not cover an area of more than 88 km^2. The distance from Djursland and Anholt to the project area is 15 and 20 km, respectively. The area is characterised by fairly uniform seabed conditions and water depths between 15 and 20 m.

3.1.2 Offshore components

3.1.2.1 Foundations

The wind turbines will be supported on foundations fixed to the seabed. The foundations will be one of two types; either driven steel monopiles or concrete gravity based structures. Both concepts have successfully been used for operating offshore wind farms in Denmark /2/, /3/.

The monopile solution comprises driving a hollow steel pile into the seabed. A steel transition piece is attached to the pile head using grout to make the connection with the wind turbine tower.

The gravity based solution comprises a concrete base that stands on the seabed and thus relies on its mass including ballast to withstand the loads generated by the offshore environment and the wind turbine.

3.1.2.2 Wind turbines

The maximum rated capacity of the wind farm is by the authorities limited to 400 MW /4/. The farm will feature from 80 to 174 turbines depending on the rated energy of the selected turbines corresponding to the range of 2.3 to 5.0 MW.

Preliminary dimensions of the turbines are not expected to exceed a maximum tip height of 160 m above mean sea level for the largest turbine size (5.0 MW) and a minimum air gap of approximately 23 m above mean sea level. An operational sound power level is expected in the order of 110 dB(A), but will depend on the selected type of turbine.

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

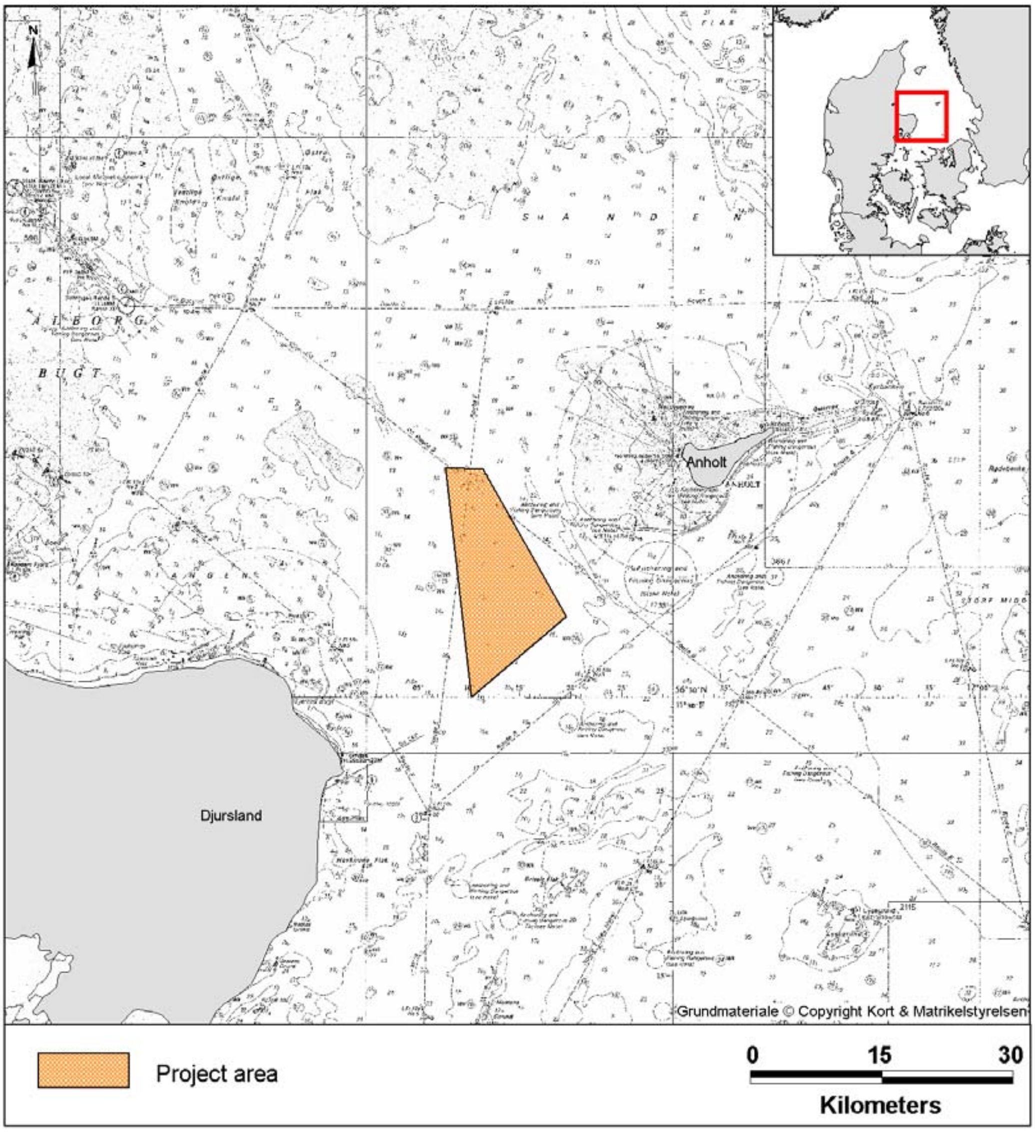

Figure 3.1 Location of the Anholt Offshore Wind Farm project area.

3.1.3 Installation

The foundations and 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 installation will be performed by jack-up barges or floating crane barges depending on the foundation design. A number of support barges, tugs, safety vessels and personnel transfer vessels will also be required.

Construction activity is expected for 24 hours per day until construction is complete. Following installation and grid connection, the wind turbines are commissioned and are available to generate electricity.

A safety zone of 500 m will be established to protect the project plant and personnel, and the safety of third parties during the construction and commissioning phases of the wind farm. The extent of the safety zone at any one time will be dependent on the locations of construction activity. However the safety zone may include the entire construction area or a rolling safety zone may be selected.

3.1.3.1 Wind turbines

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 feet is approximately 350 m^2 (in total), with leg penetrations of up to 2 to 15 m (depending on seabed properties). These holes will be left to in-fill naturally.

3.1.3.2 Foundations

The monopile concept is not expected to require any seabed preparation.

The installation of the driven monopiles will take place from either a jack-up platform or an anchored vessel. In addition, a small drilling spread may be adopted if driving difficulties are experienced. After transportation to the site the 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, the hammer is removed and the transition piece is installed.

For the gravity based foundations the seabed needs most often to be prepared prior to installation, i.e. the top layer of material is removed and replaced by a stone bed. The material excavated during the seabed preparation works will be loaded onto split-hopper barges for disposal. 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.

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. The bases will then be lowered from the barge onto the prepared stone bed and filled with ballast.

After the structure is placed on the seabed, the base is filled with a suitable ballast material, usually sand. A steel ‘skirt’ may be installed around the base to penetrate into the seabed and to constrain the seabed underneath the base.

3.1.4 Protection systems

3.1.4.1 Corrosion

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.

3.1.4.2 Scour

If the seabed is erodible and the water flow is sufficient high a scour hole will form around the structure. The protection system normally adopted for scour consists of rock placement in a ring around the in-situ structure. The rock will be deployed from the host vessel either directly onto the seabed from the barge, via a bucket grab or via a telescopic tube.

For the monopile solution the total diameter of the scour protection is assumed to be 5 times the pile diameter. The total volume of cover stones will be around 850-1,000 m^3 per foundation. For the gravity based solution the quantities are assessed to be 800–1100 m^3 per foundation.

3.2 Baseline study

No baseline study has been performed for this report.

3.3 Environmental impacts

3.3.1 Sources of potential impacts

Table 3.1 shows the project activities and the sources of impacts during construction and operation of the Anholt Offshore Wind Farm, which may result in impacts on the atmospheric environment.

Table 3.1 Project activities during construction and operation of the Anholt Offshore Wind Farm, sources of impacts and potential impacts on the atmospheric environment.

Project activity	**Source of potential impacts**	**Potential environmental impacts**
Construction		**Environmental parameter affected / target of impact**
Seabed intervention works	Vessel activity	Air quality
Installation of foundations, turbines and cables	Vessel activity	
Operation		
Inspection and maintenance	Vessel activity	Air quality

3.3.2 Methodology

Emissions estimates have been based on the fuel consumption of the engines of the vessels and equipment to be used. The workload (in kWh) of the equipment has been based on engine capacity and work time.

The estimated fuel consumption has been based on a conversion rate for the consumption of fuel per kWh. A modern two-stroke diesel engine consumes fuel at about 160 g/kWh, whereas the fuel consumption of a modern four-stroke diesel engine is about 170 g/kWh. Older diesel engines consume fuel at a rate of about 200-210 g/kWh. For this study, an average fuel consumption of 190 g/kWh was assumed for all the engines at all loads, regardless of fuel type /5/, /6/.

The marine fuels are divided into categories: heavy fuel oil (HFO), medium fuel oil (MFO), intermediate fuel oil (IFO) and light marine distillates. The light marine distillates are further divided into marine diesel oil (MDO) and marine gas oil (MGO). MGO is the ‘lightest’; i.e., it has the lowest viscosity and often the lowest sulphur content.

The classification of marine fuel oils is shown in Table 3.2. It is assumed that all vessels will be powered by either HFO or MGO.

Table 3.2 Classes and characteristics of marine fuel oils.

Fuel	Name	Characteristics
MGO	marine gas oil	made from distillate only
MDO	marine diesel oil	a blend of gas oil and heavy fuel oil
IFO	intermediate fuel oil	a blend of gas oil and heavy fuel oil, with less gas oil than marine diesel oil
MFO	medium fuel oil	a blend of gas oil and heavy fuel oil, with less gas oil than intermediate fuel oil
HFO	heavy fuel oil	pure or nearly pure residual oil

The emissions evaluated in this document comprise the three main pollutants:

- Carbon dioxide (CO_2)
- Nitrogen oxides (NO_X)
- Sulphur dioxide (SO_2)

Emissions factors have been used to derive estimates of emissions of these compounds based on either the amount of fuel combusted (equipment on deck) or the engine workload (vessels).

The estimates of SO_2 emissions have been based on limit values of sulphur content of the used fuel according to the EU Directive 2005/33/EC on the sulphur content of marine fuels /7/. As construction works are planned to commence in 2010, the maximum sulphur content permissible at that date will be 1.5% by mass for HFO and 0.1% by mass for gas oils (MGO).

The NO_X emissions of vessels working within the Baltic Sea are set at 12 g NO_X/kWh based on investigations by /6/ and /8/. For evaluation purposes, NO_X has been treated as NO_2.

The CO_2 emissions are proportional to the fuel consumption and have been estimated by an emission factor of 3.2 t CO_2/t fuel. This generally accepted value has been derived from the consumption and combustion process in a standard diesel engine. It averages over a number of different types of machines as well as the alteration of the motor rotation speed, which affects the level of emission significantly. The high variation range of diesel engines, depending on performance, technology, size, age and degree of development, was taken into account.

It should be noted that the calculated air emissions, based on the above-mentioned assumptions, are associated with uncertainties related to engine type, number of engines, working load of the engines and the exact fuel type. Despite the data limitations and uncertainties, it can nevertheless be assumed that the estimated range of emissions presented in this document will be in the order of magnitude of the emissions that will actually occur.

The data used to calculate emissions of CO_2, NO_X and SO_2 from the vessels that are expected to be used during the construction and operation of Anholt Offshore Wind Farm is presented in Table 3.3.

The engine power of the vessels is derived from data sheets for the type of vessels and equipment that has been used for the development of other, newer wind farms. Working hours are assessed based on the working hours for a single unit and compared with the total number of turbines. In addition, the working hours for the transport of foundations, turbines, and rock for scour protection is based on typical distances from potential delivery locations and typical sailing speeds. The same goes for cable-laying and inspection activities.

Table 3.3 Data used to calculate emissions from vessels and equipment used during the construction and operation of Anholt Offshore Wind Farm.

Activity / vessel	Engine power (kW)	No. of vessels	Fuel	Work time 174 units of 2,3 MW (days)	Work time 80 units of 5,0 MW (days)
Excavator	1.500	1	MGO	522 [A]	240 [A]
Barge for excavator	1.000	1	HFO	522 [A]	240 [A]
Barge for disposal of seabed material	1.000	1	HFO	391,5 [A]	180 [A]
Vessel for transport of rock for stone bed	6.250	1	HFO	607,5 [A]	364,5 [A]
Vessel for dumping of rock for stone bed	3.700	1	HFO	522 [A]	240 [A]
Jack-up vessel for transport and installation of foundations	1.500	1	HFO	174	80
Tugboats for jack-up vessel	10.000	2	MGO	174	80
Pump/generator for injection of grout	800	1	MGO	174 [B]	80 [B]
Barge for pump/generator	1.000	1	HFO	174 [B]	80 [B]
Vessel for transport of rock for scour protection	6.250	1	HFO	567 [A] 607 [B]	364,5 [A] 324 [B]
Vessel for dumping of rock for scour protection	3.700	1	HFO	609 [A] 696 [B]	240 [A] 200 [B]
Crane vessel for installation of turbines	2.750	1	HFO	174	80
Tugboats for barge for transport of turbines etc.	10.000	2	MGO	174	80
Cable lay vessel with plough	13.000	1	MGO	14	14
Vessel for tie-in of cables	7,200	1	MGO	181	87
Inspection of cables during operation (25 years)	7.200	1	MGO	350	350
Vessel for maintenance of turbines during operation (25 years)	2.000	1	MGO	5.000	5.000

[A] Gravity base
[B] Monopile

3.3.3 Impacts during construction

The construction phase accounts for the majority of the project's discharges of pollutants to the atmosphere because of the many construction activities. Emissions will therefore be limited in time and most emissions will also be geographically limited to the project area except for shipments of foundations, turbines and other components.

The results of calculations of the expected emissions during the construction of Anholt Offshore Wind Farm are shown in Table 3.4 and Table 3.5.

Table 3.4 Estimated emissions during construction of Anholt Offshore Wind Farm for the solution with 174 units of 2.3 MW.

Activity	Estimated emissions in tons		
	CO_2	NO_X	SO_2
Preparation of the seabed for gravity based foundations, including excavation, transport and disposal of removed seabed material and placement of rock foundation. Including also support vessels.	121.858 B	2.405,1 B	875,8 B
Installation of foundations, including transport and support vessels.	59.667 A	1.177,6 A	514,9 A
	69.315 B	1.368,1 B	543,2 B
Placement of rock for scour protection, including transport and support vessels.	94.500 A	1.865,1 A	708,2 A
	85.919 B	1.695,8 B	650,0 B
Laying and burial of cables in the seabed[1], including support vessels.	27.363	540,1	40,3
Installation of turbines, including support vessels.	62.840	1.240,3	544,7
Total	**244.370 A**	**4.823 A**	**1.808 A**
	367.295 B	**7.249 B**	**2.654 B**
Annual national emissions 2007 /9/	102.341.120	1.439.087	471.389
A Monopile B Gravity base			

Table 3.5 Estimated emissions during construction of Anholt Offshore Wind Farm for the solution with 80 units of 5.0 MW.

Activity	Estimated emissions in tons		
	CO_2	NO_X	SO_2
Preparation of the seabed for gravity based foundations, including excavation, transport and disposal of removed seabed material and placement of rock foundation. Including also support vessels.	63.795 B	1.259,1 B	475,5 B
Installation of foundations, including transport and support vessels.	27.433 A	541,4 A	236,8 A
	31.869 B	629,0 B	249,7 B
Placement of rock for scour protection, including transport and support vessels.	40.782 A	804,9 A	331,3 A
	46.723 B	922,2 B	376,7 B
Laying and burial of cables in the seabed[1], including support vessels.	14.744	291,0	32,5
Installation of turbines, including support vessels.	28.892	570,2	250,4
Total	**111.851 A**	**2.207 A**	**851 A**
	186.023 B	**3.671 B**	**1.384 B**
Annual national emissions 2007 /9/	102.341.120	1.439.087	471.389
A Monopile B Gravity base			

[1] Calculated for an average length of cables for the four park layouts (cable lengths vary between 80 and 150 km).

As seen from Table 3.4 and Table 3.5 the solution with the monopiles give rise to fewer emissions for both turbine types (33-41% lower than the solution with gravity based foundations). The big difference is primarily due to seabed works, which for the gravity based foundations represents the largest emissions contribution in the construction phase.

Because of the fewer units to be installed the 5.0 MW turbines give rise to the lowest emission contribution of both foundation types (49-54% lower than the 2.3 MW turbines).

Regardless of the turbine size and type of foundation the emissions from the construction phase is very low (<<1% of annual national emissions). The following Table 3.6 summarizes the overall impact on the atmospheric environment during the construction phase. For all foundation types and turbine sizes the environmental impact from construction is generally assessed to be of minor importance.

Table 3.6 Overall impact on the atmospheric environment in the construction phase of the project.

Impact	**Intensity of effect**	**Scale / geographical extent of effect**	**Duration of effect**	**Overall significance of impact**
Emission of pollutants	Small	Regional	Long-term	Minor

3.3.4 Impacts during operation

During the operational phase there will be various activities such as inspection of cables and maintenance of the turbines, which will give rise to discharges of pollutants to the atmosphere. These discharges will take place periodically throughout the entire operational phase of 25 years, but will be temporary (few hours or days at a time) and will be limited to the line from a port nearby and out to the project area and within the project area itself.

The results of calculations of the expected emissions during the operation of Anholt Offshore Wind Farm are shown in Table 3.7.

Table 3.7 Estimated emissions during operation of Anholt Offshore Wind Farm.

Aktivity	**Estimated emissions in tons**		
	CO_2	**NO_X**	**SO_2**
2.3 MW turbines in linear layout			
Inspection of cables	15,759	311.0	9.8
Maintenance of turbines	277,248	5,472.0	173.28
Total	**293,007**	**5,783**	**183**
2.3 MW turbines in circular layout			
Inspection of cables	13,133	259.2	8.2
Maintenance of turbines	240,768	4,752.0	150.4
Total	**253,901**	**5,011**	**159**

5.0 MW turbines in linear layout			
Inspection of cables	9,245	182.5	5.8
Maintenance of turbines	186,778	3,686.4	116.7
Total	**196,023**	**3,869**	**123**
5.0 MW turbines in circular layout			
Inspection of cables	8,405	165.9	5.3
Maintenance of turbines	175,104	3,456.0	109.4
Total	**183,509**	**3,622**	**115**
Annual national emissions 2007 /9/	55.749.000	185.304	25.048

The largest contribution of emissions during the operational phase consists of maintenance of turbines that will take place every six years for each turbine. Inspection of the cables only represents approx. 5% of emissions during the operational phase. Emissions will be distributed over a period of 25 years and only for short periods at a time in connection with a specific maintenance task.

In Table 3.8 an evaluation of the overall impact, on the atmospheric environment during operation phase, is presented.

Table 3.8 Overall impact on the atmospheric environment d the operation phase of the project.

Impact	**Intensity of effect**	**Scale/geographical extent of effect**	**Duration of effect**	**Overall significance of impact**
Emission of pollutants	Small	Regional	Long-term	Minor

3.4 Mitigation measures

Possible mitigation measures include the use of low-sulphur fuel and optimisation of the combustion in the engines. Also, a thorough planning of the work to limit unnecessary vessel activities is recommended.

3.5 Cumulative effects

It is assessed that there are no cumulative effects on the atmospheric environment from the construction or operation of Anholt Offshore Wind Farm and other third part projects.

3.6 Technical deficiencies or lack of knowledge

The calculations presented in this report are based on experience with regards to the use of construction vessel types on other offshore wind farm projects.

However, since the detailed design has not yet been developed and since the contractors have not yet been selected, the calculations are based on a number of assumptions. For example, assumptions have been made with regards to operation type of the different construction vessels. Also, the calculations are based on assumptions regarding port of disembarkment for the various wind farm components.

The conclusion is that this report has been elaborated with some technical deficiencies or lack of knowledge and therefore only exemplifies the emissions that will arise from the project.

4. Transformer platform and offshore cable

4.1 Project description

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

4.1.1 Transformer platform

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

The transformer platform will be placed on a location with a sea depth of 12-14 metres. The length of the export cable from the transformer station to the shore of Djursland will be approximately 25 km. On the platform the equipment is placed inside a building. In the building there will be a cable deck, two decks for technical equipment and facilities for emergency residence.

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

4.1.2 Subsea cabling

The wind turbines will be connected by 33 kV submarine cables, so-called inter-array cables. The inter-array cables will connect the wind turbines in groups to the transformer platform. There will be up to 20 cable connections from the platform to the wind turbines. From the transformer platform a 220 kV export cable is laid to the shore at Saltbæk north of Grenå. The cables will be PEX insulated or similar with armouring.

The installation of the cables will be carried out by a specialist cable lay vessel that will manoeuvre either by use of a four or eight point moving system or an either fully or assisted DP (Dynamically Positioned) operation.

All the subsea cables will be buried in order to provide protection from fishing activity, dragging of anchors etc. A burial depth of minimum one meter is expected. The final depth of burial will be determined at a later date and will vary depending on more detailed soil condition surveys and the equipment selected.

The cables will be buried either using an underwater cable plough that executes a simultaneous lay and burial technique that mobilises very little sediment; or a Remotely Operated Vehicle (ROV) that utilises high-pressure water jets to fluidise a narrow trench into which the cable is located. The jetted sediments will settle back into the trench.

4.1.3 Onshore components

At sea the submarine cable is laid from a vessel with a large turn table. Close to the coast, where the depth is inadequate for the vessel, floaters are mounted onto the cable and the cable end is pulled onto the shore. The submarine cable is connected to the land cable close to the coast line via a cable joint. Afterwards the cables and the cable joint are buried into the soil and the surface is re-established.

On shore the land cable connection runs from the coast to compensation substation 2-3 km from the coast and further on to the substation Trige near Århus. At the substation Trige a new 220/400 kV transformer, compensation coils and associated switchgear will be installed. The onshore works are not part of the scope of the Environmental Statement for the Anholt Offshore Wind Farm. The onshore works will be assessed in a separate study and are therefore not further discussed in this document.

4.2 Baseline study

No baseline study has been performed for this report.

4.3 Environmental impacts

4.3.1 Sources of potential impacts

Table 4.1 shows the project activities and the sources of impacts during construction and operation of the transformer platform and subsea cable, which may result in impacts on the atmospheric environment.

Table 4.1 Project activities during construction and operation of the transformer platform and subsea cable, sources of impacts and potential impacts on the atmospheric environment.

Project activity	Source of potential impacts	Potential environmental impacts
Construction		**Environmental parameter affected / target of impact**
Seabed intervention works	Vessel activity	Air quality
Installation of foundation, platform and cable	Vessel activity	
Operation		
Inspection and maintenance	Vessel activity	Air quality

4.3.2 Methodology

The same methodology for calculating emissions is used as presented in 3.3.1.

The data used to calculate emissions of CO_2, NO_X and SO_2 from the vessels that are expected to be used during the construction and operation of Anholt Offshore Wind Farm is presented in Table 4.2.

The engine power of the vessels is derived from data sheets for the type of vessels and equipment that has been used for the development of other, newer wind farms. Working hours are assessed based on the working hours for a single unit and compared with the total number of turbines. In addition, the working hours for the transport of foundations, turbines, and rock for scour protection is based on typical distances from potential delivery locations and typical sailing speeds. The same goes for cable-laying and inspection activities.

Table 4.2 Data used to calculate emissions from vessels and equipment used during the construction and operation of Anholt Offshore Wind Farm.

Activity / vessel	Engine power (kW)	No. of vessels	Fuel	Work time (days)
Jack-up vessel for installation of foundation	1.500	1	HFO	11.4
Tugboats for jack-up vessel	10.000	2	MGO	3.0
Crane vessel for installation of topside	2.750	1	HFO	11.4
Tugboats for barge for transport of foundation, topside etc.	10.000	2	MGO	3.0
Cable lay vessel with plough	13.000	1	HFO	2.5 [A] 5.0 [B]
Inspection of cables during operation	7.200	1	MGO	50.0 [A] 100.0 [B]
Vessel for maintenance of transformer station during operation	2.000	1	MGO	150.0

[A] One cable
[B] Two cables

4.3.3 Impacts during construction

The construction phase accounts for the majority of the project's discharges of pollutants into the atmosphere because of the many construction activities. Emissions will therefore be limited and most emissions will also be geographically limited to the project area except for shipments of foundation, topside and other components.

The results of calculations of the expected emissions during the construction of the transformer platform and subsea cable are shown in Table 4.3.

Table 4.3 Estimated emissions during construction of the transformer platform and installation of the subsea cable.

Activity	Estimated emissions in tons		
	CO_2	NO_x	SO_2
Installation of foundation incl. support vessels	1.125	22	11
Installation of topside incl. support vessels	1.333	26	13
Laying of cable and burial in the seabed	474 [A]	10 [A]	4 [A]
	948 [B]	19 [B]	8 [B]
Total	**2.932 [A]**	**58 [A]**	**28 [A]**
	3.406 [B]	**67 [B]**	**32 [B]**
Annual national emissions 2007 /9/	102.341.120	1.439.087	471.389

[A] One cable
[B] Two cables

In Table 4.4 an evaluation of the overall impact, on the atmospheric environment during construction phase, is presented.

Table 4.4 Overall impact on the atmospheric environment in the construction phase of the project.

Impact	Intensity of effect	Scale / geographical extent of effect	Duration of effect	Overall significance of impact
Emission of pollutants	Small	Regional	Long-term	Minor

4.3.4 Impacts during operation

During the operational phase there will be various activities, such as inspection of cables and maintenance of the transformer platform, which will give rise to discharges of pollutants to the atmosphere. These emissions will take place periodically throughout the operational phase of 25 years, but will be temporary (few hours or days at a time) and limited to the line from a port to the cable and along the cable corridor to the transformer platform.

The results of calculations of the expected emissions during operation of the transformer platform and the subsea cable is shown in Table 4.5.

Table 4.5 Estimated emissions during operation of the transformer platform and the subsea cable.

Activity	Estimated emissions in tons		
	CO_2	NO_X	SO_2
Inspection of cable	5.253 [A]	104 [A]	3 [A]
	10.506 [B]	207 [B]	7 [B]
Maintenance of transformer platform	1.459	29	1
Total	**6.712 [A]**	**132,5 [A]**	**4 [A]**
	11.965 [B]	**236,2 [B]**	**8 [B]**
Annual national emissions 2007 /9/	102.341.120	1.439.087	471.389

[A] One cable
[B] Two cables

In Table 4.6 an evaluation of the overall impact atmospheric environment during operation phase is presented.

Table 4.6 Overall impact on the atmospheric environment in the operation phase of the project.

Impact	Intensity of effect	Scale / geographical extent of effect	Duration of effect	Overall significance of impact
Emission of pollutants	Small	Regional	Long-term	Minor

4.4 Mitigation measures

Refer to 3.4.

4.5 Cumulative effects

Refer to 3.5.

4.6 Technical deficiencies or lack of knowledge

Refer to 3.6.

5. 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. These obligations are stipulated in the United Nations Convention of the Law of the Sea (UNCLOS).

There are no specific international regulations or guidelines on the decommissioning of offshore installations. Decommissioning will have to consider individual circumstances, such as comparative decommissioning options, removal or partial removal in a way that causes no significant adverse effects on the environment, the likely deterioration of the material involved, possibilities for re-use or recycling as well as its present and future effect on the marine environment.

Based on current available technology, today's practice for decommissioning would imply to remove the wind turbines completely and to remove all other structures and substructures to the natural seabed level. Infield and export cables would be removed, left safely in-situ, buried to below the natural seabed level or protected by rock placement depending on the hydrodynamic conditions. Scour protection would be left in-situ.

The wind turbines, structures and cables would be dismantled using similar craft and methods as deployed during the construction phase. However the operations would be carried out in reverse order. The recovered materials would be transported to shore for later material reuse, recycle or disposal.

The decommissioning programme will be developed during the operations phase, as regulatory controls and industry practices most likely will have changed in 25 years' time, when the wind farm will be decommissioned. Regardless of decommissioning method, decommissioning will comply with all applicable legal requirements regarding decommissioning at that time.

6. Conclusion

For the construction of the Anholt Offshore Wind Farm the scenario with 5.0 MW turbines and monopole foundations will give rise to the smallest discharge of pollutants to the atmosphere, while the scenario with 2.3 MW turbines at gravity based structures will cause the greatest emissions. In the operation phase the majority of the emissions are caused by the maintenance of the wind turbines, whereas the inspection of cables will only make out app. 5 % of emissions. Regardless of the turbine size and type of foundation the emissions from the construction phase is very low (<<1% of annual national emissions).

For the part of the project that concerns construction and operation of the transformer station and subsea cable the difference in emissions from installing one or two cables is negligible. Thus, installation of the transformer platform represents the largest contribution of emissions during the construction phase. The emissions level is generally very low (< 0.2% of annual national emissions). The emission level in the operations phase will also be negligible.

Emissions from construction and operation of Anholt Offshore Wind Farm are regardless of technical solution assessed to be of minor importance. This has been evaluated based on several factors. Firstly, the emissions are in all cases make out very limited part of Denmark's total discharge of pollutants to the atmosphere. In addition, the majority of the emissions occur over a fixed period (the construction phase). In the light of this, it is assessed that emissions from Anholt Offshore Wind Farm will not have a significant impact on the environment. Also, it is assessed that the health effects and socioeconomic impacts due to emissions will be negligible because the emissions will be at sea where there are no receptors present in the form of people or buildings.

Table 6.1 Summary of the different project activities in the project area and the cable corridor and their potential impact on the atmospheric environment.

Potential impacts	Overall significance of impact	Quality of available data
IMPACT ON THE AIR QUALITY		
Construction phase		
Emission of air pollutants from vessel activities related to the offshore wind farm	Minor	2
Emission of air pollutants from vessel activities related to the transformer platform and subsea cable	Minor	2
Operation phase		
Emission of air pollutants from vessel activities related to the offshore wind farm	Minor	2
Emission of air pollutants from vessel activities related to the transformer platform and subsea cable	Minor	2

Table 6.2 Principles for the evaluation of potential impact. The significance rating of the assessed impact and the quality of data/documentation (from the memo describing "Method for Impact Assessment (May 2009)".

Significance rating of data and knowledge for assessment

In order to evaluate the quality and significance of data and documentation for the impact assessment a significance rating of data and documentation should be evaluated within the specific technical subject topics using the following categories:

- 1 – Limited (scattered data, some knowledge)
- 2 – Sufficient (scattered data, field studies, documented)
- 3 – Good (time series, field studies, well documented)

In this memo, an impact arising from a planned activity will, depending on its magnitude and the environmental sensitivity, be given a significance rating as follows:

: No impact	*No impact*: There will be no impact on structure or function in the affected area;
: Minor impact	*Minor impact*: The structure or functions in the area will be partially affected, but there will be no impacts outside the affected area;
: Moderate Impact	*Moderate Impact*: The structure or function in the area will change, but there will be no significant impacts outside the affected area;
: Significant impact	*Significant impact*: The structure or function in the area will change, and the impact will have effects outside the area as well;

Generally, projects can also result in positive impacts. Positive impacts are suggested to be shown with a "+" in the comprehensive tables for the predicted impacts.

7. References

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/3/ Dong Energy, Horns Rev 2, Vurdering af Virkninger på Miljøet, VVM-redegørelse, oktober 2006.

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/5/ Wahlström, J., Karvosenoja, N., and Porvari, P., 2006, "Ship Emissions and Technical Emission Reduction Potential in the Northern Baltic Sea", Finnish Environment Institute.

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/9/ Statistics Denmark webpage, www.dst.dk, visited on 23 September 2009.