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Horns Rev 3 Offshore Wind Farm

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AIR EMISSIONS

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AIR EMISSIONS

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TABLE OF CONTENTS

SUMMARY

This report presents an estimation of air pollutant emissions (NO_x, SO_2, CO_2, and PM_{10}) associated with the construction, operation and decommissioning phases of Horns Rev3. Estimates were based on the 3MW turbine option as this is considered to represent the worst case in terms of air emissions.

Emissions were estimated for two scenarios: 1) for wind turbines supported by monopile foundations, and 2) for wind turbines supported by gravity base foundations.

Potential dust emissions associated with onshore construction activities were also considered.

With appropriate controls and management in place, emissions from the construction activities will have no greater than a minor adverse and temporary impact. During the operational phase of the development, onshore and offshore air quality effects will be negligible.

SAMMENFATNING

Denne rapport indeholder en vurdering af luftforurenende emissioner (NO_x, SO_2, CO_2, og PM_{10}) i forbindelse med opførelse, drift og nedlukning af Horns Rev3. Overslagene er baseret på opførelse af 3MW møller eftersom denne option anses for at repræsentere det værste tilfælde i form af luftemissioner.

Emissionerne er anslået for to scenarier: 1) for vindmøller opført på monopæl fundamenter, og 2) for vindmøller baseret på gravitationsfundamenter. Potentielle støvemissioner ved landbaserede byggeaktiviteter er også behandlet.
Med passende kontrol og miljøledelse, vil emissionerne fra anlægsaktiviteterne ikke overstige en mindre negativ og midlertidig effekt. I driftsfasen vil onshore og offshore luftkvalitets effekter være ubetydelige.

Earthworks along the cable route

1 INTRODUCTION

This report assesses the potential impact of emissions to atmosphere (carbon dioxide (CO_2), nitrogen oxide (NO_x), sulphur dioxide (SO_2), and particulate matter (PM_{10})) associated with the proposed onshore and offshore works for the Horns Rev 3 scheme, during the construction, operation and decommissioning phases. Potential dust emissions associated with onshore construction activities are also considered.

Where the potential for impacts is identified, mitigation measures and residual impacts are presented.

The Horns Rev 3 wind farm will have an installed power of approximately 400MW. The number and size of turbines installed has not been finalized, however five options are currently under consideration as outlined in Table 1.1..

Table 1.1. Horns Rev 3 Wind turbine installation options under consideration.

Turbine Size (MW)	Number of turbines
3	136
3.6	114
4	102
8	52
10	42

It is likely that turbine size will not affect the type of vessels used during construction of Horns Rev 3. However, it is assumed that the number of turbines requiring installation will affect the time in service for each vessel (i.e. more turbines will take longer to install). Therefore the 3MW turbine option detailed in Table 1.1. represents the worst case in terms of total exhaust emissions from marine vessel fuel combustion. Emissions were therefore estimated based on the 3MW turbine option.

The wind turbines will be supported by foundations fixed to the seabed. The type of foundation to be used for Horns Rev 3 has not yet been determined, however, they may either be driven steel monopile, concrete gravity base or jacket foundations . Fully commissioned wind farms Horns Rev 1 and 2 used driven steel monopile foundations for the turbines. Assessments of emissions associated with both options are made.

2 GUIDANCE AND CONSULTATION

The emissions assessment has been undertaken with specific reference to relevant national and/or international documents. In the absence of specific technical guidance and other relevant environmental guideline documentation produced by Danish authorities, information and guidance from other sources has been referenced as it was deemed to be beneficial for inclusion in this assessment. Key information sources are presented in Table 2.1..

Table 2.1. Key Information Sources.

Data Source	Reference
Aarhus University (AU)	AU, 2013, *Annual Danish Informative Inventory Report to UNECE. Emission inventories form the base year of the protocols to year 2011*. AU, 2013, *Denmark NFR Report 2013.* AU, 2012, *Danish Emission Inventories for Road Transport and other mobile sources. Inventories until the year 2010*.
United States Environmental Protection Agency (USEPA)	USEPA, April 2009, *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories*. USEPA, December 2002, *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emission Modelling.*
AEA Technology (AEAT)	AEAT, November 2004, *Non-Road Mobile Machinery Usage, Life and Correction Factors*.
Institute of Air Quality	IAQM (2012a) *Guidance on the Assessment of the Impacts of Construction on Air Quality and the Determination of their Significance.*
Management (IAQM)	IAQM (2012b) *Dust and Air Emissions Mitigation Measures.*
4C Offshore	Anholt Offshore Wind Farm Project Vessel Database: http://www.4coffshore.com/windfarms/vessels-on-anholt-dk13.html
Rambøll	Rambøll, November 2009, *Anholt Offshore Wind Farm Air Emissions.*
Niras	Niras, November 2013, Kreigers Flak Offshore Wind Farm Air Emissions, draft report.

Excavation along the cable route

3 METHODOLOGY

The detailed design of Horns Rev 3 has not been finalized, therefore a number of assumptions have been made (detailed below) in the calculation of emissions associated with the scheme. Emissions estimated in this report are therefore indicative of emissions likely to occur. Conservative assumptions have been made where relevant so that where there are uncertainties over the detailed project design; the associated air emissions approach provides a conservative assessment.

3.1 Study Area

The offshore study area included the offshore project site and export cable route to landfall, Figure 3.1. The onshore study area included the landfall area, onshore cable routes (220kV main and alternative proposals, 150kV main proposal), converter station and substation sites, and new overhead power line.

Figure 3.1 Overview of Study Area for Horns Rev 3, Offshore and Onshore works

For the onshore construction phase dust assessment, potential sensitive receptor locations were considered within 100m of the 220kV cable route main and alternative proposals, 150kV cable route, converter and substation sites for sensitive ecological receptors, and within 350m of these locations for sensitive 'human' receptors, in accordance with the Institute of Air Quality Management (IAQM) guidance[1].

[1] IAQM (2012a) *Guidance on the Assessment of the Impacts of Construction on Air Quality and the Determination of their Significance.*

3.2 Characterisation of the Existing Environment

A detailed assessment of existing emissions within the study area was not undertaken. The main emission sources within the study area were identified through a desk top study.

Emission trends in Denmark were obtained from the annual Danish informative inventory report to the United Nations Economic Commission for Europe (UNECE)[2], and from Statistics Denmark[3]. Air quality monitoring data were obtained from the Danish Air Quality Monitoring Programme Annual Summary for 2011[4].

3.3 Assessment of Impacts

3.3.1 Offshore Construction Phase Impacts

Wind Turbine and Foundation Embodied Carbon Dioxide

Carbon Dioxide emissions associated with embodied carbon in materials and processes used in manufacturing and construction of the main components of the wind turbines and foundations were derived using factors in Table 3.1. and materials used in Table 3.2 and Table 3.3..

Table 3.1. Ecoinvent Emission factors kg/Ton from materials[5]

Material	CO_2 kg/Ton
Concrete (Emission Factor also used for Grout)	1,040
Steel	1,333
Cast Iron	1,352
Copper	1,731
Aluminium	6,703
Fibre Glass	7,687
Soil	24.0*
Sand	2.3
Stone (Emission factor used for gravel)	5.0*
Quarried Aggregate (Emission factor used for scour protection)	79.0*
Glass	910*

*Emission factors from United Kingdom Environment Agency Carbon Calculator (2007)[6]

Table 3.2 Estimated quantity of materials for manufacture of wind turbines, total for wind farm (Ton)

[2] Aarhus University, 2013, *Annual Danish Informative Inventory Report to UNECE. Emission inventories from the base year of the protocols to year 2011*.

[3] http://www.dst.dk/en

[4] Aarhus University, 2012, *The Danish Air Quality Monitoring Programme. Annual Summary for 2011*.

[5] Kriegers Flak EIA Report.

[6] United Kingdom Environment Agency, 2007, Carbon Calculator for measuring the greenhouse gas impacts of construction activities.

Turbine component	Material	3MW	3.6MW	4MW	8MW
Nacelle	Steel	17,054	15,960	14,280	**20,280**
Hub	Cast Iron	9,316	11,400	10,200	**-**
Tower	**Steel**	**20,400**	**20,520**	**21,420**	**17,680**

Note: Data were not available on material likely to be used for turbine blades, or for 10MW turbines

Table 3.3. Estimated quantity of materials for foundations, total for wind farm (Ton)

Material	3MW	3.6MW	4MW	8MW	10MW
Steel Monopile Foundations					
Steel Pile	95,200	91,200	91,800	52,000	**58,800**
Steel Transition Piece	20,400	17,100	18,360	15,600	**16,800**
Grout	9,044	7,581	7,752	5,928	**5,586**
Scour	571,200	478,800	510,000	312,000	**319,200**
Concrete Gravity Base					
Concrete	244800	228,000	224,400	156,000	**168,000**
Ballast (sand)	548352	510,720	502,656	291,200	**263,424**
Stones	48960	45,600	46,920	31,200	**33,600**
Scour Protection	217600	228,000	224,400	135,200	**117,600**
Jacket Foundations					
Steel Pile	54,400	45,600	45,900	31,200	**33,600**
Scour Protection	**217,600**	**228,000**	**244,800**	**187,200**	**210,000**

Marine Vessel Emissions

Emissions from marine vessels associated with construction of Horns Rev 3 were estimated as described below, based on the same two turbine foundation scenarios

An inventory of marine vessels likely to be used for construction and operation of Horns Rev 3 was compiled following the United States Environmental Protection Agency (USEPA) Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories[7].

The marine vessel inventory was based on details of marine vessels used during construction of the now fully commissioned Anholt Offshore Wind Farm[8]. Marine vessels

[7] USEPA, April 2009, Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories.

[8] This information was obtained from the Anholt Offshore Wind Farm project vessel database (http://www.4coffshore.com/windfarms/anholt-denmark-dk13.html).

used during the construction and operational phases of Anholt Offshore Wind Farm (which has an installed power of 399.6MW comprising 111 turbines (3.6 MW each)), with monopile foundations, are considered representative of those likely to be used for Horns Rev 3. Marine vessels likely to be associated with installation of gravity base foundations were obtained from the Anholt Offshore Wind Farm emissions assessment report (4 C Offshore, 2013).

Emission rates from marine vessels were calculated using information such as hours of operation, time in service, vessel characteristics, and number, type and horsepower of main and auxiliary engine(s) (obtained from the Anholt Offshore Wind Farm Project Vessel Database).

The flow chart in
Figure **3.2** summarises the steps taken to estimate the majority of emissions. Emission factors used for estimating marine vessel emissions were obtained from USEPA and are shown in Table 3.4..

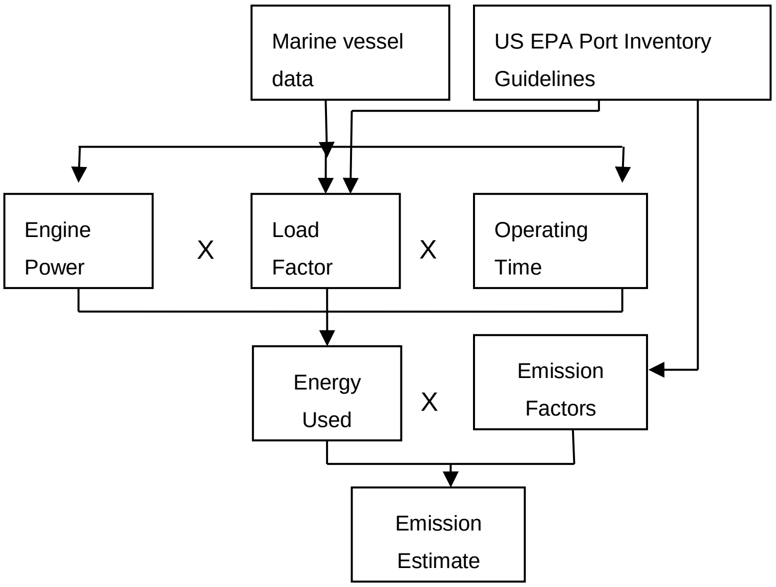

Figure 3.2 *Marine vessel emission estimation flow cart.*

Emission calculations are provided in **Appendix A**. USEPA emission factors were expressedin g/kWh, allowing emissions to be derived from working hours of marine vessels. European emission factors for marine vessels require data on fuel use (kg/Ton fuel), estimates of which were not available for this project.

Emissions estimates were derived using factors in Table 3.4. and the following assumptions:

- Marine vessels used during construction phase of the Anholt Offshore Wind Farm are representative of vessels likely to be used for Horns Rev 3;
- All vessels are assumed to operate for 24 hours in 24 hours;
- Time in service for each vessel was obtained from the Anholt Offshore Wind Farm Project vessel database[8];
- Monopile or Gravity base foundations are likely to be used for Horns Rev 3.

- The number and type of marine vessels used for installation of gravity base foundations were obtained from the Anholt Offshore Wind Farm emissions assessment report which included two scenarios for foundation types: concrete base, and gravity base (4 C Offshore, 2013) and
- All vessel main engines were assumed to be operating for 80% of the time and auxiliary engines for 20% of the time (during the working day).

Table 3.4. Emission factors g/kWh from marine vessels[9]

Emission Source	NO_x	CO_2	PM_{10}	SO_2
Turbine, substation, cable installation, and crew transfer vessels. Tier 0 Engines.	13	690	0.3	**1.3**
Turbine, substation, and cable installation vessels. Tier 2 Engines.	6.8	690	0.3	**1.3**
Crew transfer vessels. Tier 2 Engines.	**6.8**	**690**	**0.3**	**1.3**

3.3.2 Onshore Construction Phase Impacts

Cable Route, Substation and Overhead Cable, Carbon Dioxide Emissions

Carbon Dioxide emissions associated with embodied carbon in the main materials and processes used for construction of the onshore cable routes (220kV and 150kV), overhead cable and substations at Blåbjerg and Endrup were derived using factors in Table 3.1. and materials used in and Table 3.5..

Table 3.5. Estimated quantity of materials for cable routes, substation and overhead cable (Tons).

Development Aspect	Material	Quantity tons
Onshore Cable Routes		
220 kV	Aluminium, polyethylene	**2,484**
150 kV	Aluminium, polyethylene	**396**
220 kV	Sand	**5,562**
150 kV	Sand	**1,344**

[9] US Environmental Protection Agency, April 2009, *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories*.

Development Aspect	Material	Quantity tons
Substations		
Blåbjerg	Gravel	**400**
	Concrete in-situ	**627**
	Soil	**1,445**
	Reinforcing Steel	**10**
Endrup	Gravel	**3,600**
	Concrete in-situ	**2,375**
	Soil	**5,950**
	Reinforcing Steel	**35**
	Steel galvanized	**80**
Overhead Cables		
Leaders	Steel and aluminium	**340**
Insulators	**Glass**	**80**

Transport Carbon Dioxide Emissions
A carbon dioxide emission factor of 1.0 kg/km[10] was applied to each heavy goods vehicle (HGV) used during construction of the onshore cable routes (220kV and 150kV), overhead cable and substations at Blåbjerg and Endrup. Based on the materials delivery requirements each HGV was assumed to travel 50km and have a 35 ton capacity. The estimated number of HGVs associated with onshore construction works are presented inTable 3.6.

Substation Endrup

[10] Department for the Environment, Food and Rural Affairs (Defra), *2012 Greenhouse Gas Conversion Factors for Company Reporting*.

Table 3.6. Estimated number of heavy goods vehicles (HGVs) associated with construction of the cable routes, substation and overhead cable (Tons).

Development Aspect	Material	No. of HGV trips
Onshore Cable Routes		
220 kV	Aluminium, polyethylene	**25**
150 kV	Aluminium, polyethylene	**4**
220 kV	Sand	**159**
150 kV	Sand	**38**
Substations		
Blåbjerg	Gravel	**11**
	Concrete in-situ	**18**
	Soil	**41**
	Reinforcing Steel	**1**
Endrup	Gravel	**103**
	Concrete in-situ	**68**
	Soil	**170**
	Reinforcing Steel	**1**
	Steel galvanized	**2**
Overhead Cables		
Leaders	Steel and aluminium	**10**
Insulators	**Glass**	**2**

Dust Emissions

The assessment of impacts due to the generation and dispersion of dust and PM_{10} during the construction phase was undertaken in accordance with the methodology detailed in IAQM guidance. Full details of the construction phase assessment methodology are provided in **Appendix B**.

Locations potentially sensitive to construction emissions were identified with reference to guidance provided by the IAQM.

The approximate number of receptors was determined within the distance bands provided in the IAQM guidance as detailed in Table 3.7. for the proposed cable routes (main and alternative 220kV, and 150kV), new converter station at Blåbjerg, extension to substation at Endrup, and alterations to substation at Revsing.

Table 3.7. Number of Receptors within Specified Distance Bands from Proposed: cable routes (main and alternative 220kV, and 150kV), new converter station at Blåbjerg, extension to substation at Endrup, and alterations to substation at Revsing..

Distance from Proposed Development Boundary	Approximate Number of Receptors within Distance Band
Less than 20m	Less than 10 receptors
20m – 50m	10 - 100 receptors
50m – 100m	10 - 100 receptors
More than 100m	More than 500 receptors

Vehicle Emissions
Emissions from on road vehicles associated with onshore construction works were assessed qualitatively.

Non Road Mobile Machinery (NRMM) Emissions
An inventory of NRMM likely to be used for construction of Horns Rev 3 onshore cable route was compiled and the duration of construction works estimated.

Emission rates from NRMM were calculated using information such as hours of operation, time in service, and number, type and horsepower of engine(s). Emission factors were obtained from the *Danish Emission Inventories for Road Transport and other mobile sources. Inventories until the year 2010* (Table 3.8), and details such as average rated horsepower were obtained from the AEA Technology[11] and load factors from the USEPA[12].

Emissions were estimated using the formula:

E = N x HRS x HP x LF x EF

E = Mass of emissions
N = number of units
HRS = hours of use
HP = average rated horse power
LF = load factor
EF = emission factor (g/kWh)

Emissions estimates were derived using factors in Table 3.8 and the following assumptions:

- All NRMM are diesel fuelled;
- Engines installed in all NRMM meet Stage II (if below 37kW), or Stage IIIA (if above 37kW) emission limits agreed by the European Union; and
- All NRMM are operational for 10 hours in 24 hours.

[11] AEA Technology, November 2004, *Non-Road Mobile Machinery Usage, Life and Correction Factors*.
[12] United States Environmental Protection Agency, December 2002, *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emission Modelling.*

Table 3.8. Emission factors g/kWh from NRMM.

Emission Source	NO_x	TSP*
Forklift	6.5	**0.4**
Backhoe Loader	4.0	**0.2**
Excavator	3.4	**0.2**
Tractor	3.4	**0.2**
Wheeled Loader	3.4	**0.2**
Mobile Crane	3.4	0.1

*Total suspended particulates

3.3.3 Offshore Operational Phase Impacts

Marine Vessel Emissions

Emissions from marine vessels associated with maintenance and operation of Horns Rev 3 were estimated as described in section 3.3.1.

Emissions estimates were derived using factors inTable 3.4. and the following assumptions:

- Marine vessels used during the operational phase of the Anholt Offshore Wind Farm are representative of vessels likely to be used for Horns Rev 3;
- All vessels are assumed to operate for 10 hours in 24 hours;
- Time in service for each vessel was obtained from the Anholt Offshore Wind Farm Project database[8] (where this information was not available 3 months' service was assumed); and
- All vessels main engines were assumed to be operating for 80% of the time and auxiliary engines for 20% of the time (during the working day).

Carbon Dioxide Savings

The annual energy output (MWh yr) from the Horns Reef 3 Offshore wind farm was estimated using formula A below, and the carbon dioxide emissions 'saved' compared to equivalent power derived from fossil-fuel sources were estimated using formula B below:

Formula A – Annual Energy Output

$$\varepsilon_{out} = 24\ x\ 365\ x\ \frac{P_{cap}}{100}\ x\ n_{turb}\ x\ C_{turb}$$

ε_{out} = Annual Energy Output MWh yr

P_{cap} = Capacity Factor at the site (%)[13] (Assumed to be 44.9%)[14]

n_{turb}=Number of Turbines

C_{turb} = Turbine Capacity (MW)

Formula B – Carbon Savings

$$S_{fuel} = \varepsilon_{out}\ x\ \varepsilon_{fuel}$$

S_{fuel} = annual emission savings (t CO_2 yr^{-1})

ε_{out} = Annual Energy Output MWh yr

ε_{fuel}=Emission factor (tCO_2 MWh^{-1}) counterfactual case (assumed to be fossil fuel mix using emission factor[15] of 0.43 tCO_2 MWh^{-1})

Note that carbon savings calculations are based solely on a power generation comparison and do not account for loss of carbon due to production, transportation, erection, operation (backup power generation) and decommissioning of the wind farm. However, it may be argued that equivalent fossil fuel fired power stations have an equivalent or greater embedded carbon during their construction and decommissioning phases.

3.3.4 Onshore Operational Phase Impacts

Potential emissions during the operational phase were assessed qualitatively with reference to proposed onshore activities.

3.3.5 Decommissioning

The potential air quality impacts associated with the decommissioning phase were assessed qualitatively with reference to the potential impacts associated with the construction phase.

3.4 Assessment Criteria

3.4.1 Emission Assessment

Emissions associated with the construction, operational and decommissioning phases of Horns Rev 3 were compared with annual emission trends in Denmark[2]. Impacts were assessed following criteria outlined in the Horns Rev 3 report on the methodology for the EIA.

[13] Capacity factor is the ratio of the actual energy produced in a given period, to the hypothetical maximum possible, i.e. running full time at rated power.

[14] http://energynumbers.info/capacity-factors-at-danish-offshore-wind-farms

[15] The Scottish Government, *Calculating Potential Carbon Losses & Savings from Wind Farms on Scottish Peatlands: Technical Note – Version 2.0.1*

3.4.2 Construction Phase Dust Assessment

To determine the significance of dust effects associated with the construction phase, the sensitivity of the study area was defined using the criteria detailed in Table 3.9..

The impact significance was determined through the interaction of sensitivity and risk of the site giving rise to dust effects. The impact significance is detailed in Table 3.10. and Table 3.11. for both without mitigation and with mitigation in place.

Table 3.9. Sensitivity of the Area Surrounding the Site.

Area Sensitivity	Human / Residential Receptors	Ecological Receptors (*)
Very High	Very densely populated area; >100 dwellings within 20m; Local PM_{10} concentrations exceed the objective; Contaminated building present; Very sensitive receptors (e.g. oncology units); Works continuing in one area of the site for more than 1 year	European Designated site
High	Densely populated area; 10 - 100 dwellings within 20m; Local PM_{10} concentrations close to the objective (90% - 100%); Commercially sensitive horticultural land within 20m.	Nationally designated site
Medium	Suburban or edge of town area; <10 dwellings within 20m; Local PM_{10} concentrations below the objective (75% – 90%)	Locally designated site
Low	Rural or industrial area; No receptor within 20m; Local PM_{10} concentrations well below the objective (<75%) Wooded area between site and receptors	No designations

Note (*) only if there are habitats that might be sensitive to dust

Table 3.10. Significance of Effects for Each Activity (Without Mitigation).

Sensitivity of Area	Risk of Site Giving Rise to Dust Effects		
	High	Medium	Low
Very High	Substantial Adverse	Moderate Adverse	Moderate Adverse
High	Moderate Adverse	Moderate Adverse	Slight Adverse
Medium	Moderate Adverse	Slight Adverse	Negligible
Small	Slight Adverse	Negligible	Negligible

Table 3.11. Significance of Effects for Each Activity (With Mitigation).

Sensitivity of Area	Risk of Site Giving Rise to Dust Effects		
	High	**Medium**	**Low**
Very High	Slight Adverse	Slight Adverse	Negligible
High	Slight Adverse	Negligible	Negligible
Medium	Negligible	Negligible	Negligible
Small	Negligible	Negligible	Negligible

3.5 Local Emission Sources

Existing sources of air pollution in the study area include marine vessels and road transport. The main pollutants of concern from these emission sources are likely to be those relating to fuel combustion, such as CO_2, NO_2, SO_2, and PM_{10}.

The majority of larger particulate and dust in the study area is likely to be formed through mechanical generation, for example from wear of vehicle tyres and brakes, and re-suspension of settled materials due to road transport. In coastal locations a proportion of airborne particles are typically from sea salt.

3.6 Emission Trends in Denmark

National trends in emissions of NO_x, SO_2, and PM_{10} are provided in the 2013 annual Danish emission inventory report to the UNECE[2]. Data from this report are available in Nomenclature for Reporting (NFR) tables[16][17].

A projection national of greenhouse gas emissions 2010 to 2030 is provided by the National Environmental Research Institute, Aarhus University[18].

A summary of trends in these pollutants and national 2011 emission estimates from Statistics Denmark[3] are provided below.

3.6.1 Nitrogen Oxide (NO_x)

Between 1985 and 2011 total emissions of NOx decreased by 55%, mainly due to the increasing use of catalyst cars and installation of low-NO_x burners and denitrifying units in power plants and district heating plants. In 2011 the largest source of emissions of NO_x

[16] Denmark NFR Report 2013
[17] The UNECE Report and NFR Tables are available on the Eionet central data repository: http://cdr.eionet.europa.eu/dk/Air_Emission_Inventories/Submission_EMEP_UNECE

[18] Nielsen, O-K., Winther, M., Nielsen, M., Mikkelsen, M.H., Albrektsen, R., Gyldenkærne, S.,Plejdrup, M., Hoffmann, L., Thomsen, M., Hjelgaard, K. & Fauser, P., 2011: *Projection of Greenhouse Gas Emissions 2010 to 2030*. National Environmental Research Institute, Aarhus University, Denmark. 178 pp. – NERI Technical Report no. 841. http://www.dmu.dk/Pub/FR841

was road transport followed by other mobile sources and combustion in energy industries. National NO_x emissions in 2011 were estimated at 1,151,573 tons.

3.6.2 Particulate Matter

The particulate matter emissions inventory includes total suspended particles (TSP), particles smaller than 10µm (PM_{10}) and particles smaller than 2.5µm ($PM_{2.5}$).

Between 2000 and 2011 $PM_{2.5}$ emissions increased by 2% due to an increase in wood combustion in the residential sector. In 2011 the largest sources of emissions of PM_{10} were residential plants (67%) followed by road traffic and other mobile sources. The largest TSP emission sources were the residential and the agricultural sectors. National PM_{10} emissions in 2011 were estimated at 50138 tons.

3.6.3 Sulphur Dioxide (SO_2)

Between 1980 and 2010 SO_2 emissions decreased by 97%, mainly due to installation of desulphurization plant and use of fuels with lower content of sulphur in public power and district heating plants. In 2011 the largest source of emissions of SO_2 continued to be combustion of fossil fuels in public power and district heating plants. National SO_2 emissions in 2011 were estimated at 247,874 tons.

3.6.4 Carbon Dioxide (CO_2)

The largest source of CO_2 emissions (49%) is the energy sector, including combustion of fossil fuels such as oil, coal and natural gas, followed by transport which contributes to 27% of emissions. CO_2 emissions in 2009 were about 8.3 % lower than they had been in 1990[19]. National CO_2 emissions in 2011 were estimated at 98,718,000 tons[3] (including biomass).

3.7 Air Quality in Denmark

National monitoring of air quality in Denmark is undertaken by Aarhus University at a network of monitoring sites throughout the country. None of these sites are within the study area. 2011 annual average concentrations of NO_2, PM_{10} and SO_2 from these sites are presented in Table 3.12.[20]. Annual average air quality limit values were met for all pollutants at all monitoring sites with the exception of one street site in Copenhagen where an annual average concentration of 54 µg.m^{-3} was recorded. There were no exceedences of the short-term (hourly) limit value for NO_2 but two exceedences of the daily limit value for $PM_{10,}$ in Copenhagen at both sites, and at Jagtvej.

Table 3.12. 2011 Annual average concentrations of NO_2, $PM_{10,}$ SO_2 (µg.m-³).

Monitoring Sites	NO_2	PM_{10}	SO_2

[19] Nielsen, O-K., Winther, M., Nielsen, M., Mikkelsen, M.H., Albrektsen, R., Gyldenkærne, S.,Plejdrup, M., Hoffmann, L., Thomsen, M., Hjelgaard, K. & Fauser, P., 2011: *Projection of Greenhouse Gas Emissions 2010 to 2030*. National Environmental Research Institute, Aarhus University, Denmark. 178 pp. – NERI Technical Report no. 841. http://www.dmu.dk/Pub/FR841

[20] Aarhus University, 2012, *The Danish Air Quality Monitoring Programme. Annual Summary for 2011*.

Monitoring Sites	**NO_2**	**PM_{10}**	**SO_2**
Street Sites			
Copenhagen/1257	40	32	
Copenhagen/1103	54	35	3
Arhus/6153	39	29	
Odense/9155	25	27	
Aalborg/8151	31		2
Urban Background Sites			
Copenhagen/1259	18	23	
Arhus/6159	20		
Odense /9159	16		
Aalborg (Østerbro)	13		
Rural Sites			
Risø	9	20	
Keldsnor	10	20	
Limit Values	40	40	20

Sea cabling at landfall site

4 SOURCES OF IMPACTS

4.1 Main Impacts – Construction Phase

Onshore and offshore construction activities such as those described below have the potential to affect atmospheric emissions:

- dust emissions generated by excavation, construction and earthworks along the cable route, and construction of the converter stations and associated landscaping, which have the potential to cause nuisance to, and soiling of, sensitive receptors, as well as potentially increasing local PM_{10} concentrations;
- emissions of NO_2 and PM_{10} from non-road mobile machinery (NRMM) operating within the construction footprint;
- emissions of exhaust pollutants, especially NO_x, SO_2 and PM_{10} from on road construction traffic and marine vessels;
- CO_2 emissions associated with fuel use (on road construction traffic, non-road mobile machinery and marine vessels); and
- CO_2 emissions associated with embodied carbon in the materials and processes used during the manufacture of the wind turbines and construction of the onshore cable routes (220kV and 150kV), overhead cable and substations.

4.2 Main Impacts – Operational Phase

Once operational, there will be site traffic associated with maintenance of the onshore cable systems and converter stations, albeit likely to be low vehicle numbers. Offshore, marine vessels will be used for cable and turbine maintenance activities.

Emissions of exhaust pollutants from road vehicles and marine vessels associated with these maintenance activities have the potential to affect atmospheric concentrations.

Energy generated by the wind farm may replace energy that would otherwise have been produced by fossil fuels, and so provide a potential emissions benefit.

4.3 Main Impacts – Decommissioning Phase

Impacts associated with the decommissioning of the cable route, converter stations and offshore infrastructure will be similar to those identified during construction. These include emissions of dust, emissions from NRMM and emissions from road traffic during the decommissioning phase.

5 ASSESSMENT OF EFFECTS OFFSHORE

5.1 Construction Phase

5.1.1 Wind Turbine and Foundation Embodied Carbon Dioxide

The embodied carbon dioxide emitted during the manufacture, transport and construction of the main components of the wind turbines and foundations was estimated following the methodology outlined in section 3, and are presented in Table 5.4. and Table 5.2..

Table 5.1. Estimated embodied CO_2 (Ton) emissions from turbine manufacture, total for wind farm.

Turbine component	Material	3MW	3.6MW	4MW	8MW
Nacelle	Steel	131,097	122,685	109,770	**155,892**
Hub	Cast Iron	12,595	15,413	13,790	
Tower	Steel	27,193	27,353	28,553	**23,567**
TOTAL CO_2 t		**170,886**	**165,450**	**152,114**	**179,460**

Note: Data were not available on material likely to be used for turbine blades, or for 10MW turbines.

Table 5.2. Estimated embodied CO_2 (Ton) emissions from turbine foundations, total for wind farm.

Material	3MW	3.6MW	4MW	8MW	10MW
Steel Monopile Foundations					
Steel Pile	126,902	121,570	122,369	69,316	**78,380**
Steel Transition Piece	27,193	22,794	24,474	20,795	**22,394**
Grout	9,406	7,884	8,062	6,165	**5,809**
Scour	2,856	2,394	2,550	1,560	**1,596**
TOTAL CO_2 t	166,357	154,642	157,455	97,836	**108,180**
Concrete Gravity Base					
Concrete	254,592	237,120	233,376	162,240	**174,720**
Ballast (sand)	1,261	1,175	1,156	670	**606**
STone	3,868	3,602	3,707	2,465	**2,654**
Scour Protection	1,088	1,140	1,122	676	**588**
TOTAL CO_2 t	260,809	243,037	239,361	166,051	**178,568**
Jacket Foundations					
Steel Pile	72,515	60,785	61,185	41,590	**44,789**
Scour Protection	1,088	1,140	1,224	936	**1,050**
TOTAL CO_2 t	**73,603**	**61,925**	**62,409**	**42,526**	**45,839**

CO_2 emissions are highest from the concrete gravity base foundations (due to the energy intensive process associated with concrete production). A summary of embodied CO_2 emissions from the turbines with concrete gravity base foundations is presented in Table 5.3., providing a worst case scenario. The table shows that the impact of CO_2 emissions associated with turbine manufacture and foundations on national emissions is considered to be negligible.

Table 5.3. Estimated embodied CO_2 (Ton) from turbine manufacture, and foundations total for wind farm.

	3MW	3.6MW	4MW	8MW
Turbine Manufacture	170,886	165,450	152,114	**179,460**
Concrete Gravity Base Foundations	260,809	243,037	239,361	**166,051**
TOTAL CO_2 t (% of National Emissions)	431,695 (0.4%)	408,488 (0.4%)	391,474 (0.4%)	**345,510 (0.3%)**
TOTAL NATIONAL EMISSIONS 2011 CO_2 t	**98,718,000**			

5.1.2 Marine Vessel Emissions

Engine exhaust emissions from marine vessels associated with offshore construction activities for Horns Rev 3 will contribute to concentrations of NOx, CO_2, SO_2 and PM_{10}.

The wind turbines will be supported by foundations fixed to the seabed. It is likely that the foundations will comprise driven steel monopiles or concrete gravity bases. The installation techniques for each of these foundation types are different as described below.

For monopile foundations seabed preparation works are unlikely to be required, although some removal of seabed obstructions may be necessary. A 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.

For concrete gravity base foundations seabed preparation works would be required, including removal of the top layer of seafloor material which would be replaced by a stone bed. When the foundation is placed on the seabed, the foundation base is filled with a suitable ballast material (typically sand), and a steel 'skirt' may be installed around the base to penetrate into the seabed and to constrain the seabed underneath the base.

The installation of concrete gravity base foundations is likely to require more marine vessels than for the installation of monopile foundations. This is due to excavation works during seabed preparation, disposal of excavated materials, and material deliveries.

Marine vessels likely to be associated with offshore construction activities for the 3MW turbine option (136 turbines) and their time in service is detailed in Table 6-1. This information was obtained from the Anholt Offshore Wind Farm project vessel database[8] (for monopile foundations), and the air emissions assessment report for Anholt Offshore Wind

Farm (4 C Offshore, 2013) (for gravity base foundations). These vessels may operate separately or concurrently throughout the construction period.

Table 5.4. Marine vessels likely to be associated with construction activities.

Activity	Vessel Type	Number of vessels	Time in Service (months)
Turbine Installation – Monopile Foundations	Heavy Lift Vessel	2	8 and 4
	Jack up Vessel	3	9, 3 and 5
	Jack up Barge	1	4
	Tug Boat	2	5
Turbine Installation – Gravity Base Foundations	Heavy Lift Vessel	4	17,15,8 and 4
	Jack up Vessel	3	9, 3 and 5
	Jack up Barge	1	4
	Tug Boat	3	4 and 15
	Barge Excavator	1	15
	Barge	1	11
Substation Installation	Jack up Vessel	1	24
	Heavy Lift Vessel	1	3 (days)
Cable Installation	Cable Laying Ship	1	3
	Support Vessel	1	8
	Multi-purpose barge	1	5
	Tug boat	1	5
Crew Transfer	Crew Boat	9	10,9,8,8,7,6,4,3, 0.25.
Other – support	Support Vessel	1	6
Other – Transport of transition pieces	Heavy Lift Vessel	1	1

Emissions of NO_x, CO_2, SO_2, and PM_{10} from marine vessels in Table 5.4. were estimated following the methodology outlined in section 3, and are presented in Table 5.5..

Emissions of all pollutants are higher for turbines installed with concrete gravity base foundations due to the greater number of vessels required for installation of this foundation type.

Engine exhaust emissions from marine vessels operating offshore will be subject to effective dilution and dispersion, and will have dispersed well by the time they reach any terrestrial receptors, at a distance of some 20-30km. It is therefore likely that their impact on air quality at existing human receptors along the coastline within the study area will be negligible.

With monopile and gravity base foundations, emissions from marine vessels associated with construction of Horns Rev 3 (presented in Table 5.5.) are predicted to be less than one percent of 2011 national emissions of NOx, CO_2, SO_2, and $PM_{10.}$ With a gravity-base foundation scenario, emissions would be marginally greater, than with a monopile foundation scenario. Overall the impact of air emissions from marine vessels during the construction phase on local and national emissions is considered to be negligible.

Table 5.5. Estimated emissions from marine vessels associated with construction activities (Tonnes).

Activity	Vessel Type	Number of Vessels	NO_x	CO_2	SO_2	PM_{10}
Turbine Installation – Monopile foundations	Heavy Lift Vessel	2	359	21,667	41	9
	Jack up Vessel	3*	161	12,654	24	6
	Jack up Barge	1**	-	-	-	-
	Tug Boat	2	30	3,050	6	1
Turbine Installation – Gravity Base Foundations	Heavy Lift Vessel	4	1,160	75,386	142	33
	Jack up Vessel	3*	161	12,654	24	6
	Jack up Barge	1**	-	-	-	-
	Tug Boat	2	75	7,625	14	3
	Barge Excavator	1**	-	-	-	-
	Barge	1**	-	-	-	-
Substation Installation	Jack up Vessel	1	200	10,623	20	5
	Heavy Lift Vessel	1	2	88	0	0
Cable Installation	Cable Laying Ship	1	32	3,268	6	1
	Support Vessel	1	80	8,110	15	4
	Multi-purpose barge	1	-	-	-	-
	Tug Boat	1	15	1,525	3	1
Crew	Crew Boat	9	142	12,895	24	6

Activity	Vessel Type	Number of Vessels	NO_x	CO_2	SO_2	PM_{10}
Transfer						
Other – support	Support Vessel	1	10	994	2	0
Other – Transport of transition pieces	Heavy Lift Vessel	1	14	1,378	3	1
TOTAL (% of national emissions) – Mono-pile Foundations			1,043 (0.09%)	76,254 (0.08%)	144 (0.06%)	33 (0.07%)
TOTAL (% of national emissions)– Gravity Base Foundations			2,933 (0.25%)	210,801 (0.21%)	397 (0.16%)	92 (0.18%)
TOTAL NATIONAL EMISSIONS 2011			1,151,573	98,718,000	247,874	50,138

*1 drawn by two tugs

** drawn by one tug

5.2 Operational Phase

5.2.1 Marine Vessel Emissions

Engine exhaust emissions from marine vessels associated with inspection of the offshore cable and maintenance of the turbines for Horns Rev 3 will contribute to concentrations of NO_2, SO_2 and PM_{10}. (Helicopters may also be used with respect to maintenance. These have not been included in the overall calculations).

It is likely that the majority of offshore maintenance will occur periodically during the summer months to take advantage of better weather conditions.

Marine vessels likely to be associated with offshore maintenance activities and their time in service (annually) are detailed in Table 5.6.. This information was obtained from the Anholt Offshore Wind Farm project vessel database[8]. These vessels may operate separately or concurrently throughout the year.

Table 5.6. Marine vessels likely to be associated with maintenance activities (annually).

Activity	**Vessel Type**	**Number of vessels**	**Time in Service (months)**
Crew Transfer	Crew Boat	16	Between 0.2 (6 days) and 7 months
Other – support	ROV Support Vessel	1	3

Annual emissions of NO_x, CO_2, SO_2, and PM_{10} from marine vessels in **Table 5.6.** were estimated following the methodology outlined in section 3, and are predicted to be around 0.01 percent of 2011 national emissions (results are presented in **Table 5.7.**). Overall the impact of emissions from marine vessels during the operational phase on local and national emissions is considered to be negligible.

Table 5.7. Estimated annual emissions from marine vessels associated with maintenance activities (Tons)

Activity	Vessel Type	Number of Vessels	NO_x	CO_2	SO_2	PM_{10}
Crew Transfer	Crew Boat	16	60	5816	11	3
Other – support	ROV Support Vessel	1	14	1458	3	1
TOTAL (% of national emissions)			74 (0.01%)	7,274 (0.01%)	14 (0.01%)	4 (0.01%)
TOTAL NATIONAL EMISSIONS 2011			1,151,573	98,718,000	247,874	50,138

5.2.2 Carbon Dioxide Savings

Energy generated by the wind farm may replace energy that would otherwise have been produced by fossil fuels, thereby leading to a reduction in CO_2 emissions. Estimated annual carbon savings associated with the wind farm are presented Table 5.8.. These savings may contribute to a significant reduction in national CO_2 emissions, which, depending on the turbine scenario would amount to savings of between 690 and 710 ktons per year, around 0.7 percent of national (2011) emissions.

Table 5.8. Estimated annual carbon savings (Tons).

	3MW	3.6MW	4MW	8MW	10MW
Annual energy output MWh/yr	1,604,762	1,614,202	1,604,762	1,636,228	1,651,961
*Annual emission savings tCO_2/yr	**690,048**	**694,107**	**690,048**	703,578	710,343

*Compared to electricity grid mix.

5.3 Decommissioning Phase

As a precautionary worst case scenario it is assumed that all infrastructure including cables will be removed. Exact decommissioning arrangements would be detailed in a Decommissioning Plan, which would be drawn up prior to decommissioning. Any impacts arising from the decommissioning process will be the subject of future assessment, once the nature of activities is understood.

6 ASSESSMENT OF EFFECTS ONSHORE

6.1 Construction Phase

6.1.1 Cable Route, Substation and Overhead Cable, Carbon Dioxide Emissions

Emissions of NO_x and total suspended particulates (TSP) from NRMM were estimated following the methodology outlined in section 3, and are predicted to be well below one percent of 2011 national emissions (results are presented in Table 6.7.).

CO_2 emissions associated with embodied carbon in the main materials and processes used for construction of the onshore cable routes (220kV and 150kV), overhead cable and substations at Blåbjerg and Endrup were estimated following the methodology outlined in section 3. Construction material assumptions are given in Table 6.1. and results are presented in Table 6.2., which show that total cable route construction CO_2 emissions are predicted to be well below one percent of 2011 national emissions.

Table 6.1. Estimated embodied CO_2 (Ton) from materials for construction of underground cable routes, substation and overhead cable (Tons).

Development Aspect	**Material**	**CO_2 t**
Onshore Cable Routes		
220 kV	Aluminium, polyethylene	**16,745**
150 kV	Aluminium, polyethylene	**2,559**
220 kV	Sand	**13**
150 kV	Sand	**3**
Substations		
Blåbjerg	Gravel	**32**
	Concrete in-situ	**652**
	Soil	**35**
	Reinforcing Steel	**13,330**
Endrup	Gravel	**284**
	Concrete in-situ	**2,470**
	Soil	**143**
	Reinforcing Steel	**46,655**
	Steel galvanized	**106,640**
Overhead Cables		
Leaders	Steel and aluminium	**227,750**
Insulators	**Glass**	**73**

Table 6.2. Estimated embodied CO_2 (Ton) from materials for cable routes, substation and overhead cable (Tons).

Development Aspect	**CO_2 t**
Cable route (cables + sand)	6,692
Substation Blabjerg	14,048
Substation Endrup	156,192
Overhead Cables	227,822
TOTAL CO2 t (% of National emissions)	404,755 (0.4%)
TOTAL NATIONAL EMISSIONS 2011 CO2 t	98,718,000

The impact of CO_2 emissions associated with materials used for construction of the underground cable routes, substations and overhead cable on national CO_2 emissions is considered to be negligible.

6.1.2 Transport Carbon Dioxide Emissions

HGVs used during construction of the onshore underground cable routes (220kV and 150kV), overhead cable and substations at Blåbjerg and Endrup were estimated to emit 41 tons of CO_2 during the construction phase. The impact on national CO_2 emissions is considered to be negligible.

6.1.3 Dust Emissions

Sensitive Receptors

Locations potentially sensitive to construction dust emissions within the study area were identified with reference to guidance provided by the IAQM. The potential for sensitive receptors to be affected will depend on where within the study area the dust-raising activity takes place, the nature of the activity and controls, and meteorological dispersion conditions.

The sensitivity of the study area to construction phase dust emissions was determined with reference to the sensitivity criteria detailed in Table 3-2.

Sensitive receptors were identified less than 20m from the proposed cable routes (main and alternative 220kV cable routes and the 150kV cable route), substation and converter station sites.

The cable routes, converter station and substations are located within a predominantly rural area with some existing residential development. The construction works will be undertaken over cultivated land and there are fewer than 10 residential dwellings located within 20m of construction sites. The surrounding area was therefore defined as being of ‘medium’ sensitivity with respect to human receptors.

A number of ecological sites were identified within 100m of the cable routes, converter station and substations (Table 6.3., Table 6.4. and Table 6.5.), including statutory designations under the Habitats Directive and Bird Directive. There are also a number of nationally designated areas including national parks and habitat & species management areas.

Table 6.3. Ecological Receptors identified within 100m of 220 kV cable route from Henne Strand to station Endrup - Main Proposal.

Location	Ecological Classification
Stretch from Henne Strand to station Blåbjerg	Natura 2000 area, (protected dunes, protected nature conservation area)
Stretching from the station Blåbjerg through Blåbjerg-plantation	Forest Reserve, Protected Nature, Natura 2000 site
Søndersig	Protected Forest
Varde Å	Natura 2000 area
Station Endrup	Protected Nature reserve

Table 6.4. Ecological Receptors identified within 100m of 220 kV cable route from Henne Strand to station Endrup - Alternative Proposal.

Location	Ecological Classification
Stretch from Henne Strand to station Blåbjerg	Natura 2000 area, protected dunes, protected nature conservation area
Stretching from the station Blåbjerg through Blåbjerg plantation	Forest reserve, Protected Nature reserve, Natura 2000 site
Område ved Dybvad Gårde	Protected Nature reserve and Burial Mounds
The area west from Galtho	Protected Nature and Forest reserve.
Area West to Hoddeskov	Protected Nature and Forest reserve.
Varde Å	Natura 2000 area and Protected Nature reserve
Område ved Porsmose	Protected Nature reserve
Holme Å	Protected Nature and Forest reserve.
Nord for Biltoft	Protected Nature reserve
Bækhede Plantage	Protected Nature and Forest reserve.
Station Endrup	Protected Nature reserve

Table 6.5. Ecological Receptors identified within 100m of 150 kV cable route from station Endrup to station Holsted.

Location	Ecological Classification
Sneum Å	Protected Nature and Forest reserve.
Area West to Sekær mose	Archaeological Interest
The area west from Station Holsted	Heritage Area

All proposed cable routes will cross sections of European designated sites. The surrounding areas were therefore defined as being of 'very high' sensitivity with respect to ecological receptors.

PM_{10} and Dust Effects

If construction operations were un-mitigated, the effects of dust during dry and windy conditions, could lead to an increase in the 24-hour mean PM_{10} concentration immediately surrounding construction activities.

Monitoring results in Table 3.12 indicate that the PM_{10} concentrations found at the urban background and rural locations are low, at 20-23µg.m-³. In consideration of human health effects, it is unlikely that the short-term construction operations would cause the annual mean limit value to be exceeded within the study area.

A qualitative assessment of construction phase dust emissions was carried out in accordance with the IAQM guidance. The potential overall significance, in terms of construction dust prior to mitigation is summarised in the construction phase assessment matrix and is provided in Table B6 of Appendix B for the main proposal and Table B7 of Appendix B for the alternative proposal.

Results from the assessment for the 220kV cable route main and alternative proposals, 150kV cable route, converter and substation sites indicate that the route is of 'medium' sensitivity in terms of proximate human receptors and 'very high' sensitivity in relation to proximate ecological receptors. The overall effects of dust and PM_{10} releases during the construction phase of the main proposal are considered to have at worst, a moderate adverse impact at the nearest sensitive 'human' and 'ecological' receptor locations without any mitigation measures applied (See **Appendix A**).

Mitigation

Conventional good practice measures to mitigate dust emissions from Horns Rev 3 construction activities should be included within a Construction and Environmental Management Plan (CEMP) to prevent or minimise the release of dust entering the atmosphere and/or being deposited on nearby receptors. Particular attention should be paid to operations which must unavoidably take place close to the site boundary.

The moderate adverse risk of dust emissions identified above is associated with construction, trackout and earthwork activities. It is therefore recommended that mitigation measures outlined in Table 6.3. (taken from IAQM guidance) are included in the CEMP.

Table 6.6. Potential Dust Mitigation Measures.

Mitigation Measures
Earthworks • damping down all dusty activities and surfaces, especially during dry, windy weather; • temporary covering of earthworks, or if possible secure covering during dry, windy weather; • re-vegetation of earthworks and other exposed areas to stabilise surfaces; • reuse hard core material where possible; • removal of secure covers in small areas during work; and • implementation of hessian or mulches where it is not possible to re-vegetate or cover with topsoil. **Construction** • Erect appropriate hoarding and / or fencing, particularly adjacent to the site boundaries, to reduce dust dispersion and restrict public access; • Sheet buildings, chutes, skips and vehicles removing wastes; • Appropriate handling and storage of materials; • Prevent dust contaminated runoff water from the site; • Use gas powered generators rather than diesel if possible; • Ensure that all plant and vehicles are well maintained so that exhaust emissions do not breach statutory emission limits; • Use dust extraction techniques where available; • Minimise drop heights to control the fall of materials; and • Fit all equipment (e.g. for cutting, grinding, crushing) with dust control and / or water suppressant measures such as water sprays wherever possible. **Trackout** • use of a wheel wash, limiting of vehicle speeds onsite, avoidance of unnecessary idling of engines and routing of site traffic as far from residential and commercial properties as possible; • avoid dry sweeping of large areas; • ensure vehicles transporting material entering and leaving sites are covered to prevent escape of materials during transport; • use of a road sweeper to clean mud and other deposited particulates from hard standing roads and footpaths; and • use of hard surface haul routes where possible.

Residual Impact

Step four of the IAQM guidance defines the significance of each potential dust effect and is undertaken after applying site-specific mitigation.

The significance of effects for each activity is determined through the interaction of area sensitivity and the effect of dust emissions with mitigation in place as detailed in Table B6 and Table B7 in Appendix B.

Effective implementation of a CEMP and incorporation of the recommended mitigation measures would reduce the effect of dust emissions from earthworks, construction and trackout on sensitive human receptors to a negligible impact and a minor adverse impact on statutory ecological receptors.

6.1.4 Vehicle Emissions

Emissions of NO_2 and PM_{10} are strongly related to vehicle speeds, with highest vehicle emission rates occurring at very slow speeds and lowest emission rates occurring in free flowing traffic. The estimated 442 Heavy Goods Vehicles (HGVs) associated with on-shore construction works will change the traffic volume and composition on haul roads, potentially resulting in reduced speeds and hence increased NO_2 and PM_{10} emissions along the route.

It is anticipated that the installation of cable systems, trenching and directional drilling works, and construction of the converter station and substation works will result in changes in traffic volume and composition on local roads used by construction vehicles. In addition, construction works have the potential to result in disruption to traffic due to temporary road closures, temporary traffic lights and detours, all of which can potentially result in localised traffic congestion.

Vehicle emissions may increase around the primary compound areas, which will be established at specified locations along the length of the cable route and at the converter stations site.

Emissions from HGVs associated with onshore construction works will add to the existing background NO_2 and PM_{10} concentrations. However, although the number of vehicles have been estimated, the haul route details are currently unknown and a quantitative assessment of on road construction vehicles was not possible at the time this assessment was undertaken. Nevertheless with a well-managed construction scheme and due consideration to haul routes and existing traffic flows, it is unlikely that any associated air quality effects will be significant in the context of the existing environment.

6.1.5 Non Road Mobile Machinery (NRMM)

Non Road Mobile Machinery (NRMM) likely to be used for onshore construction activities and their time in service are detailed in Table 6.7.. Engine exhaust emissions from this machinery will contribute to ambient concentrations of NO_2, and PM_{10}.

Emissions of NO_x and total suspended particulates (TSP) from NRMM were estimated following the methodology outlined in section 3, and are predicted to be well below one percent of 2011 national emissions (results are presented in Table 6.7.). Overall the impact of emissions from site based NRMM during the construction phase on local and national emissions is considered to be minor.

Table 6.7. Non Road Mobile Machinery (NRMM) likely to be used for construction works.

Activity	NRMM Type	Number	Size (kW) (Average)[21]	Load Factor (fraction[22] of power)	Time in Service (months)
Laying of 220kV cable (Main and alternative Proposals require the same number and type of NRMM)	Excavators	5	100	0.59	7
	Backhoe Loader	4	67.5	0.21	
	Tractors	4	78	0.21	
	Wheel Loader	1	112.5	0.59	
	Drilling Machine	2	~	~	
Laying of 150 kV cable	Excavators	5	100	0.59	4
	Backhoe Loader	4	67.5	0.21	
	Tractors	4	78	0.21	
	Wheel Loader	1	112.5	0.59	
	Drilling Machine	2	~	~	
Construction of new converter station at Blåbjerg	Excavators	1	100	0.59	6-9
	Backhoe Loader	1	67.5	0.21	
	Wheel Loader	1	112.5	0.59	
Extension to substation at Endrup	Excavators	1	100	0.59	12-18
	Backhoe Loader	2	67.5	0.21	
	Wheel Loader	1	112.5	0.59	
	Tractors	1	78	0.21	
	Fork Lift	1-2	35	0.59	
Alterations to the substation at Holsted	Fork Lift	1	35	0.59	14 days
Alterations to the substation at Revsing	Fork Lift	1	35	0.59	5 days
Upgrade of overhead power line	Winch	2	~	~	4
	Mobile Crane	2	225	0.43	
	Fork Lift	2	35	0.59	
	Conductor Brake	1	~	~	

[21] AEAT Document
[22] USEPA Document

Activity	NRMM Type	Number	Size (kW) (Average)[21]	Load Factor (fraction[22] of power)	Time in Service (months)
	Backhoe Loader	1	67.5	0.21	

~ Information not available

Table 6.8. Estimated emissions from NRMM associated with construction works (Tons).

Activity	NRMM Type	Number	NOx	TSP
Laying of 220kV cable (Main and alternative Proposals require the same number and type of NRMM)	Excavators	5	2.63	0.15
	Backhoe Loader	4	0.60	0.03
	Tractors	4	0.59	0.03
	Wheel Loader	1	0.59	0.02
	Drilling Machine	2	~	~
		TOTAL	4.41	0.24
Laying of 150 kV cable	Excavators	5	1.51	0.09
	Backhoe Loader	4	0.34	0.02
	Tractors	4	0.33	0.02
	Wheel Loader	1	0.34	0.02
	Drilling Machine	2	~	~
		TOTAL	2.52	0.15
Construction of new converter station at Blåbjerg	Excavators	1	0.68	0.04
	Backhoe Loader	1	0.19	0.01
	Wheel Loader	1	0.76	0.04
		TOTAL	1.63	0.09
Extension to substation at Endrup	Excavators	1	1.35	0.08
	Backhoe Loader	2	0.77	0.04
	Wheel Loader	1	1.52	0.09
	Tractors	1	0.38	0.02
	Fork Lift	2	1.81	0.11
		TOTAL	5.83	0.34
Alterations to the substation at Holsted	Fork Lift	1	0.03	0.00
Alterations to the substation at	Fork Lift	1	0.01	0.00

Activity	NRMM Type	Number	NOx	TSP
Revsing				
Upgrade of over-head power line	Winch	2	~	~
	Mobile Crane	2	0.99	0.03
	Fork Lift	2	0.40	0.02
	Conductor Brake	1	~	~
	Backhoe Loader	1	0.09	0.00
TOTAL			1.48	0.06
TOTAL ALL ACTIVITIES (% of national emissions)			15.90 (0.001)	0.88 (0.002)
TOTAL NATIONAL EMISISONS 2011			1,151,573	50,138*

*Emission factor not available to estimate emissions *PM_{10} emissions

Mitigation Measures

NRMM and plant should be well maintained. If any emissions of dark smoke occur then the relevant machinery should stop immediately and any problem rectified. In addition, the following controls should apply to NRMM:

- All NRMM should use fuel equivalent to ultra-low sulphur diesel (fuel meeting the specification within EN590:2004);
- All NRMM should comply with either the current or previous EU Directive Staged Emission Standards (97/68/EC, 2002/88/EC, 2004/26/EC). As new emission standards are introduced the acceptable standards will be updated to the previous and most current standard;
- All NRMM should be fitted with Diesel Particulate Filters (DPF) conforming to defined and demonstrated filtration efficiency (load/duty cycle permitting);
- The on-going conformity of plant retrofitted with DPF, to a defined performance standard, should be ensured through a programme of on-site checks; and
- Energy conservation measures should be implemented including instructions to throttle down or switch off idle construction equipment; switch off the engines of trucks while they are waiting to access the site and while they are being loaded or unloaded, ensure equipment is properly maintained to ensure efficient energy consumption.

Residual Impact

Successful implementation of the above mitigation measures would ensure that emissions from NRMM used during construction are not significant.

6.2 Operational Phase

Following completion of construction, local traffic will return to existing flows and volumes. There will be minimal maintenance and site traffic associated with the operation of the cable systems and converter stations. As such, a negligible impact on emissions is anticipated.

6.3 Decommissioning Phase

The decommissioning of the onshore elements of Horn Rev3, including the cable route and the converter stations will form part of an overall Decommissioning Plan, for which a full EIA would be carried out ahead of any decommissioning works being undertaken.

In relation to the converter stations, the programme for decommissioning would be expected to be similar in duration to the construction phase. The detailed activities and methodology will be determined later within the project lifetime, but is expected to include:

- dismantling and removal of above ground electrical equipment;
- removal of any building services equipment;
- demolition of the buildings and removal of security fences; and
- landscaping and reinstatement of the site.

At the time of decommissioning, it will be evaluated whether the buried cable system could be used for another purpose. If this is not feasible, the above ground features will be removed to a sufficient depth to allow agricultural (or other) practices to occur unhindered.

Converter station Revsing

7 CUMULATIVE IMPACTS

This section describes the approach to cumulative impact assessment for air emissions, taking into consideration other plans, projects and activities.

The air emission produced in relation to the development of Horns Rev 3 is almost entirely related to the construction phase, with negligible emissions associated with operational phase maintenance activities. Therefore there will be no permanent cumulative air quality effects generated by the project. Temporary cumulative effects have been considered in relation to other relevant construction works relevant to the construction sites of Horns Rev 3. At present no relevant projects or plans are known.

Installation of transformer platform – Anholt Offshore Wind Farm

8 SUMMARY OF IMPACT ASSESSMENT

This technical report to the EIA has assessed the potential impact of onshore and offshore activities, associated with Horns Rev 3 on airborne emissions of NOx, CO2, SO2 and PM10. It has also assessed the potential impact of dust emissions associated with onshore works during the construction phase.

Table 8 1 provides a summary of the potential impacts on emissions arising from the scheme. The main impacts in relation to air emissions are associated with the construction phase of Horns Rev 3. However, residual impacts with appropriate mitigation in place are assessed as minor adverse or less. These are considered acceptable given the temporary nature of the impacts, encountered during construction only. During operation, air quality impacts are assessed as negligible. The impacts during decommissioning will be similar to those during construction and will be subject to a decommissioning plan and associated EIA at the relevant time.

Table 8 1. Summary of predicted impacts on emissions associated with Horns Rev 3.

Description of impact	Mitigation measures	Residual impact
Construction phase		
Wind turbine and foundations embodied CO_2	N/A	Negligible
Marine vessel exhaust emissions	N/A	Negligible
Cable route, substation and overhead cable CO_2 emissions.	N/A	Negligible
Transport CO_2 emissions	N/A	Negligible
Dust Emissions	Dust mitigation measures included in CEMP	Negligible* Minor Adverse**
Vehicle Exhaust Emissions	N/A	Minor Adverse
Non Road Mobile Machinery Emissions	Mitigation measures included in CEMP	Negligible
Operational phase		
Onshore emissions	N/A	Negligible
Offshore emissions	N/A	Negligible
CO_2 Savings	N/A	Beneficial
Decommissioning phase		
Onshore emissions	As for construction	As for construction
Offshore emissions	As for construction	As for construction

* Human Receptors

** Ecological Receptors

CO_2 emissions associated with the construction phase of the wind farm development are likely to be paid back within the near future due to the potentially significant CO_2 savings associated with its operation.

Offshore wind farm construction Horns Rev 1 Offshore wind Farm

9 REFERENCES

Aarhus University, 2013, Annual Danish Informative Inventory Report to UNECE. Emission inventories form the base year of the protocols to year 2011.

Aarhus University, 2013, Denmark NFR Report 2013.

Aarhus University, 2012, Danish Emission Inventories for Road Transport and other mobile sources. Inventories until the year 2010.

Aarhus University, 2012, The Danish Air Quality Monitoring Programme. Annual Summary for 2011.

AEA Technology, November 2004, Non-Road Mobile Machinery Usage, Life and Correction Factors.

4 C Offshore. (2013). *Vessels working on Anholt. Vessel Database*. Hentet fra 4C Offshore: Anholt Wind Farm Project http://www.4coffshore.com/windfarms/vessels-on-anholt-dk13.html

Department for the Environment, Food and Rural Affairs (Defra), *2012 Greenhouse Gas-Conversion Factors for Company Reporting*.

http://energynumbers.info/capacity-factors-at-danish-offshore-wind-farms

Institute of Air Quality Management, 2012, Guidance on the Assessment of the Impacts of Construction on Air Quality and the Determination of their Significance.

Institute of Air Quality Management IAQM, 2012, Dust and Air Emissions Mitigation Measures.

Rambøll, November 2009, Anholt Offshore Wind Farm Air Emissions.

Statistics Denmark : [1] http://www.dst.dk/en

United Kingdom Environment Agency, 2007, Carbon Calculator for measuring the greenhouse gas impacts of construction activities.

United States Environmental Protection Agency, April 2009, Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories.

United States Environmental Protection Agency, December 2002, Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emission Modelling.

10 APPENDIX A –EMISSION CALCULATIONS

Emissions Estimate for Turbine Installation Vessels – Monopile Foundations

Ship Name	Vessel Category	Main Engine Propulsion kW	Auxiliary Engines kW
Svanen	Workboat/ Heavy Lift Vessel	12260	1600
Jumbo Javelin	Workboat/ Heavy Lift Vessel	8640	
Sea Power	Workboat/Jack up Vessel	2400	1500
Sea Installer	Workboat/Jack up Vessel	18120	
Sea Worker	(drawn by tug)		
Sea Jack	(drawn by tug)		
Tug Boat	Tug Tow Pushboat	2610	170
Tug Boat	Tug Tow Pushboat	2610	170

Months in service	Power Rating Propulsion and Auxiliary Assume 80% use of Propulsion and 20% Auxiliary all the time	P=Power Rating (Propulsion+Auxiliary)	Engine Tier
8	Svanen	10128	0
4	Jumbo Javelin	6912	2
9	Sea Power	2220	0
3	Sea Installer	14496	2
5	Sea Worker (drawn by tug)	0	-
4	Sea Jack (drawn by tug)	0	-
5	Tug Boat	2122	2
5	Tug Boat	2122	2

Load Factor	LF= Load Factor
Work Boat	0.43
Tug Boat	0.31

Assume operating 24hrs in 24	A = Activity Hours per year
3 Months	2016
4 Months	2688
5 Months	3360
8 Months	5376
9 Months	6048

kW hrs per year	kW hrs per year Propulsion
Svanen	54448128
Jumbo Javelin	18579456
Sea Power	13426560
Sea Installer	29223936
Sea Worker (drawn by tug)	-
Sea Jack (drawn by tug)	-
Tug Boat	7129517
Tug Boat	7129517

Emission Factors for Harbour Craft Tier 0 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	13	2.5	0.3	1.3	690

Emission Factors for Harbour Craft Tier 2 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	6.8	5	0.3	1.3	690

EMISSION ESTIMATE TIER 0

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2
Svanen	**304.37**	**58.53**	**7.02**	**30.44**	**16154.76**
Sea Power	**75.05**	**14.43**	**1.73**	**7.51**	**3983.66**

EMISSION ESTIMATE TIER 2

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2
Jumbo Javelin	**54.33**	**39.95**	**2.40**	**10.39**	**5512.52**
Sea Installer	**85.45**	**62.83**	**3.77**	**16.34**	**8670.74**
Tug Boat	**15.03**	**11.05**	**0.66**	**2.87**	**1525.00**
Tug Boat	**15.03**	**11.05**	**0.66**	**2.87**	**1525.00**

SUMMARY

Activity	Vessel Type	Number of Vessels	NO_x	PM10	SO2	CO2
Turbine Installation	Heavy Lift Vessel	2	359	9	41	21667
	Jack up Vessel	3 (1 drawn by two tugs)	161	6	24	12654
	Jack up Barge	1 (drwan by one tug)				
	Tug Boat	2	30	1	6	3050

Emissions Estimate for Turbine Installation Vessels – Concrete Gravity Base Foundations

Ship Name	Vessel Category	Main Engine Propulsion kW	Auxiliary Engines kW
Svanen	Workboat/ Heavy Lift Vessel	12260	1600
Jumbo Javelin	Workboat/ Heavy Lift Vessel	8640	
Sea Power	Workboat/Jack up Vessel	2400	1500
Sea Installer	Workboat/Jack up Vessel	18120	
Sea Worker	(drawn by tug)		
Sea Jack	(drawn by tug)		
Tug Boat	Tug Tow Pushboat	2610	170
Tug Boat	Tug Tow Pushboat	2610	170

Months in service	Power Rating Propulsion and Auxiliary Assume 80% use of Propulsion and 20% Auxiliary all the time	P=Power Rating (Propulsion+Auxiliary)	Engine Tier
8 and 15	Svanen	10128	0
4 and 17	Jumbo Javelin	6912	2
9	Sea Power	2220	0
3	Sea Installer	14496	2
5	Sea Worker (drawn by tug)	0	-
4	Sea Jack (drawn by tug)	0	-
5	Tug Boat	2122	2
5	Tug Boat	2122	2

Load Factor	LF= Load Factor
Work Boat	0.43
Tug Boat	0.31

Assume operating 24hrs in 24	A = Activity Hours per year
3 Months	2016
4 Months	2688
5 Months	3360
8 Months	5376
9 Months	6048
15 Months	10080
17 Months	11424

kW hrs per year	kW hrs per year Propulsion
Svanen 8 months	54448128
Svanen 15 months	102090240
Jumbo Javelin 4 months	18579456
Jumbo Javelin 17 months	78962688
Sea Power	13426560
Sea Installer	29223936
Sea Worker	
Sea Jack	
Tug Boat 5 months	7129517
Tug Boat 5 months	7129517
Tug Boat 15 months	21388550

Emission Factors for Harbour Craft Tier 0 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	13	2.5	0.3	1.3	690

Emission Factors for Harbour Craft Tier 2 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	6.8	5	0.3	1.3	690

EMISSION ESTIMATE TIER 0

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2
Svanen 8 months	**304.37**	**58.53**	**7.02**	**30.44**	**16154.76**
Svanen 15 months	**570.68**	**109.75**	**13.17**	**57.07**	**30290.17**
Sea Power	**75.05**	**14.43**	**1.73**	**7.51**	**3983.66**

EMISSION ESTIMATE TIER 2

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2

Jumbo Javelin 4 months	**54.33**	**39.95**	**2.40**	**10.39**	**5512.52**
Jumbo Javelin 17 months	**230.89**	**169.77**	**10.19**	**44.14**	**23428.23**
Sea Installer	**85.45**	**62.83**	**3.77**	**16.34**	**8670.74**
Tug Boat 5 months	**15.03**	**11.05**	**0.66**	**2.87**	**1525.00**
Tug Boat 5 months	**15.03**	**11.05**	**0.66**	**2.87**	**1525.00**
Tug Boat 15 months	**45.09**	**33.15**	**1.99**	**8.62**	**4575.01**

SUMMARY

Activity	Vessel Type	Number of Ves-sels	NO_x	PM10	SO2	CO2
Turbine Installation	Heavy Lift Vessel	4	1160	33	142	75386
	Jack up Vessel	3 (1 drawn by two tugs)	161	6	24	12654
	Jack up Barge	1 (drwan by one tug)				
	Tug Boat	3	75	3	14	7625

Emissions Estimate for substation Installation Vessels

Ship Name	Vessel Category	Main Engine Propulsion kW	Auxiliary Engines kW
Sea Power	Workboat/ Jack Up Vessel	2400	1500
Stanislav Yudin	Workboat/ Heavy Lift Vessel	4095	3680

Months in service	Power Rating Propulsion and Auxiliary Assume 80% use of Propulsion and 20% Auxiliary all the time	P=Power Rating (Propul-sion+Auxiliary)	Engine Tier
24	Sea Power	2220	0
0.11	Stanislav Yudin	4012	0

Load Factor	LF= Load Factor
Work Boat	0.43
Tug Boat	0.31

Assume operating 24hrs in 24	A = Activity Hours per year
24 Months	16128
0.11 Months (3 days)	74

kW hrs per year	kW hrs per year Propulsion
Sea Power	35804160
Stanislav Yudin	296567

Emission Factors for Harbour Craft Tier 0 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	13	2.5	0.3	1.3	690

EMISSION ESTIMATE TIER 0

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2
Svanen	**200.15**	**38.49**	**4.62**	**20.01**	**10623.09**
Sea Power	**1.66**	**0.32**	**0.04**	**0.17**	**87.99**

SUMMARY

Activity	Vessel Type	Number of Ves-sels	NO_x	PM10	SO2	CO2
Substation Installation	Jack up Vessel	1	200	5	20	1062 3
	Heavy Lift Vessel	1	2	0	0	88

Emissions Estimate for cable Installation Vessels

Ship Name	Vessel Category	Main Engine Propulsion kW	Auxiliary Engines kW
Toisa Wave	Workboat/ Cable laying ship	6000	3320
Swiber Else Marie	Workboat/ Support Vessel - Tug	8000	3265
Stemat 82	Workboat/Multi purpose barge (No Engine)		
Tugboat	Workboat	2610	170

Months in service	Power Rating Propulsion and Auxiliary	P=Power Rating (Propul-sion+Auxiliary)	Engine Tier
	Assume 80% use of Propulsion and 20% Auxiliary all the time		
3	Toisa Wave	5464	2
8	Swiber Else Marie	7053	2
5	Stemat 82 (No Engine)	0	2
5	Tugboat	2122	2

Load Factor	LF= Load Factor
Work Boat	0.43
Tug Boat	0.31

Assume operating 24hrs in 24	A = Activity Hours per year
3 Months	2016
5 Months	3360
8 Months	5376

kW hrs per year	kW hrs per year Propulsion
Toisa Wave	11015424
Swiber Else Marie	37916928
Stemat 82 (No Engine)	0
Tugboat	7129517

Emission Factors for Harbour Craft Tier 2 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	6.8	5	0.3	1.3	690

EMISSION ESTIMATE TIER 2

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2 Tons
Toisa Wave	**32.21**	**23.68**	**1.42**	**6.16**	**3268.28**
Swiber Else Marie	**79.93**	**58.77**	**3.53**	**15.28**	**8110.43**
Stemat 82					
Tugboat	**15.03**	**11.05**	**0.66**	**2.87**	**1525.00**

SUMMARY

Activity	Vessel Type	Number of Ves-sels	NO_x	PM10	SO2	CO 2
Cable Installation	Cable Laying Ship	1	32	1	6	326 8
	Tug Boat	1	80	4	15	811 0
	Multi-purpose barge (No Engine)	1				
	Tug Boat	1	15	1	3	152 5

Emissions Estimate for crew transfer Vessels

Ship Name	Vessel Category	Main Engine Propulsion kW	Auxiliary Engines kW
Offshore Wandelaar	Crew and Supply	1528	
Seacat Reliance	Crew and Supply	1780	
Windcrew 1	Crew and Supply	1260	
Seacat Vigilant	Crew and Supply	2160	
MS Cathrin	Crew and Supply	1528	
MV Accomplisher	Crew and Supply	1440	
MV Attender	Crew and Supply	1440	
MV Performer	Crew and Supply	1176	
MV Assister	Crew and Supply	1440	

Months in service	Power Rating Propulsion and Auxiliary	P=Power Rating (Propulsion+Auxiliary)	Engine Tier
	Assume 80% use of Propulsion and 20% Auxiliary all the time		
0.25	Offshore Wandelaar	1222	2
6	Seacat Reliance	1424	2
8	Windcrew 1	1008	0
3	Seacat Vigilant	1728	2
10	MS Cathrin	1222	2
7	MV Accomplisher	1152	2
8	MV Attender	1152	2
9	MV Performer	941	2
4	MV Assister	1152	2

Load Factor	LF= Load Factor
Work Boat	0.43
Tug Boat	0.31

Assume operating 24hrs in 24	A = Activity Hours per year
0.25 months (1 week)	168
3 Months	2016
4 Months	2688
5 Months	3360
6 Months	4032
7 Months	4704
8 Months	5376
9 Months	6048
10 Months	6720

kW hrs per year	kW hrs per year Propulsion
Offshore Wandelaar	205363
Seacat Reliance	5741568
Windcrew 1	5419008
Seacat Vigilant	3483648
MS Cathrin	8214528
MV Accomplisher	5419008
MV Attender	6193152
MV Performer	5689958
MV Assister	3096576

Emission Factors for Harbour Craft Tier 0 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	13	2.5	0.3	1.3	690

Emission Factors for Harbour Craft Tier 2 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	6.8	5	0.3	1.3	690

EMISSION ESTIMATE TIER 0

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2 g/kWh
Windcrew 1	**30.29**	**5.83**	**0.70**	**3.03**	**1607.82**

EMISSION ESTIMATE TIER 2

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2 g/kWh
Offshore Wandelaar	**0.60**	**0.44**	**0.03**	**0.11**	**60.93**
Seacat Reliance	**16.79**	**12.34**	**0.74**	**3.21**	**1703.52**
Seacat Vigilant	**10.19**	**7.49**	**0.45**	**1.95**	**1033.60**
MS Cathrin	**24.02**	**17.66**	**1.06**	**4.59**	**2437.25**
MV Accomplisher	**15.85**	**11.65**	**0.70**	**3.03**	**1607.82**
MV Attender	**18.11**	**13.32**	**0.80**	**3.46**	**1837.51**
MV Performer	**16.64**	**12.23**	**0.73**	**3.18**	**1688.21**
MV Assister	**9.05**	**6.66**	**0.40**	**1.73**	**918.75**
TOTAL	111.24	81.79	4.91	21.27	11287.60

SUMMARY

Activity	Vessel Type	Number of Ves-sels	NO_x	PM10	SO2	CO2
Crew Transfer		9	142	6	24	12895

Emissions Estimate for other Vessels

Ship Name	Vessel Category	Main Engine Propulsion kW	Auxiliary Engines kW
Swiber Else Marie	Workboat/ Support Vessel - Tug	8000	3265
Jumbo Javelin	Workboat/ Heavy Lift Vessel	8640	

Months in service	Power Rating Propulsion and Auxiliary Assume 80% use of Propulsion and 20% Auxiliary all the time	P=Power Rating (Propulsion+Auxiliary)	Engine Tier
6	Swiber Else Marie	7053	2
1	Jumbo Javelin	6912	2

Load Factor	LF= Load Factor
Work Boat	0.43
Tug Boat	0.31

Assume operating 24hrs in 24	A = Activity Hours per year
1 Month	672
6 Months	4032

kW hrs per year	kW hrs per year Propulsion
Swiber Else Marie	28437696
Jumbo Javelin	4644864

Emission Factors for Harbour Craft Tier 2 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	6.8	5	0.3	1.3	690

EMISSION ESTIMATE TIER 2

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2 g/kWh
Swiber Else Marie	**9.79**	**7.20**	**0.43**	**1.87**	**993.54**
Jumbo Javelin	**13.58**	**9.99**	**0.60**	**2.60**	**1378.13**

SUMMARY

Activity	Vessel Type	Number of Vessels	NO_x	PM10	SO2	CO 2
Other	Support Vessel	1	10	0	2	994
	Heavy Lift Vessel	1	14	1	3	137 8

Emissions Estimate for operation and maintenance Vessels

Ship Name	Vessel Category	Main Engine Propulsion kW	Auxiliary Engines kW
Offshore Wandelaar (6 days)	Crew and Supply	1528	
Seacat Reliance (5 months)	Crew and Supply	1780	
Windcrew 1	Crew and Supply	1260	
Seacat Vigilant (2 months)	Crew and Supply	2160	
Bayard 5	Crew and Supply	1498	
Anholt Wind	Crew and Supply	2160	
Djurs Wind	Crew and Supply	2160	
Kattergat Wind	Crew and Supply	2160	
MV Deliverer (1 mth)	Crew and Supply	956	
MV Styrbjorn (4 mth)	Crew and Supply	900	
MV Advancer (4 mth)	Crew and Supply	1440	
MS Cathrin (1 mth)	Crew and Supply	1528	
MV Accomplisher (6 months)	Crew and Supply	1440	
MV Attender (FT)	Crew and Supply	1440	
MV Performer (FT)	Crew and Supply	1176	
MV Assister (7 Months)	Crew and Supply	1440	
ROV Support Vessel	Workboat	5850	

Time in service	Power Rating Propulsion and Auxiliary	P=Power Rating (Propul-sion+Auxiliary)	Engine Tier
	Assume 80% use of Propulsion and 20% Auxiliary all the time		
6 Days	Offshore Wandelaar (6 days)	1528	2
5 Months	Seacat Reliance (5 months)	1780	2
3 Months	Windcrew 1	1260	0
2 Months	Seacat Vigilant (2 months)	2160	2
3 Months	Bayard 5	1498	2

Load Factor	LF= Load Factor
Work Boat	0.43
Tug Boat	0.31

3 Months	Anholt Wind	2160	2
3 Months	Djurs Wind	2160	2
3 Months	Kattergat Wind	2160	2
1 Months	MV Deliverer (1 mth)	956	2
4 Months	MV Styrbjorn (4 mth)	900	2
4 Months	MV Advancer (4 mth)	1440	2
1 Month	MS Cathrin (1 mth)	1528	2
6 Months	MV Accomplisher (6 months)	1440	2
3 Months	MV Attender (FT)	1440	2
3 Months	MV Performer (FT)	1176	2
7 Months	MV Assister (7 Months)	1440	2
3 Months	ROV Support Vessel	5850	2

Assume operating 10hrs in 24	**A = Activity Hours per year**
0.2 (6 days)	60
1 Month	280
2 Month	560
3 Months	840
4 Months	1120
5 Months	1400
6 Months	1680
7 Months	1960

kW hrs per year	**kW hrs per year Propulsion**
Offshore Wandelaar	91686
Seacat Reliance	2492000
Windcrew 1	1058400
Seacat Vigilant	1209600
Bayard 5	1258320
Anholt Wind	1814400
Djurs Wind	1814400
Kattergat Wind	1814400

MV Deliverer	267680
MV Styrbjorn	1008000
MV Advancer	1612800
MS Cathrin	427840
MV Accomplisher	2419200
MV Attender	1209600
MV Performer	987840
MV Assister	86406
ROV Support Vessel	4914000

ROV Support Vessel	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	13	2.5	0.3	1.3	690

Emission Factors for Harbour Craft Tier 2 Engines	NOx g/kWh	CO g/kWh	PM10 g/kWh	SO2 g/kWh	CO2 g/kWh
Minimum Power 1,000kW	6.8	5	0.3	1.3	690

EMISSION ESTIMATE TIER 0

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2 g/kWh
Windcrew 1	**5.92**	**1.14**	**0.14**	**0.59**	**314.03**

EMISSION ESTIMATE TIER 2

E=LF*kWh*EF	NOx Tons	CO Tons	PM10 Tons	SO2 Tons	CO2 g/kWh
Offshore Wandelaar (6 days)	**0.27**	**0.20**	**0.01**	**0.05**	**27.20**
Seacat Reliance (5 months)	**7.29**	**5.36**	**0.32**	**1.39**	**739.38**
Seacat Vigilant (2 months)	**3.54**	**2.28**	**0.16**	**0.68**	**358.89**
Bayard 5	**3.68**	**2.60**	**0.16**	**0.70**	**373.34**
Anholt Wind	**5.31**	**2.71**	**0.23**	**1.01**	**538.33**
Djurs Wind	**5.31**	**3.90**	**0.23**	**1.01**	**538.33**
Kattergat Wind	**5.31**	**3.90**	**0.23**	**1.01**	**538.33**

MV Deliverer (1 mth)	**0.78**	**3.90**	**0.03**	**0.15**	**79.42**
MV Styrbjorn (4 mth)	**2.95**	**0.58**	**0.13**	**0.56**	**299.07**
MV Advancer (4 mth)	**4.72**	**2.17**	**0.21**	**0.90**	**478.52**
MS Cathrin (1 mth)	**1.25**	**3.47**	**0.06**	**0.24**	**126.94**
MV Accomplisher (6 months)	**7.07**	**0.92**	**0.31**	**1.35**	**717.78**
MV Attender (FT)	**3.54**	**5.20**	**0.16**	**0.68**	**358.89**
MV Performer (FT)	**2.89**	**2.60**	**0.13**	**0.55**	**293.09**
MV Assister (7 Months)	**0.25**	**2.12**	**0.01**	**0.05**	**25.64**
ROV Support Vessel	**14.37**	**0.19**	**0.63**	**2.75**	**1457.98**
TOTAL	68.50	42.08	3.02	13.10	6951.14

SUMMARY

Activity	**Vessel Type**	**Number of Vessels**	**NO_x**	**PM10**	**SO2**	**CO2**
O&M	Crew Transfer	16	60	3	11	5807
	ROV Support	1	14	1	3	1458
	TOTAL	**17**	**74**	**3.2**	**14**	**7265**

Emissions Estimate for Non Road Mobile Machinery (NRMM)

Emission Factors for NRMM (g/kWh)	NOx	TSP*
Forklift	6.5	0.4
Backhoe Loader	4	0.2
Excavator	3.4	0.2
Tractor	3.4	0.2
Wheeled Loader	3.4	0.2
Mobile Crane	3.4	0.1

Activity	NRMM Type	Number	Size (kW) (Average)[1]	Load Factor (fraction[2] of power)	Time in service (months)	Time in Service (hours)	Emissions Estimate (E = N x HRS x HP x LF x EF)	Tons NOx	Tons TSP
Laying of 220kV cable (Main and alternative Proposals require the same number and type of NRMM)	Excavators	5	100	0.59	7	1960		2.63	0.15
	Backhoe Loader	4	67.5	0.21				0.60	0.03
	Tractors	4	78	0.21				0.59	0.03
	Wheel Loader	1	112.5	0.59				0.59	0.02
	Drilling Machine	2	~	~					
							TOTAL	**4.41**	**0.24**
Laying of 150 kV cable	Excavators	5	100	0.59	4	1120		1.51	0.09
	Backhoe Loader	4	67.5	0.21				0.34	0.02
	Tractors	4	78	0.21				0.33	0.02
	Wheel Loader	1	112.5	0.59				0.34	0.02
	Drilling Machine	2	~	~					
							TOTAL	**2.52**	**0.15**
Construction of new converter station at Blåbjerg	Excavators	1	100	0.59	9	2520		0.68	0.04
	Backhoe Loader	1	67.5	0.21				0.19	0.01
	Wheel Loader	1	112.5	0.59				0.76	0.04

							TOTAL	**1.63**	**0.09**
Extension to substation at Endrup	Excavators	1	100	0.59	18.00	5040		1.35	0.08
	Backhoe Loader	2	67.5	0.21				0.77	0.04
	Wheel Loader	1	112.5	0.59				1.52	0.09
	Tractors	1	78	0.21				0.38	0.02
	Fork Lift	2.00	35	0.59				1.81	0.11
							TOTAL	**5.83**	**0.34**
Alterations to the substation at Holsted	Fork Lift	1	35	0.59	0.5	140	**TOTAL**	**0.03**	**0.00**
Alterations to the substation at Revsing	Fork Lift	1	35	0.59	0.25	70	**TOTAL**	**0.01**	**0.00**
Upgrade of overhead power line	Winch	2	~	~	4	1120			
	Mobile Crane	2	225	0.43				0.99	0.03
	Fork Lift	2	35	0.59				0.40	0.02
	Conductor Brake	1	~	~					
	Backhoe Loader	1	67.5	0.21				0.09	0.00
							TOTAL	**1.48**	**0.06**
							Grand	**15.90**	**0.88**

[1] AEAT Document

[2] USEPA Document

CO_2 Emissions Estimate Onshore

Material Onshore

Conversion Factors	
Material	**Density (ton/m^3)**
Sand	2.2
Quarried Aggregate	2.0
Mortar	1.9
Stainless Steel	8.0
Aluminium (general)	2.7
Glass (primary)	2.5
Soil - general	1.7

Assumed HGV capacity (tons)	35
Assumed Avg Distance Travelled Km	50

Emission Factors Ecoinvent	
Material	**CO2 kg/ton**
Concrete	1040
Steel	1333
Cast Iron	1352
Copper	1731
Aluminium	6703
Fiber Glass	7687
Sand	2.3

Defra 2012 GHG conversion factors for company reporting	
HGV kg CO2/km	1.0

Emission Factors Environment Agency (U.K)	
Material	tCO2 e/t
Concrete	0.95
Steel	1.46
Cast Iron	2.03
Copper	2.71
Aluminium	9.16
Fiber Glass	8.10
Soil	0.02
Sand	0.01
Quarried Aggregate	0.01
Mortar	0.22
Stone	0.08
Glass	0.91

Category	**Materials**	**Quantity (m^3)**	**Quantity (tons)**	**Total Tons**	**No of HGV trips**
Cables					
220 kV	Aluminium, poly-ethylene		2880	2880	25
150 kV	Aluminium, poly-ethylene		996	996	4
Sand					
220 kV	Sand	2483		5562	159
150 kV	Sand	600		1344	38
Substations					
Blabjerg	Gravel	200		400	11
	Concrete in-situ	330		627	18

CO_2 Emissions (per ton)

Category	**Materials**	**CO2 Emissions Materials (tons)**	**CO2 Emissions HGVs (tons)**
Cables			
220 kV	Aluminium, polyethylene	16745	1.2
150 kV	Aluminium, polyethylene	2559	0.2
TOTAL		**19304**	**1**
Sand			
220 kV	Sand	13	7.8
150 kV	Sand	3	1.9
TOTAL		**16**	**10**
Substations			
Blabjerg	Gravel	32	0.6
	Concrete in-situ	652	0.9

	Soil	850		1445	41
	Reinforcing Steel (tons)		10	10	1

Endrup	Gravel	1800		3600	103
	Concrete in-situ	1250		2375	68
	Soil	3500		5950	170
	Reinforcing Steel (tons)		35	35	1
	Steel galvinized (tons)		80	80	2
Overhead cables					
Leaders	Steel and alumini-um (tons)		340	340	10
Insulators	Glass (tons)		80	80	2
TOTAL					**442**

	Soil	35	2.0
	Reinforcing Steel	13330	0.0
TOTAL		**14048**	**0**
Endrup	Gravel	284	5.1
	Concrete in-situ	2470	3.4
	Soil	143	8.4
	Reinforcing Steel	46655	0.0
	Steel galvinized	106640	0.1
TOTAL		**156192**	**21**
Overhead cables			
Leaders	Steel and aluminium	227750	0.5
Insulators	Glass	73	0.1
TOTAL		**227822**	**1**

SUMMARY

Cable route	19304	11
Substation Blabjerg	14048	10
Substation Endrup	156192	0
Overhead Cables	227822	21
Total	**417366**	**41**

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CO_2 Emissions Estimate Offshore

Material Offshore

Number of Turbines

MW	No of turbines
3	136
3.6	114
4	102
8	52
10	42

Conversion Factors

Material	Density (t/m^3)
Sand	2.24
Quarried Ag-gregate	2.0
Mortar	1.9
Stainless Steel	8
Iron	7.9
GRP	1.7
Stone (general)	2.0

Emission Factors Ecoinvent

Materials	CO2 kg/ton
Concrete	1040
Steel	1333
Cast Iron	1352
Copper	1731
Aluminium	6703
Fiber Glass	7687
Sand	2.3

Efs Env Agency

Materials	tCO2e /t
Concrete	0.95
Steel	1.46
Cast Iron	2.03
Copper	2.71
Aluminium	9.16
Fiber Glass	8.1
Sand	0.005
Quarried Ag-gregate	0.005
Mortar	0.221
Stone	0.079

Turbine Materials

tons

Each Turbine	Materials	3.0MW	3.6MW	4MW	8MW
Nacelle	Steel/GRP	125.4	140	140	390
Hub	Cast Iron	68.5	100	100	
Blade	GRP				
Tower	Steel	150	180	210	340

Total for WF	Total				
Nacelle	Steel/GRP	17054	15960	14280	20280
Hub	Cast Iron	9316	11400	10200	0
Blade	GRP		0	0	0

CO_2 Emissions per ton

Total for WF	Total	3.0MW	3.6MW	4MW	8MW
Nacelle (assume 100% GRP)	Steel/GRP	131097	122685	109770	155892
Hub	Cast Iron	12595	15413	13790	0
Blade	GRP				

Tower	Steel	20400	20520	21420	17680	

Tower	Steel	27193	27353	28553	23567	
TOTAL		**170886**	**165450**	**152114**	**179460**	

Foundations

Driven Steel Monopile

Each Turbine	**3MW**	**3.6MW**	**4MW**	**8MW**	**10MW**
Steel Pile (ton)	700	800	900	1000	1400
Transistion Piece (steel) (ton)	150	150	180	300	400
Grout (cement based prod-uct) (m^3)	35	35	40	60	70
Scour (m^3)	2100	2100	2500	3000	3800

Each Turbine (tons)	**3MW**	**3.6MW**	**4MW**	**8MW**	**10MW**
Steel Pile	700	800	900	1000	1400
Transistion Piece (steel)	150	150	180	300	400
Grout (cement based prod-uct)	66.5	66.5	76	114	133
Scour (for WF)	4200	4200	5000	6000	7600

Total for WF (tons)	**3MW**	**3.6MW**	**4MW**	**8MW**	**10MW**
Steel Pile (ton)	95200	91200	91800	52000	58800
Transistion Piece (steel) (ton)	20400	17100	18360	15600	16800
Grout (cement based prod-uct)	9044	7581	7752	5928	5586
Scour (for WF)	571200	478800	510000	312000	319200

CO_2 Emissions per ton

Total for WF	**3MW**	**3.6MW**	**4MW**	**8MW**	**10MW**
Steel Pile	126902	121570	122369	69316	78380
Transistion Piece (steel)	27193	22794	24474	20795	22394
Grout (cement based product)	9406	7884	8062	6165	5809
Scour	2856	2394	2550	1560	1596
TOTAL	**166357**	**154642**	**157455**	**97836**	**108180**

Foundations

Concrete Gravity Base

Each turbine	3MW	3.6MW	4MW	8MW	10MW
Concrete (ton)	1800	2000	2200	3000	4000
Ballast (sand) (m^3)	1800	2000	2200	2500	2800
Stone (m^3)	180	200	230	300	400
Scour Protection (m^3)	800	1000	1100	1300	1400

Each Turbine (tons)	3MW	3.6MW	4MW	8MW	10MW
Concrete	1800	2000	2200	3000	4000
Ballast (sand)	4032	4480	4928	5600	6272
Stone	360	400	460	600	800
Scour Protection	1600	2000	2200	2600	2800

Total for WF (tons)	3MW	3.6MW	4MW	8MW	10MW
Concrete	244800	228000	224400	156000	168000
Ballast (sand)	548352	510720	502656	291200	263424
Stone	48960	45600	46920	31200	33600
Scour Protection	217600	228000	224400	135200	117600

CO_2 Emissions per ton

Total for WF (tonnes)	3MW	3.6MW	4MW	8MW	10MW
Concrete	254592	237120	233376	162240	174720
Ballast (sand)	1261	1175	1156	670	606
Stone	3868	3602	3707	2465	2654
Scour Protection	1088	1140	1122	676	588
TOTAL	**260809**	**243037**	**239361**	**166051**	**178568**

Jacket Foundations

Each Turbine	3MW	3.6MW	4MW	8MW	10MW
Steel Pile (ton)	400	400	450	600	800
Scour Protection (m^3)	800	1000	1200	1800	2500

Each Turbine (tons)	3MW	3.6MW	4MW	8MW	10MW

Steel Pile	400	400	450	600	800
Scour Protection	1600	2000	2400	3600	5000

Total for WF (tons)	3MW	3.6MW	4MW	8MW	10MW
Steel Pile	54400	45600	45900	31200	33600
Scour Protection	217600	228000	244800	187200	210000

CO_2 Emissions per ton

Total for WF (tonnes)	3MW	3.6MW	4MW	8MW	10MW
Steel Pile	72515	60785	61185	41590	44789
Scour Protection	1088	1140	1224	936	1050
TOTAL	**73603**	**61925**	**62409**	**42526**	**45839**

Summary of CO_2 Emissions per ton

	3MW	3.6MW	4MW	8MW	10MW
Wind Turbines	170886	165450	152114	179460	0
Monopile Foundations	166357	154642	157455	97836	108180
Concrete Gravity Base Foundations	260809	243037	239361	166051	178568
Jacket Foundations	73603	61925	62409	42526	45839
TOTAL - Worst Case (Turbine + Concrete Gravity)	**431695**	**408488**	**391474**	**345510**	**178568**

TOTAL – Monopile Foundations	1043	76254	144	33
TOTAL – Gravity Base Foundations	2933	210801	397	92
TOTAL NATIONAL EMISSIONS 2011	1151573	98718000	247874	50138

TOTAL – Monopile Foundations	0.1	0.1	0.1	0.1
TOTAL – Gravity Base Foundations	0.3	0.2	0.2	0.2

11 APPENDIX B - CONSTRUCTION DUST IMPACT CRITERIA AND ASSESSMENT

The following section outlines criteria developed by the Institute of Air Quality Management (IAQM) for the assessment of air quality impacts arising from construction activities. This section details the construction phase dust assessment undertaken for the proposed development. The construction phase assessment itself is detailed in **Table B6** for the main proposal and **Table B7** for the alternative proposal.

The assessment procedure is divided into four steps and is summarised below:

Step One: Screening the need for a Detailed Assessment

An assessment will normally be required where there are sensitive receptors within 350m of the site boundary and/or within 100m of the route(s) used by construction vehicles on the public highway, up to 500m from the site entrance(s). Ecological receptors are also identified at this stage. An ecological receptor refers to any sensitive habitat affected by dust soiling and includes locations with a statutory designation such as a Site of Specific Scientific Interest (SSSI), Special Area of Conservation (SACs) and Special Protection Areas (SPAs).
Where the need for a more detailed assessment is screened out, it can be concluded that the level of risk is 'negligible'.

Step Two: Assess the Risk of Dust Effects Arising

A site is allocated to a risk category based on the scale and nature of the proposed works and the proximity of dust sensitive receptors. Risk categories are defined for each of the four defined activities: demolition, earthworks, construction and trackout.

No demolition is proposed as part of the development and therefore demolition activities were not considered in the assessment.

Table B1 details the dust emission class criteria for each outlined activity.

Table B1: Criteria used in the Determination of Dust Emission Class

Activity	Criteria used to Determine Dust Emission Class		
	Small	**Medium**	**Large**
Earthworks	Total site area <2,500m^2	Total site area 2,500 – 10,000m^2	Total site area >10,000m^2
Construction	Total building volume <25,000m^3	Total building volume 25,000 – 100,000m^3	Total building volume >100,000m^3
Trackout	<25 HDV trips in any one day, unpaved road length <50m	25 - 100 HDV trips in any one day, unpaved road length 50 - 100m	>100 HDV trips in any one day, unpaved road length >100m

Table B2 and **Table B3** detail the risk categories for the potential dust and PM_{10} impacts from earthworks; general construction activities and trackout. They assume that no mitigation measures are applied and are dependent on the available information on the construction phase of works and professional judgement. The risk categories should be used as guidance for determining the level of mitigation to be applied. The dust emission class, determined using **Table B1**, is input into the matrices contained in **Table B2** and **Table B3** to determine the risk category with no mitigation applied, associated with earthworks, construction, and trackout activities, based on the distance to the nearest receptors.

Table B2: Risk Category from Earthworks and Construction Activities

Distance to Nearest Receptor (m) *		Dust Emission Class		
Dust Soiling and PM_{10}	**Ecological**	**Large**	**Medium**	**Small**
< 20	-	High Risk Site	High Risk Site	Medium Risk Site
20 – 50	-	High Risk Site	Medium Risk Site	Low Risk Site
50 - 100	< 20	Medium Risk Site	Medium Risk Site	Low Risk Site
100 – 200	20 – 40	Medium Risk Site	Low Risk Site	Negligible
200 - 350	40 – 100	Low Risk Site	Low Risk Site	Negligible
* Distance from dust emission source. Where this is not known then the distance should be taken from the site boundary. The risk is therefore based on the distance to the nearest receptor.				

Table B3: Risk Categories from Trackout Activities

Distance to Nearest Receptor (m) *		Dust Emission Class		
Dust Soiling and PM_{10}	**Ecological**	**Large**	**Medium**	**Small**
< 20	-	High Risk Site	Medium Risk Site	Medium Risk Site
20 – 50	< 20	Medium Risk Site	Medium Risk Site	Low Risk Site
50 - 100	20 - 100	Low Risk Site	Low Risk Site	Negligible
* For the trackout, the distance is from the roads used by construction traffic.				

Professional judgement must be applied when determining the dust emission class for trackout. Factors to be considered include vehicle size, vehicle speed, vehicle numbers, geology and duration of trackout activities. Only receptors within 100m of the route(s) used by vehicles on the public highway and up to 500m from the site entrance(s) are considered to be at risk and the risk classification distances should reflect this.

There is an extra dimension to the assessment of trackout, as the distance over which it might occur depends on the site. As general guidance, significant trackout may occur up to 500m from large sites, 200m from medium sites and 50m from small sites, as measured from the site exit. These distances assume no site-specific mitigation.

Step Three: Identification of Site Specific Mitigation

Once the risk categories for each of the four activities have been assigned, the site-specific mitigation measures required can be determined. These measures will be related to whether the site is a low, medium or high risk site.

Step Four: Identification of Site Specific Mitigation

Once step two (assessing the risk of dust effects arising) and step three (identification of site-specific mitigation) are completed the significance of potential dust effects can be determined (step four).

The sensitivity of the area surrounding the application site should be determined with regard to Table 1. The significance of dust effects is then determined with reference to the sensitivity of the area and the risk of the site giving rise to dust effects for each of the four activities.

The preference in the IAQM guidance is to assign significance to the impact with mitigation. The residual effects for most sites will be negligible, as shown in Table B4.

Table B4: Significance of Effects of Each Activity with Mitigation

Sensitivity of Area	Risk of Site Giving Rise to Dust Effects		
	High	**Medium**	**Low**
Very High	Slight Adverse	Slight Adverse	Negligible
High	Slight Adverse	Negligible	Negligible
Medium	Negligible	Negligible	Negligible
Small	Negligible	Negligible	Negligible

When an assessment of the significance of the effects without mitigation is required, the recommended significance criteria in **Table B5** should be used.

Table B5: Significance of Effects of Each Activity without Mitigation

Sensitivity of Area	Risk of Site Giving Rise to Dust Effects		
	High	**Medium**	**Low**
Very High	Substantial Adverse	Moderate Adverse	Moderate Adverse
High	Moderate Adverse	Moderate Adverse	Slight Adverse
Medium	Moderate Adverse	Slight Adverse	Negligible

Sensitivity of Area	Risk of Site Giving Rise to Dust Effects		
	High	**Medium**	**Low**
Small	Slight Adverse	Negligible	Negligible

The final step is to determine the overall significance of the effects arising from the construction phase of the proposed development. This is based on professional judgement but should take account of the significance of the effects for each of the four activities.

Table B6 and **Table B7** contain the construction phase dust assessment matrices carried out as part of this assessment.

Table B6: Construction Phase Assessment Matrix – Main Proposal

Sensitivity of Receptor	Dust Emission Class (1)			Risk Category (2)	Risk of Site giving rise to Dust Effects (3)			
	Source Activity	Dust Emission Class	Justification		Before Mitigation		After Mitigation	
					Significance	Overall	Significance	Overall
Human Receptors								
Medium	Demolition	Not Applicable	Onshore Cable route to traverse open countryside / cultivated land. Demolition is therefore not anticipated or planned as part of the construction works for the project.	Not Applicable	Not Applicable	**Moderate Adverse**	Not Applicable	**Negligible**
	Earthworks	Large	Total site area to be developed is anticipated to be more than 10,000m^2 and the total material to be moved anticipated to be more than 100,000 tonnes, on account of the size of the project. New cable station at Blåbjerg is 4488m^3 in building volume.	High Risk	Moderate Adverse		Negligible	
	Construction	Large	Installation of a 220kV cable route, approximately 50km in length; Large installation volume is therefore anticipated to be more than 100,000m^3; potentially dusty materials to be incorporated into the construction programme such as concrete. Upgrading of air power lines between Endrup and Holsted from 150kV to 400kV, with an additional underground cabling system of approx. 15km to be constructed. Station Blåbjerg – Construction of a new cable station, with a new building to be constructed to house compensation inductors, switchgear, auxiliary supply facilities, remote control systems and relay boards. Dimensions of new station – 8.5m high x 22m wide x 24m long – total building volume = 4488m^3 Cable station will include 10t reinforcing steel, 850m^3 of subsoil, and 330 m^3 of concrete (in situ) and 200m^3 of gravel. Station Endrup – Preparation of new site, including expansion with a 220kV station, in an area approx.140m x 140m. New filter and transformer fields will be constructed for the 400kV and 220kV transformers and expansion of busbars will be undertaken. The cable station will also include 35t reinforcing steel, 3500m^3 of subsoil, 1250m^3 of concrete (in situ), 80t of galvanised steel and 1800m^3 of gravel.	High Risk	Moderate Adverse		Negligible	
	Trackout	Medium	Number of receptors located less than 20m from potential routes used by construction vehicles along the public highway; Anticipated to be between 25 and 100 HDV trips in any one day; unpaved road lengths are anticipated to be less than 50m. Steel plating will be laid along sections of the cable route to undertake	Medium Risk	Slight Adverse		Negligible	

<table>
<tr><th colspan="9">Ecological Receptors</th></tr>
<tr><td rowspan="4">Very High</td><td>Demolition</td><td>Not Applicable</td><td>As specified above</td><td>Not Appli-cable</td><td>Not Applicable</td><td rowspan="4">Moderate Adverse</td><td>Not Applicable</td><td rowspan="4">Slight Adverse</td></tr>
<tr><td>Earthworks</td><td>Large</td><td>As specified above</td><td>Medium Risk</td><td>Moderate Adverse</td><td>Slight Adverse</td></tr>
<tr><td>Construction</td><td>Large</td><td>As specified above</td><td>Medium Risk</td><td>Moderate Adverse</td><td>Slight Adverse</td></tr>
<tr><td>Trackout</td><td>Medium</td><td>As specified above</td><td>Medium Risk</td><td>Moderate Adverse</td><td>Slight Adverse</td></tr>
</table>

(1) See **Table B1** (2) See **Table B2** to **Table B3** (3) See **Tables B4** and **B5**.

Table B7: Construction Phase Assessment Matrix – Alternative Proposal

Sensitivity of Receptor	Dust Emission Class (1)			Risk Category (2)	Risk of Site giving rise to Dust Effects (3)			
	Source Activity	Dust Emission Class	Justification		Before Mitigation		After Mitigation	
					Significance	Overall	Significance	Overall
Human Receptors								
Medium	Demolition	Not Applicable	Onshore Cable route to traverse open countryside / cultivated land. Demolition is therefore not anticipated or planned as part of the construction works for the project.	Not Applicable	Not Applicable	**Moderate Adverse**	Not Applicable	**Negligible**
	Earthworks	Large	Total site area to be developed is anticipated to be more than 10,000m^2 and the total material to be moved anticipated to be more than 100,000 tonnes, on account of the size of the project. New cable station at Blåbjerg is 4488m^3 in building volume.	High Risk	Moderate Adverse		Negligible	
	Construction	Large	Installation of a 220kV cable route, approximately 60km in length; Large installation volume is therefore anticipated to be more than 100,000m^3; potentially dusty materials to be incorporated into the construction programme such as concrete. Upgrading of air power lines between Endrup and Holsted from 150kV to 400kV, with an additional underground cabling system of approx. 15km to be constructed. Station Blåbjerg – Construction of a new cable station, with a new building to be constructed to house compensation inductors, switchgear, auxiliary supply facilities, remote control systems and relay boards. Dimensions of new station – 8.5m high x 22m wide x 24m long – total building volume = 4488m^3 Cable station will include 10t reinforcing steel, 850m^3 of subsoil, and 330 m^3 of concrete (in situ) and 200m^3 of gravel. Station Endrup – Preparation of new site, including expansion with a 220kV station, in an area approx.140m x 140m. New filter and transformer fields will be constructed for the 400kV and 220kV transformers and expansion of busbars will be undertaken. The cable station will also include 35t reinforcing steel, 3500m^3 of subsoil, 1250m^3 of concrete (in situ), 80t of galvanised steel and 1800m^3 of gravel.	High Risk	Moderate Adverse		Negligible	
	Trackout	Medium	Number of receptors located less than 20m from potential routes used by construction vehicles along the public highway; Anticipated to be between 25 and 100 HDV trips in any one day; unpaved road lengths are anticipated to be less than 50m. Steel plating will be laid along sections of the cable route to undertake	Medium Risk	Slight Adverse		Negligible	
Ecological Receptors								
Very High	Demolition	Not Applicable	As specified above	Not Applicable	Not Applicable	**Moderate Adverse**	Not Applicable	**Slight Adverse**

Sensitivity of Receptor	Dust Emission Class (1)			Risk Category (2)	Risk of Site giving rise to Dust Effects (3)			
					Before Mitigation		After Mitigation	
	Source Activity	**Dust Emission Class**	**Justification**		**Significance**	**Overall**	**Significance**	**Overall**
Human Receptors								
	Earthworks	Large	As specified above	Medium Risk	Moderate Adverse		Slight Adverse	
	Construction	Large	As specified above	Medium Risk	Moderate Adverse		Slight Adverse	
	Trackout	Medium	As specified above	Medium Risk	Moderate Adverse		Slight Adverse	

(1) See **Table B1** (2) See **Table B2** to **Table B3** (3) See **Tables B4** and **B5**.