16. AIR AND CLIMATE

16.1 INTRODUCTION

The release of greenhouse gases, in particular carbon dioxide (CO_2), is one of the main causes of climate change (UNFCCC, 2009). Climate change is essentially a natural phenomenon which occurs continuously; however, the rate of climate change has been greatly accelerated by the release of greenhouse gases as a result of human activities, primarily the burning of fossil fuels. The use of renewable energy technologies is one of the key methods for maintaining energy security while reducing the greenhouse gas emissions associated with energy production.

CO_2 emissions are not only associated with burning fossil fuels. All organic material is composed of carbon which is released as CO_2 when the material decomposes. Organic material, therefore, acts as a store of carbon. Peat bogs are major stores of organic carbon. The vegetation on a peat bog slowly absorbs CO_2 from the atmosphere and converts it to organic carbon. When the vegetation dies, it does not decompose fully due to the waterlogged and acidic conditions which prevail and the carbon is retained in the ground.

There has been much attention in recent years on the development of wind farms on peat bogs. When peat bogs are developed it is necessary to install drainage in certain areas to allow construction. The drainage allows the peat to dry out which permits the full decomposition of the stored organic material with the associated release of the stored carbon as CO_2. It is essential therefore that any wind farm development on a peat bog saves more CO_2 than is released.

This chapter of the Viking Wind Farm Environmental Statement addresses the air and climate impacts of the proposed development. An assessment of the impact of wind farms on peat bogs has been conducted in accordance with the recently published guidance document "Calculating the carbon savings from wind farms on Scottish peat lands – a new approach" (Nayak *et al.*, 2008). The guidance provides a method for calculating the time taken to pay back any carbon losses through the carbon savings gained by the use of a renewable energy technology. The document is supported by a spreadsheet to calculate the payback period for the specific development.

An overview of the current carbon emissions associated with the Shetland Islands is also presented which utilises published emissions data from government statistics. This provides an indication of the overall carbon footprint of the Shetlands Islands and how it will be affected by the proposed development.

Finally, the potential effects and management of dust particulates during the construction phase of the development are identified and an estimation of the CO_2 emissions generated by construction traffic is given.

16.2 SCOPE OF ASSESSMENT

16.2.1 Project interactions

The Viking Wind Farm will result in significant savings of greenhouse gas emissions through the use of renewable energy technologies. The electricity generated by the wind farm will displace the electricity currently generated by Lerwick Power Station and also electricity generated by power stations on the Scottish mainland. The surplus electricity not required on Shetland will be linked to the National Grid via a subsea transmission line. The impacts of the linkage to the Scottish mainland are not included in the scope of this assessment.

The Viking Wind Farm will also result in the generation of greenhouse gas emissions through the loss of stored carbon within the peat bogs on site. The removal of surface vegetation to accommodate turbines, access tracks and associated infrastructure will reduce the amount of CO_2 removed from the atmosphere. Greenhouse gas emissions will also be generated during the manufacture, transportation, construction, operation and decommissioning of the wind turbines. It is important to ensure that any greenhouse gas emission savings outweigh any emissions that are generated by the wind farm.

Dust emissions will be generated by construction activities, quarrying activities at borrow pits and through dust re-suspension on roads. The impact of dust emissions on local sensitive receptors is assessed.

16.2.2 Study area

The study area in this chapter is not restricted to a specific locality. The study takes into account the greenhouse gas emissions which would be both generated by and saved by the Viking Wind Farm, regardless of the location. The study is therefore focused on a desk based exercise which utilises both published information and site- and project-specific details.

The impact of dust emissions is assessed at local sensitive receptors. Sensitive receptors include both the human population and sites of nature conservation value.

16.2.3 Scoping and consultation

Scoping was undertaken to identify the main issues to be addressed in the Environmental Statement. The scoping opinion agreed that an assessment of carbon emissions should be undertaken to determine the expected carbon savings over the lifetime of the wind farm. A summary of the scoping responses is presented in Table 16.1. Overall, the main concern of the respondents was to ensure that the carbon impact of the wind farm is assessed which this chapter will do.

Table 16-1: Summary of scoping and consultation responses

Consultee	Key item of response
Scottish Ministers	A statement of expected carbon savings over the life of the wind farm is required. This should include an assessment of the carbon emissions associated with the track preparation, foundations, steel and transport and any carbon losses from the degradation of peat.
The Climate Change Team	Expect to see a detailed analysis of the carbon impact of the development.
SNH	In addition to the aspects noted above, SNH request that traffic CO_2 emissions are included.
RSPB	Expect to see a detailed analysis of the carbon balance between the use of renewable energy and the loss of carbon stored in peat.

16.2.4 Effects to be assessed

The potential effects of the Viking Wind Farm on air and climate were identified during the scoping stage. The potential effect on global greenhouse gas emissions was determined to be both beneficial and adverse. The wind farm has beneficial, long term effects related to the displacement of fossil fuel powered electricity generation which will result in a reduction of greenhouse gas emissions. The wind farm also has the potential to damage the peat bogs which can have a long term adverse effect through the release of stored carbon. This chapter is designed to assess whether the beneficial carbon savings outweigh any carbon losses or emissions generated by the wind farm throughout the whole life cycle. A summary of the potential effects is included in Table 16.2.

Table 16-2: Summary of the potential effects on air and climate

Project activity	Impact	Potential effect on receptors	Specific receptor identified in Scoping
Manufacture of turbines	Energy consumption and associated release of greenhouse gas emissions.	No direct effect on receptors. Indirect effect through the impacts of climate change.	-
Construction of turbine bases, crane pads, access tracks etc	Removal of peat and subsequent potential for release of stored carbon.	No direct effect on receptors. Indirect effect through the impacts of climate change.	-
Generation of electricity from renewable energy technologies	Displacement of electricity generated from fossil fuel fired power stations.	No direct effect on receptors. Indirect effect through the impacts of climate change.	-
Borrow pit operations	Dust emissions.	Effects on local air quality.	Several properties within the vicinity of potential borrow pit and access track locations

Project activity	Impact	Potential effect on receptors	Specific receptor identified in Scoping
Vehicle movements	Atmospheric emissions of CO_2 related to burning of fossil fuels.	No direct effect on receptors. Indirect effect through the impacts of climate change.	-

16.3 POLICY CONTEXT

Key policy documents in the UK and Scotland related to climate change include the following:

(a) Kyoto protocol

Climate change is a global problem requiring local solutions. The UK government has a commitment under the Kyoto Protocol to reduce greenhouse gas levels by 12.5% below 1990 levels by 2008 – 2012. They also have a more ambitious domestic target to reduce CO_2 emissions by 20% below 1990 levels by 2010. Currently, the UK is on track to meet the commitments under the Kyoto Protocol; however, more work is necessary to meet the domestic target. Work towards achieving the domestic target will be progressed through the implementation of the Climate Change Act 2008.

(b) UK Climate Change Programme

In order to help meet greenhouse gas targets, the Climate Change Programme (CCP) was published in 2006. The CCP outlines various policy measures designed to help reduce greenhouse gas emission, one of which is to continue to support renewable energy technologies under the Renewables Obligation

(c) Renewables Obligation

The Renewables Obligation requires electricity suppliers to supply an annually increasing percentage of electricity from renewable sources. The current level is set at 7.9% for 2007/2008 which will rise to 15.4% by 2015/16.

(d) Changing our Ways: Scotland's Climate Change Programme

Scotland has no specific target for the reduction of greenhouse gases; however, the Scottish share of the UK target amounts to 1.7 million tonnes of carbon. Scotland is working towards achieving this share through policy measures outlined in the Scottish Climate Change Programme. Scotland has a target for the provision of 18% of electricity from renewables by 2010 and 40% by 2020.

(e) Climate Change (Scotland) Bill

The Scottish Government introduced the Climate Change (Scotland) Bill in December 2008. The Bill aims to introduce legally binding greenhouse gas emission reduction targets. The overall target is for greenhouse gas emissions to be 80% below 1990 levels by 2050 with an interim target of 50% below 1990 levels by 2030. These targets will be aided by annual maximum net emissions in designated periods.

16.4 METHODOLOGY

16.4.1 Overview

The air and climate chapter presents an assessment of the impacts of dust on local air quality and an assessment of the CO_2 emissions associated with the proposed wind farm. The assessments are conducted in accordance with various guidance documents and published information sources where relevant.

16.4.2 Baseline Assessment

The baseline assessment provides an indication of the existing carbon emissions generated by the Shetland Islands. The assessment uses the most recent published emissions data from the UK government and other sources which are calculated the meet the UK's commitment under the Kyoto protocol.

16.4.3 Effects evaluation

(a) Air quality

Dust emissions can be generated during the construction phase of a development. Potential sources of dust emissions include quarrying operations at borrow pit locations, cement batching plants, construction of roads, turbine bases and infrastructure, and dust re-suspension on access tracks. Fugitive dust emissions can contribute to both local nuisance episodes as well as increased atmospheric particulate concentrations.

Fugitive emissions from industrial and vehicle movement sources are difficult to assess. The Local Air Quality Management (LAQM) Technical Guidance (Defra *et al.*, 2003) provides estimates for the potential contribution of dust sources towards annual mean particulate concentrations. The typical contribution of coarse particulates from fugitive dusts, stockpiling, quarries and construction activities can be up to 5 $\mu g/m^3$ towards the immediate locality of the source and up to 2 $\mu g/m^3$ towards urban background concentrations. Typical background particulate concentrations in the Shetland Islands are low (in the region of 8 $\mu g/m^3$) (Defra, *et al.*, 2009).

Re-suspended road dusts from traffic and tyre wear can contribute 1 – 6 $\mu g/m^3$ to the immediate local environment and 1 – 2 $\mu g/m^3$ to urban background concentrations. The regional contribution of re-suspended dust/soil is estimated to be between 2 – 3 $\mu g/m^3$.

The effects of dust emissions are evaluated using a simple screening assessment conducted in accordance with the Scottish Office Planning Advice Note on controlling the environmental effects of surface mineral workings (Scottish Office, 1998). The effects of dust can vary according to the size of the particles. Large dust particles (>30 μm) can travel up to 100 m from the source, medium sized particles (10 – 30 μm) can travel between 250 m and 500 m and smaller dust particles ($<$ 10 μm) can travel up to 1 km from the source. In order to account for the worst case impact, local sensitive receptors up to 1 km from the dust sources have been identified and are presented in Table 16.3.

Table 16-3: Locations of dust sensitive receptors

Receptor	National grid reference	Distance to source (m)	Direction from source to receptor
Tigh-na-Binn	HU 37760 50326	203	SSW
Nethersound	HU 38052 50131	375	S
Oversound	HU 38278 50320	339	SE
Uppersound	HU 38382 50424	390	ESE
Djuba	HU 38573 50722	572	ENE
Stranvaara	HU 38791 50248	829	ESE
Kallibrig	HU 38660 50078	798	SE
Kurkigarth	HU 38744 51222	953	NE
Cott R1	HU 37937 49801	680	S
Hellister R1	HU 38569 49774	946	SE
Sandwater	HU 41741 55165	627	SSW
		980	SSW
Flammister	HU 44027 55862	655	SSE
		888	SSW
Whinnia lea	HU 46680 55855	120	NE
		388	SSE
South Newing	HU 46850 55936	308	NE
		425	SE
Clymlsa	HU 47145 56233	500	E
		710	NE
Burns	HU 46600 55064	591	S
Skellister	HU 46780 54961	735	SSE
Skellister W	HU 46207 54820	907	SSW
Susseter	HU 40900 65406	934	SW
Garthsvale	HU 40969 65677	726	WSW
		872	WSW
Garth of Susetter	HU 40936 65736	738	WSW
		861	WSW
Souther house	HU 40864 69819	584	SW
		955	NW
Norther House	HU 40688 67021	717	W
Easterscord	HU 41362 66345	296	WNW
		671	S
		370	NW
Southtown	HU 37092 69742	254	NE
Voxter	HU 37113 69953	444	NNE
Hardwall	HU 37407 70072	721	NE
Pund of Grutin	HU 40918 69015	778	N
Pund of Grutin R1	HU 40954 69175	634	N
Setter	HU 39820 62112	560	E
Lower House	HU 45842 59592	973	NE

Receptor	National grid reference	Distance to source (m)	Direction from source to receptor
Upper Kergord	HU 40312 58428	266	E
Otervik	HU 36502 66210	356	NW
Trondavoe	HU 37779 70552	240	SW
Garven	HU 40210 72868	240	SW
Moorfield	HU 42510 72660	296	SE
Yell Sound coast SAC	HU 45167 72516	742	SE
Sandwater SSSI	HU 41416 55031	370	E
		767	SW
Kergord Plantations SSSI	HU 39379 55079	837	E
		565	W
Burn of Lunklet SSSI	HU 37290 57308	645	N
Sullom Voe SAC	HU 36787 69624	43	NW
Burn of Valayre SSSI	HU 36816 69429	5	SE

(b) **CO_2 emissions**

The main ways in which peat bogs are affected by a development are:

- Through the removal of carbon fixing vegetation;
- through the direct removal of peat; and
- through the indirect effects of drainage.

Of the above three factors, the one with the greatest influence on the overall impact of a development is the indirect effect of drainage. A fundamental characteristic of peat bogs is the fact that they are wet. Peat bogs are formed when waterlogged and acidic conditions prevent the decomposition of organic matter. When peat is drained and allowed to dry out, decomposition of the organic matter occurs which releases as CO_2 the stored carbon contained within it.

The impact of the Viking Wind Farm on CO_2 emissions was calculated in accordance with the guidance document "Calculating carbon savings from wind farms on Scottish peat lands – a new approach" (Nayak *et al.*, 2008). The method refines and improves upon the SNH guidance document "Wind farms and carbon savings" (SNH, 2003) which was previously the most widely used guidance available. The calculation method aims to provide a more accurate estimation of the carbon balance of a wind farm development on peat bogs through the inclusion of emissions generated through the full life cycle of a wind farm. The method uses up-to-date emissions factors and site specific details to obtain the payback period of the wind farm.

The guidance document is accompanied by a spreadsheet which contains in-built calculations and assumptions which are used in association with site specific data to obtain an overall pay back period for the wind farm. The spreadsheet requires details on the characteristics of the wind farm; volume of peat removed to accommodate turbine bases, access tracks and associated infrastructure; the extent of the site which will be affected by drainage; and restoration proposals.

The area of peat lost through infrastructure can be calculated from the area occupied by the wind farm. However, the extent of the bog affected by the drainage will depend on the nature of the bog in question and the hydrological characteristics of the peat. Detailed information on the hydrological characteristics of the peat bogs on Shetland was not available due to the scale of the development. Hydrological characteristics vary across a site depending on the season and the general features of the bog at each location. In the absence of site specific data, best case, intermediate and worst case estimates of the impact of drainage have been used. A copy of the input data used in each scenario is included in Appendix 16.1.

The overall impact of the Viking wind farm with regards to CO_2 emissions is evaluated using the payback period obtained from the calculation spreadsheet. The payback period of the wind farm is the length of time it takes for the CO_2 emissions generated by the development to be offset by the CO_2 savings achieved by the use of a renewable energy technology in place of fossil fuels.

16.4.4 Discussion of calculation method and data assumptions

The calculation method utilised the spreadsheet which accompanies the guidance document (Nayak *et al.*, 2008). The spreadsheet is divided into several sections in which the characteristics of the development, peatlands, bog plants, and restoration are outlined. As mentioned above, three scenarios were considered in the assessment, namely best case, intermediate case and worst case. The input data in each scenario are presented in Appendix 16.1. The choice of input data included in Appendix 16.1 is discussed below.

(a) Wind farm characteristics

The first section of the spreadsheet requires the input of basic data on the wind farm characteristics, including number of turbines, capacity factor and emissions during the wind farm life cycle. It is recommended that a site specific capacity factor is used where possible since this will give a more realistic estimation of the potential electricity generation. Viking Energy Partnership estimate that the capacity factor for the Viking Wind Farm will be around 45%, which is the value used in the assessment. Life cycle emissions are calculated using the in-built factors with regard to installed capacity as it was not feasible to conduct a detailed life cycle analysis for the Viking Wind Farm.

(b) Characteristics of the peat land

The extent of drainage around site features and the water table depth are two parameters which are highly influential in determining the payback period of the wind farm. During construction, water has to be kept away from the areas around turbine foundations and hardstanding areas to allow the concrete to be poured. For this reason, water is either drained or pumped from the area. The overall effect of drainage on the extent of drying which will occur will depend on the depth of drainage ditch, distance between ditches and the hydraulic conductivity of the peat (Nayak *et al.*, 2008).

The main consequence of drainage ditches is a reduction in the water table depth of the peat bog. This reduction in water table depth is greatest close to the ditch but can also persist for some distance from the ditch. Studies have shown that drainage can be affected by as much as 200 m from the ditch (Nayak *et al.*, 2008). In the absence of detailed hydrological and hydraulic conductivity data, it is recommended that a worst case estimation of the extent of drainage is used. The likely extent of drainage associated with the creation of cut faces through deep peat is discussed in Chapter 10 – Ecology. In

Chapter 10, it is suggested that the peat bogs on the development site have a low hydrological conductivity and that the extent of drying in the lower layers is not likely to extend beyond 10 m. However, it also suggests that a 20 m zone of drying may occur in the upper layers of the bog. Considering the information in Chapter 10 and to account for the inherent uncertainty in predicting the extent of drainage, three drainage scenarios were considered, namely 10 m, 50 m and 100 m to account for best, intermediate and worst case drainage impacts.

The water table depth of a peat bog is highly variable across the site and is influenced by the depth of peat and the geological and terrain characteristics within the particular location. No detailed information on the water table depth was available for use in this assessment, therefore three depths were utilised in each scenario, 0.5 m, 0.75 m and 1 m.

(c) **Characteristics of bog plants**

The characteristic of the bog plants on site are required in order to calculate the loss of carbon fixing potential from bog plants. The time taken for bog plants to regenerate is highly variable across the site and so the recommended default parameters were used for this section. Overall, the impact of the loss of carbon fixing potential is relatively small due to the slow rate at which the bog plants absorb CO_2 from the atmosphere.

(d) **Forestry plantation characteristics**

There are no substantial areas of forestry which will be felled and so this section of the spreadsheet was omitted from the calculation.

(e) **Counterfactual emissions factors**

The conversion factors for coal-fired power station, UK grid electricity mix and UK fossil fuel grid electricity mix are included in the spreadsheet. It is unlikely that any wind farm will displace electricity generated solely from a coal fired power station and so the use of this factor would overestimate the potential savings. Similarly, the UK grid electricity mix also accounts for other renewable energy technologies and nuclear power stations which will not be displaced by a new wind farm. The use of the UK grid electricity emissions factor can, therefore, provide an inaccurate estimation of the potential savings. For these reasons, the guidance recommends that the UK fossil fuel grid electricity mix emissions factor is used to calculate the final payback period.

The spreadsheet provides results based on all three emissions factors, however, only the fossil fuel grid electricity mix factors are reported. The results for all emissions factors can be viewed in Appendices 16.2, 16.3 and 16.4.

(f) **Borrow pits, wind turbine foundations and hard-standing areas**

The dimensions of borrow pits, wind turbine foundations and hard-standing areas are required to allow the calculation of the loss of carbon from removed peat. The average depth of peat removed is also required. Extensive peat depth probes were taken across the Viking Wind Farm site and cross referenced with the wind farm layout (refer to Chapter 14). The average depth of peat at proposed borrow pit locations, wind turbine foundations and hard-standing areas was determined to be 1.6m.

(g) **Access tracks**

The two main types of road construction which will be utilised on the Viking Wind Farm are floating roads and excavated road. Floating roads will be constructed on areas where the peat depth is greater than 1 m. Floating roads are designed to 'float' on top of the peat and so no peat is excavated for the road construction. They are also designed to have no associated drainage in order to minimise the impact on the peat. However, floating roads are highly likely to sink over time and can be subject to flooding. It often becomes necessary to install drains along the length of floating roads to reduce damage to the road surface. For this reason, the calculation has been undertaken with three assumptions: assuming no drainage is installed; assuming 50% of the road eventually requires drainage; and assuming that the entire length of the road will be drained. No drainage ditches are planned at this stage but it is impossible to predict if any will be required in future.

In addition, since drainage alongside floating roads is not planned at this stage, no ditch depths have been proposed. In the absence of any other data, potential ditch depths of 0.5 m and 1 m have been used for the intermediate and worst case scenarios.

For excavated roads, all peat is removed back to the bedrock and drains are usually necessary. Assumptions relating to drainage of excavated roads are built into the spreadsheet. There will be no rock filled roads on site.

(h) **Cable trenches**

The impact of cable trenches is primarily related to drainage which is particularly pertinent when the trenches are lined with sand or other permeable medium and if they do not follow the lines of access tracks. For the Viking Wind Farm several methods of installing cable trenches will be utilised. The cable trenches will be laid adjacent to access tracks where possible. The installation technique will be least disruptive possible, using a lift and turn approach where the excavated material is immediately placed back on top of the newly laid cable. In the locations where conventional trenches are required, clay bunds will be installed for every 50 cm change in altitude to minimise groundwater flow along the trench line.

In order to account for the possibility that some cable trenches may deviate from the line of access tracks, the calculation was repeated assuming all cable trenches would follow access tracks; assuming 5% of cables would deviate from access tracks; and assuming 10% of cables would deviate from tracks. The length of cable trench included in the best case, intermediate case and worst case scenarios were 0 m, 5,876 m and 11,752 m respectively.

(i) **Peat landslide hazard**

The loss of peat due to landslides is excluded from the calculation because it is assumed that the Scottish Executive good practice guidance on 'Peat landslide hazard and risk assessments, best practice guide for proposed electricity generation developments' (Scottish Executive, 2006) will have been followed. In accordance with this guidance, a peat stability assessment has been conducted for the Viking Wind Farm (see Appendix 14.1).

(j) **Improvements of carbon sequestration at site by blocking drains, restoration of habitat etc**

Restoring the hydrology and habitats on site is critical for minimising the carbon losses associated with developing a peat bog. A Habitat Management Plan has been prepared which outlines the activities which will be undertaken to mitigate the impacts of the development on the habitats on site.

There will be negative construction impacts on 238.5 ha of peat bog, of which approximately 197 ha will not be restored after construction (mainly consisting of land which will be occupied by turbine foundations and access tracks) (See Chapter 10 – Ecology). To compensate for this, the Habitat Management Plan proposes to restore twice that area and so the total area of peat bog to be restored is approximately 394 ha.

In addition, this section also requires data on the length of time until the hydrology and habitats on site are restored. This information is highly site specific and cannot be predicted. A time scale of 10 years is used in the assessment as a default parameter.

(k) **Restoration of site after decommissioning**

As mentioned above, restoration of the site is essential for minimising carbon losses. The calculation assumes that if the hydrology and habitats on site are restored, carbon losses occur for the lifetime of the wind farm only. However, if the hydrology and habitats on site are not restored, the default assumption in the calculation is that carbon losses are 100%.

Habitat restoration proposals, to be put into effect during and after construction, are outlined in the Habitat Management Plan. This includes provision to restore or improve the hydrology of the site where possible, and also to improve a greater area of habitat than that which will be permanently affected. At present large areas of the site consist of degraded and eroding blanket bog, badly affected by hagging and overgrazing by sheep. An objective of the Habitat Management Plan is to investigate ways in which the wider moorland environment can benefit from improved management, and then to put those management measures into effect. For more details see Chapter 10, Non-avian Ecology, and Appendix 10.9, Habitat Management Plan.

The critical component of restoration is to restore the hydrology on site since this is fundamental to peat bog functioning. Certain elements of the infrastructure such as turbine bases and access roads will likely be left in situ, however, since it is expected that the site will re-establish equilibrium provided all drains are blocked on decommissioning. Attempting to remove turbine foundations would likely cause more damage to the surrounding peat environments.

The calculation has been undertaken assuming that the hydrology and habitats on site will be restored upon decommissioning. Therefore, the results presented in the assessment assume that carbon losses are for the duration of the wind farm lifetime only. It is imperative that the hydrology of the site is restored upon decommissioning to prevent substantial losses of stored carbon.

(l) **Payback period**

The overall impact of the Viking wind Farm is determined by calculating the payback period required to offset any carbon losses. The expected life time of the wind farm is 25 years. Clearly, a payback period in excess of 25 would be unacceptable since the wind farm would release more CO_2 than it would save. It is also deemed unacceptable for the wind farm to 'break even' since the point of renewable energy is to benefit the environment through reducing emissions of greenhouse gases.

There are no published data on determining the significance of the payback period of a wind farm on peat bogs. The SNH guidance on calculating the effects of wind farms suggests that many wind farms pay for themselves within 3 years. A payback period in excess of 10 - 15 years is deemed unacceptable (SNH, 2003). In the absence of any published criteria against which to judge the impact of the payback period, the criteria presented in Table 16.4 have been devised.

The determination of the overall relative significance of the payback of the wind farm is a matter of judgement. It can be argued that any payback period of less than 25 years is beneficial because it indicates that more CO_2 is saved than released. However, it is the author's opinion that the aim of renewable energy technologies is to achieve notable savings of greenhouse gases in order to fully maximise the benefits of utilising the technology. In addition, there is an inherent uncertainty in the calculation and there are many areas where emissions can not be included in the calculation. For example, the emissions associated with the construction of the sub-sea transmission line; and the emissions generated during the production of the ES are not included in the payback period. It is for these reasons that a payback period of 10 – 25 years has been defined as neutral since it is not feasible to account for all possible associated emissions in this assessment.

Table 16-4: Significance criteria for wind farm payback period

Significance	Definition
Adverse	A payback period in excess of the wind farm lifetime (25 years)
Neutral	A payback period of 10 – 25 years
Beneficial	A payback period of 0 – 10 years

16.4.5 Limitations of the assessment

In the absence of predicted quantities of dust emissions, it is only possible to undertake a qualitative assessment of the potential impacts on local sensitive receptors by comparing the distance between the source and receptor to known worst case situations.

The baseline assessment is limited to the use of the most recent available published carbon emissions data. The most recent year available at the time of writing is 2006. In addition, the calculation methodologies used are constantly subject to change as more accurate information becomes available. When the calculation methodologies change, historical emissions data are retrospectively recalculated so that the emissions data from all years are directly comparable. This assessment has utilised the most recent available data; however, it should be appreciated that the data may be subject to change in future.

Another limitation of the assessment is the availability of hydrological data on the peat. The calculation of the carbon losses associated with developing a peat bog is highly sensitive to the extent of drainage. Drainage causes the peat to dry out which permits the release of stored organic carbon. Accurate identification of the extent of drainage is crucial for an accurate estimation of the carbon losses. No detailed site specific data on the extent of drainage that could occur as a result of the development was available for this assessment. The results should therefore be viewed as an indication of the potential effects should all the input parameters be correct. In the event that the input data and assumptions are incorrect, it should be appreciated that the results could be significantly different.

16.5 BASELINE CONDITIONS

16.5.1 Overview

The Viking Wind Farm will displace electricity currently generated on the Shetland Islands and also a proportion of the electricity currently generated on the UK mainland. This section provides an estimation of the current CO_2 emissions related to the Shetland Islands and the UK.

16.5.2 CO_2 emissions from Shetland and UK electricity generation

Electricity on the Shetland Islands is currently provided by three main sources, Lerwick Power Station, Sullom Voe Terminal Power Station and Burradale Wind Farm. At present, the majority of the electricity generated at the Sullom Voe Terminal Power Station is used on site only; however, a capped amount is exported to SSE when required.

CO_2 emissions from large point sources throughout the UK are reported on the National Atmospheric Emissions Inventory website (NAEI, 2009). The most recent year of data reported on the website is 2006. The 2006 total CO_2 emissions associated with electricity generation from fossil fuel fired power stations in Scotland is presented in Table 16.5 and the total CO_2 emissions in the UK are presented in Table 16.6. In total, Scotland released 18,691,551 tonnes CO_2 from electricity generation in 2006. The total UK CO_2 emissions associated with electricity generation was 181,201,457 tonnes.

Table 16-5: CO_2 emissions from electricity generation in Scotland (2006)

Station Operator	**Station name**	**CO_2 emissions 2006 (tonnes)**
Scottish Power Ltd	Cockenzie	4,990,156
Scottish Power Ltd	Longannet	10,023,268
Scottish and Southern Energy Plc	Peterhead	3,450,000
Fife Power Ltd	Westfield Development Centre	140,286
Scottish and Southern Energy Plc	Lerwick	77,394
Scottish & Southern Energy Generation Ltd	Kirkwall	254
Scottish & Southern Energy plc	Arnish	203
Scottish & Southern Energy plc	Barra	136
Scottish & Southern Energy plc	Bowmore	407
Scottish & Southern Energy plc	Loch Carnan	1,489
Scottish & Southern Energy plc	Stornoway	5,770
Scottish & Southern Energy plc	Tiree	203

Station Operator	Station name	CO_2 emissions 2006 (tonnes)
EPR Scotland Ltd	Westfield Biomass Plant	1,985
Total power station emissions		18,691,551

Table 16-6: CO_2 emissions from electricity generation in the UK (2006)

Country	CO_2 (tonnes)
Scotland	18,691,551
England	142,881,185
Wales	13,883,301
Northern Ireland	5,745,420
Total power station emissions	181,201,457

16.6 IMPACT ASSESSMENT

16.6.1 Air quality

(a) Dust emission

During the construction phase, materials will be exposed and disturbed by various activities which have the potential to generate dust particulate matter. In particular borrow pit material extraction, crushing operations, passage of vehicles along site tracks and tipping may generate dust particulate, the potential impacts of which are:

- Visual impacts of dust plumes and a reduction in visibility;
- physical and / or chemical contamination of surfaces;
- coating of vegetation and the contamination of soils; and
- contamination of water sources.

Dust particles have the potential to travel for up to 1 km, therefore sensitive receptors within 1 km of potential sources of dust on the Viking Wind Farm site were identified. Several dust-sensitive receptors were identified within 1 km of potential dust sources. The identified receptors are presented in Table 16.3. The impact of dust emissions on sensitive receptors is linked to the meteorological conditions at the time of release. The main meteorological conditions which influence dust particles are wind and rain.

Dust particles can be extremely small and can be carried for long distances before settling out of the atmosphere. Wind speed and direction can therefore influence how a receptor is affected. The prevailing wind on the Shetland Islands is from the south west. The Shetland Islands are typically very windy with strong winds occurring frequently, particularly during the winter months. Receptors will be at risk of adverse effects from dust emissions at times when the wind is blowing from the source towards the receptor.

Rainfall also influences the impact of dust emissions as particles are washed from the atmosphere. The Shetland Islands experience high levels of rainfall on an annual basis with around 1200 mm per year (Met Office, 2009). High levels of rainfall will reduce the severity of dust emissions.

The locations of receptors in relation to potential dust sources are variable and there are some located within the vicinity of more than one potential dust source. Many of the identified receptors are located towards the south west of the closest dust source. These receptors are likely to be least affected by dust emissions since the prevailing wind will usually take any dust emissions away from the receptor locations. Receptors located towards the north east are most likely to be affected by dust emissions. All receptor locations have the potential to be affected in the event that dust emissions are generated when the meteorological conditions are such that the emissions will travel to the receptor.

It is impossible to predict the magnitude of impact at receptor locations. Mitigation measures are proposed in Section 16.7 which will reduce any potential impacts by reducing dust production and increasing dust suppression.

(b) **Vehicle emissions**

Vehicle emissions will be generated through construction traffic and operational traffic. An estimation of the vehicle emissions generated by the proposed wind farm has been obtained using EMIT. EMIT is an emissions inventory software tool which can be used to calculate emissions generated by traffic sources. The number of vehicles, type of vehicle, distance travelled and vehicle speed are input to the database and the estimated emissions are calculated using in built emissions factors. EMIT uses published emissions factors from the Design Manual for Roads and Bridges (DMRB). Emissions are reported in tonnes/year or g/km/s.

In order to calculate the emissions from traffic movements, the aforementioned data are required, namely number of vehicles per day, type of vehicle (HGV's), vehicle speed (km/hr) and distance travelled (km). The traffic data input into EMIT is presented in Table 16.7.

The total number of vehicle movements has been obtained from the Transport Statement. The traffic will be spread over the construction period which is estimated to occur between late spring and early autumn for a period of five years. EMIT calculates emissions on an annual basis; therefore an average number of vehicles per day assuming all construction traffic would occur in a single year has been calculated. The calculated emissions will be representative of the total emissions for the construction period.

An area of uncertainty associated with the calculation of CO_2 emissions from vehicle movements is the distance travelled. Vehicles will need to travel from their origin to the development site. It is not possible to determine how far the vehicles will travel before arriving in Shetland. In addition, it is also not possible to determine how far throughout the site each vehicle will travel. For the purposes of this assessment, due to a lack of detailed information outlining exactly how far each vehicle will travel it is necessary to make some assumptions. It is therefore assumed that all vehicles will travel the full 117.52 km of access track on site. It is recognised that this will not be the case in reality because some vehicles will only travel a small proportion of the distance; others may make smaller journeys back and forth, for example from the borrow pit to turbine base and some may travel further. Most vehicles will also have had to travel to the Shetland Islands from a variety of locations, potentially throughout the UK. For these reasons it is impossible to quantify the total distance travelled by each vehicle.

In addition, the speed at which vehicles travel affects the emission rate due to engine efficiencies. Lower vehicle speeds generally result in higher emission rates for example.

Considering that many of the access tracks may be narrow and steep, and that the vehicles will be fully loaded with supplies, a lower vehicle speed of 30 km/hr has been assumed.

Overall, considering the assumptions in the table below, the estimated total CO_2 release over the construction period is 2,126.79 tonnes CO_2.

Table 16-7: Summary of vehicle movements and estimated emissions

Activity/phase	Number of vehicle movements (in and out)	Average number of vehicles per day	Assumed distance travelled (km)	Assumed vehicle speed (km/hr)	CO_2 emissions (tonnes)
Concrete requirements	7,793	10	117.52	30	310.96
Cabling sand	2,526	7	117.52	30	217.67
Construction plant requirements	140	2	117.52	30	62.19
Additional deliveries	155	1	117.52	30	31.10
Turbine components	2,108	6	117.52	30	186.57
Workforce traffic	-	100	117.52	30	665.29
Total					1,473.51

(c) **CO_2 emissions**

The overall impact of the Viking Wind Farm is calculated as a payback period which is the time it takes for all CO_2 emissions generated by the development to be offset by the emissions saved by the use of renewable energy. The payback period reported is based on the savings achieved by the use of the UK fossil fuel electricity mix emissions factor. The use of the UK fossil fuel electricity mix factor is appropriate for use in this project for two reasons. Firstly, the electricity generated by the wind farm will displace that generated by Lerwick Power Station which is diesel fired. The most appropriate emissions factor for a diesel fired power station is that of an oil fired power station which is 0.65.

Throughout the calculation methodology, there are many areas where assumptions have had to be made due to a lack of site specific data for particular parameters. To account for this, and to highlight the effect of changing input parameters, three scenarios were conducted namely best case, intermediate case, and worst case. The results obtained indicate the payback period for the Viking Wind Farm for the particular input data used and do not indicate a definitive result for what the actual payback period will be. The results from the calculation spreadsheet detailing the CO_2 savings and losses and payback periods are presented in Tables 16.8 to 16.12. The calculation spreadsheets for all scenarios are included in Appendices 16.2 to 16.4.

The calculation is carried out in a phased process. Firstly, the CO_2 savings obtained by the use of renewable energy technology are calculated based on the installed capacity and expected number of hours of operation (see Table 16.8). This provides an estimation of the amount of electricity which will be generated by the windfarm. The predicted CO_2 savings are then calculated using the emissions factors as discussed previously. In this case, the expected CO_2 savings which will be achieved by the Viking Wind Farm is 1,292,109 tonnes per year.

Table 16-8: CO_2 emissions saved by Viking Wind Farm

Displacement scenario	CO_2 saving (tonnes/year)	CO_2 saving over life of wind farm (tonnes)
UK fossil fuel electricity mix	1,292,109	32,302,725

Next, the CO_2 emissions which will be generated by the Viking Wind Farm are calculated (see Table 16.9). This includes:

- emissions generated by the wind turbine life cycle (including manufacture, transportation, construction and disposal);
- emissions generated by back up electricity supply (to account for periods where alternative sources of energy need to be sourced because the wind is not blowing and for inefficiencies in the energy generation process);
- reduced carbon fixing potential which accounts for the loss of carbon fixing vegetation;
- soil organic matter losses which accounts for the direct removal of peat and for the indirect loss through drainage; and
- losses through the leaching of dissolved and particulate organic matter.

As mentioned in Section 16.4.4 (k), the calculation assumes that the hydrology of the site will be restored upon decommissioning and so reported CO_2 losses are for the duration of the wind farm lifetime only. If the hydrology of the site is not restored, the CO_2 losses would be substantially greater. The CO_2 emissions generated by the Viking Wind Farm and the difference these features make to the payback time, if taken in isolation, are shown in Table 16.9.

Table 16-9: CO_2 emissions generated by the Viking Wind Farm

Emissions Loss	CO_2 losses (tonnes)			Payback period (months)		
	Best case scenario	Intermediate scenario	Worst case scenario	Best case scenario	Intermediate scenario	Worst case scenario
Turbine life cycle	175,140	175,140	175,140	1.6	1.6	1.6
Back up electricity supply	358,919	358,919	358,919	3.3	3.3	3.3
Reduced carbon fixing potential	8,973	90,366	496,431	0.1	0.8	4.6
Soil organic matter	1,983,248	3,520,798	16,139,191	18.4	32.7	149.9
Leaching of dissolved and particulate organic carbon	503,678	696,821	2,183,263	4.7	6.5	20.3

Emissions Loss	CO_2 losses (tonnes)			Payback period (months)		
	Best case scenario	Intermediate scenario	Worst case scenario	Best case scenario	Intermediate scenario	Worst case scenario
Felled forestry	0	0	0	0.0	0.0	0.0
Total	3,029,959	4,842,043	19,352,944	28.1	45.0	179.7

The main cause of CO_2 emissions occurs as a result of site drainage. Therefore, the opportunity exists to minimise CO_2 losses through drained peat by restoring the site upon decommissioning.

The calculation takes into consideration the extent of degraded bog which will be improved, restoration of borrow pits, and removal of drainage from turbine bases and hardstanding. In addition, the calculation takes into consideration the effect of methane emissions which are released from active bogs through anaerobic conditions. The CO_2 gains due to site improvement and the difference these features make to the payback time, if taken in isolation, are shown in Table 16.10

Table 16-10: Total CO_2 gains due to site improvements

Site improvement gains	CO_2 gains (tonnes)			Reduction in pay back period (months)		
	Best case scenario	Intermediate scenario	Worst case scenario	Best case scenario	Intermediate scenario	Worst case scenario
Degraded bogs	60,757	106,687	152,617	0.6	1.0	1.4
Felled forestry	0	0	0	0.0	0.0	0.0
Restoration of peat from borrow pits	6,763	7,529	8,295	0.1	0.1	0.1
Removal of drainage from foundations and hard standings	0	0	0	0.0	0.0	0.0
Total	67,520	114,216	160,912	0.6	1.1	1.5

Finally, the net CO_2 emissions, taking into consideration all emissions generated by the wind farm and all the subsequent gains through site improvement are calculated (see Table 16.11).

Table 16-11: Net CO_2 emissions

Emissions loss	Best case scenario	Intermediate scenario	Worst case scenario
Net CO_2 emissions (tonnes CO_2 eq)	2,962,439	4,727,827	19,192,032

The overall payback period is then calculated using the CO_2 emissions saved compared with the net CO_2 emissions released by the wind farm. This is presented as a time scale because the emissions are calculated over the anticipated life time of the wind farm i.e. 25 years.

Table 16-12: Total pay back period for Viking Wind Farm

Displacement scenario	Payback period (years)			Payback period (months)		
	Best case scenario	Intermediate scenario	Worst case scenario	Best case scenario	Intermediate scenario	Worst case scenario
Fossil fuel mix electricity generation	2.3	3.7	14.9	28	44	178

The net CO_2 savings obtained by the Viking Wind Farm are calculated in Table 16.13 by subtracting the net emission release (Table 16.11) from the total CO_2 savings (Table 16.8). The percentage reduction in annual CO_2 emissions related to fossil fired power stations in Scotland and the UK has then been calculated. The estimated reduction in CO_2 emissions related to electricity generation in Scotland is 6.3% for the best case scenario, 5.9% for the intermediate scenario, and 2.8% for the worst case scenario.

Table 16-13: Predicted change in CO_2 emissions from electricity generation

Parameter	Best case scenario	Intermediate scenario	Worst case scenario
CO_2 emissions savings (tonnes/year)	1,292,109	1,292,109	1,292,109
Net CO_2 emissions (tonnes/year)	118,498	189,113	767,681
Net CO_2 saving (tonnes/year)	1,173,611	1,102,996	524,428
Total CO_2 emissions from electricity generation in Scotland	18,691,551	18,691,551	18,691,551
Total CO_2 emissions from electricity generation in the UK	181,201,457	181,201,457	181,201,457
Anticipated reduction in total CO_2 emissions in Scotland per year	6.3%	5.9%	2.8%
Anticipated reduction in total CO_2 in the UK per year	0.65%	0.61%	0.29%

16.7 DISCUSSION OF RESULTS

The results presented in the previous section reflect the influence of the extent of drainage on the overall payback period of a wind farm. Based on the input data used (refer to Appendix 16.1), the payback period has been calculated to range from 2.3 years to 14.9 years depending on the extent of drainage and hydrological conditions of the peat bog.

Due to the assumptions used to calculate the payback period, and the nature of the assessment, the results should be regarded as indicative, rather than a definitive prediction of the actual payback period which would occur in practice. The results also assume that the hydrology of the site is restored upon decommissioning which is the critical component for determining the payback period of the wind farm. It should also be noted that the restoration of habitats on site has less effect on the payback period than restoration of the hydrology.

However, considering the predicted payback period in relation to the criteria defined in Table 16.4, the overall effect of the Viking Wind Farm on climate change is determined to be beneficial for the best and intermediate scenarios and neutral for the worst case scenario.

Overall, the Viking Wind Farm would reduce CO_2 emissions associated with electricity generation in Scotland by between 2.8% and 6.3%, and in the UK by between 0.29% and 0.65% respectively.

16.8 MITIGATION

16.8.1 Air quality mitigation

The following mitigation measures are generic and are devised from typical good practice techniques designed to minimise the impact of dust emissions during construction activities. The main principles to apply to dust control during the construction phase include:

- Minimise the creation of dust by planning and design;
- control the escape of dust;
- minimise dust pick up by wind;
- remove dust from the atmosphere; and
- temporarily suspend the activity or operation if the creation of dust cannot be avoided.

Site haulage roads will be subject to road dust re-suspension. Re-suspension is a function of vehicle speed and road condition, and hence controls should primarily be focussed on the following:

- Prevention of roads becoming dusty,
- suppression of dust on the road, and
- control of vehicle speeds.

This can be achieved by the use of:

- Wheel cleaning devices (wet or dry);
- regular washing of surfaced roads;
- consideration of additives in sprays/wash water, e.g. use of calcium chloride on un-surfaced roads;
- use of wind breaks; and
- restriction of vehicle speeds to suit conditions using site signage.

In addition, the following dust mitigation measures can be considered:

- Use windbreaks/netting screens/semi-permeable fences;

- vegetate exposed surfaces, with quick growing plants;
- use closed or sheeted vehicles carrying dry material;
- use fine water sprays/mists, with or without additives, as dust barriers; and
- use trees or shrubs around the site.

16.8.2 CO_2 emissions mitigation

The potential adverse effects on CO_2 emissions related to the construction of wind farms on peat bogs include emissions generated during the manufacture of turbines, manufacture of concrete for construction of turbine bases, hard standing areas, compounds etc. and the release of CO_2 through destruction of peat bogs. Overall, the destruction of peat bogs presents the greatest risk to climate change due to the fact that peat bogs store a significant amount of carbon which may be released if the bog is disturbed.

The main mitigation measures necessary to minimise the impact on climate relate, therefore, to the treatment of peat on site. Detailed mitigation measures relating to peat are outlined in Chapter 14. A Habitat Management Plan has also been prepared. Overall the impact on peat will be considered at all stages of the project to ensure that the volumes of peat removed are minimised and also to ensure that as much displaced peat as possible is re-used on site. Any displaced peat will not be allowed to dry out.

Further to this, the extent of drainage on site is critical to the overall payback period of the wind farm. A key method of reducing the payback period is to minimise the extent of drainage associated with the turbine bases, hard standings and roads. Peat bogs are essentially hydrological systems and so the drainage will be minimised at all opportunities. Also any drains will be blocked upon decommissioning to help restore the hydrology of the site.

In addition, the following best practice techniques will be applied consistently throughout the development:

- Peat will be excavated in large intact turfs or clumps to minimise the potential for drying out.
- Once the peat has been excavated, disturbance or movement will be minimised.
- Where appropriate, peat will be sprayed to keep it moist.
- Peat will be stored in large amounts while considering peat slide risk.
- Restoration will take place as soon as possible following extraction.
- Floating roads will be used on areas where the peat is greater than 1m deep.
- Submerged foundations will be used on deeper areas of peat.
- Tracks will be designed to avoid acting as drainage channels or barriers to water flow.
- Tracks will incorporate cross drains where appropriate to minimise water collection.

- Habitat improvement activities, for example, blocking drains and re-wetting areas will be undertaken.
- An environmental clerk of works will be on site at all times during construction to oversee environmental management of the project.

Finally, a monitoring programme will be implemented during the construction phase to ensure that the best practice recommendations and construction techniques outlined throughout the ES are adhered to.

16.9 SUMMARY OF EFFECTS

The assessment considered the risks of dust emissions from borrow pit operations and construction activities on local sensitive receptors. There is the potential for some receptors to be adversely affected by dust emissions under certain meteorological conditions. The impacts of dust will be adequately mitigated by following best practice guidance for dust suppression.

The assessment also considered the impact of the release of CO_2 emissions associated with the wind farm. The assessment considered three scenarios to account for the unknown extent of bog which may be adversely affected by drainage. Based on the input data used, the payback period was calculated to be 2.3 years for the best case scenario, 3.7 years for the intermediate scenario and 14.9 years for the worst case scenario.

The payback period calculated for the best case scenario is the most favourable considering the life time of the wind farm since more CO_2 will be saved than is released. However, there are some areas where the assumptions may not be totally representative of reality; for example, it is highly likely that at least some of the floating roads will sink and require drainage at some point.

Similarly, the worst case scenario assumes that all floating roads will sink and that the drainage will affect bog for a distance of 100m. The calculation does not take into account local variations in the quality of the bog and so this scenario will likely over estimate the CO_2 emissions.

The intermediate scenario assumes some floating roads will require drainage. It is therefore considered that the intermediate scenario represents the most likely payback period depending on the accuracy of the input data.

Overall, considering the nature of peat bogs and their hydrological characteristics, it is not possible to calculate a definitive payback period. The payback period is highly sensitive to the hydrological characteristics of the site and the extent of bog which will be affected by drainage. The results presented in this assessment should, therefore, be taken as indicative of the results obtained from the input data utilised in each scenario. The results indicate that it is crucial that the peat bogs on site are disturbed as little as possible to prevent extensive loss of peat, and that all mitigation measures are implemented.

Therefore, in order to ensure that the payback period is as short as possible, all appropriate mitigation measures concerning peat removal and drainage features will be utilised to minimise the loss of peat throughout all stages of the Viking Wind Farm.

16.10 REFERENCES

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