A16. AIR AND CLIMATE

A16.1 INTRODUCTION

The design of the proposed Viking Wind Farm has changed since the Section 36 application, and its associated Environmental Statement, was submitted in the Spring of 2009. This chapter describes how these changes would affect local air quality and emissions of greenhouse gases.

Before reading this chapter, please first read Addendum Chapter A1, the Introduction, and Chapter A4, the Development Description. Failure to read these two chapters carefully may lead to a misunderstanding of the assessment work described in this chapter. Furthermore, because this addendum chapter is not intended to provide a complete new assessment of the issues, but instead provides a discussion of the effects of the work which has taken place since the 2009 ES was submitted, it must be read in conjunction with the air and climate chapter of the 2009 Environmental Statement.

The Macaulay Land Use Research Institute undertook an independent review of the basis of the carbon payback calculations on behalf of Viking Energy with the aim of improving the robustness of these calculations, and to inform further assessments based upon them.

A16.1.1 Air Quality

As described in Chapter A4, revision to the Viking Wind Farm layout has resulted in the deletion of turbines and associated infrastructure and a consequent reduction in the development footprint. The number and location of borrow pit search areas has also been revised. Reducing the site footprint would result in a corresponding reduction in the potential emissions of dust and air pollutants from construction activities. The assessment presented in this Addendum Chapter re-evaluates the potential for adverse impacts to local air quality and dust nuisance resulting from the development.

A16.1.2 Calculating the Carbon Payback Period

The carbon payback period of a wind farm is the length of time it would need to be in operation before contributing positively to carbon emission reduction targets. To establish the carbon payback period it is first necessary to account and determine values for all carbon losses and gains associated with a development. These can be broadly categorised as follows:

1. CO_2 emission savings according to counterfactual fuel sources (coal fired, grid-mix, or fossil-fuel mix of electricity generation);
2. CO_2 losses from fossil-fuel fired back up generators;
3. CO_2 losses from the manufacture of wind farm turbines, construction and decommissioning activities;
4. CO_2 losses due to impacts on soils and vegetation; and
5. CO_2 gains due to measures put in place by the developer to restore and improve the carbon absorption and fixing potential of soils and vegetation at the site.

The University of Aberdeen and Macaulay Land Use Research Institute have developed a carbon calculation spreadsheet based on formula within the report *Calculating carbon savings from wind farms on Scottish peatlands – A New Approach* [Nayak et al, 2008]. The calculator enables data to be input for each of the five categories described above to arrive at the carbon payback period. This calculator was used to arrive at the carbon payback values presented in the 2009 ES.

Use of the calculator however masks significant variation in the robustness of input values across the categories.

There is much evidence to support and calculate input values for counterfactual fuel sources and back-up generators. These are relatively fixed values and can be recorded with a relatively high degree of confidence. Counterfactual emission savings have been recalculated for the revised wind farm layout to take account of the reduction in the electricity generating potential of the development. The calculation therefore reflects the reduced potential of the wind farm to offset carbon emissions associated with fossil fuel combustion electricity generation.

CO_2 losses associated with wind farm infrastructure production, construction and decommissioning activities are also robust and are based on information available from manufacturers and generic values for materials including concrete. These input values however are dependent on the number and type of turbines and nature and quantity of associated infrastructure. The values used in the carbon payback calculation for this addendum chapter have therefore been revised to take account of the altered Viking Wind Farm layout described in Chapter A4. The calculation consequently reflects the reduction in materials and associated energy required to construct the wind farm.

The establishment of input values for losses due to impacts on soils and vegetation, and gains due to restoration and improvement measures implemented, is open to greater subjectivity in the case of wind farms developed on peat.

Peat is a major store of carbon. Pristine peatland (also referred to as blanket bog) absorbs CO_2 from the atmosphere and retains it within the soil structure. However, peatland that has been damaged, for example through over-grazing, lowering of the water table or other erosive forces, releases greenhouse gases from the carbon store back into the atmosphere (see for example the Natural England report *England's Peatlands, Carbon Storage and Greenhouse Gases* published in 2010). It is therefore important to establish the quality of peatland affected by wind farm development to arrive at a realistic input value.

The carbon calculator used in the 2009 ES assumed that all peat is in pristine condition and does not enable alteration of the input value. The 2009 ES Chapters 10 and 14 however identified that much of the peatland affected by the proposed Viking Wind Farm is degraded and therefore this section of the calculation has been undertaken manually as per the methodology described in Section A16.4.2. The alteration to the baseline peat emission value is considered in detail in Section A16.5.2.

In addition to the quality of peatland, CO_2 emissions are also affected by drainage caused by the intrusion of infrastructure in the peat body. Good quality, undamaged peat absorbs CO_2. The placing of infrastructure, for example tracks or turbine foundations, within peat alters the flow of groundwater in the peat and can create drying of the surface in areas surrounding imposed structures, with a consequent reduction in peat quality. Degraded drying areas of peat can release greenhouse gases from the peat carbon store. There is however little agreement in the literature as to the extent of the peat area affected.

Whilst it has been claimed that drainage distances can be up to 200 m, evaluation of peat in Scotland indicates that distances of between 0 and 21.3 m would be expected. In light of this evaluation the calculation has been re-run for three drainage distance scenarios: 10 m, 20 m, and 50 m. The 50 m drainage scenario has been selected as the worst case based on the available evidence, rather than the 100 m distance in the 2009 ES. A full discussion of the rationale and methodology is presented in Section A16.4.2.

The consideration of impacts on peat within the addendum calculation is therefore more robust than in the 2009 ES. The calculation also takes account of the reduced development footprint and consequent reduction in emissions associated with the disturbance of peat.

Input values relative to CO_2 gains from restoration and improvement of soils and vegetation are also subject to variability due to the nature of peat and the primacy of restoration techniques. The input values used in this addendum calculation have been derived from historical, site specific research studies.

The revised carbon payback calculation methodology is considered in full in Section A16.4.2. Comments from statutory consultees that have influenced the revised calculation methodology are discussed in section A16.4.2 and results are provided in section A16.8.2.

It should also be noted that the version of the carbon payback calculator used in the 2009 assessment has subsequently been found to contain an error which has led to an overestimate in greenhouse gas emissions, and thus the carbon payback period. The error, relating to the calculation of effects from cable trenches, was further magnified where large higher drainage values were assumed. The error in the calculator has now been corrected.

A16.2 CONSULTATION RESPONSES

No statutory consultees objected to the proposed wind farm on the grounds of effects on air and climate. SEPA were unable to comment in detail on this issue at the time because their position regarding the use and re-use of peat on construction sites, and their view on the status of the excavated material as waste, was in a state of development. SEPA and SNH both commented that they were awaiting clarification from the Scottish Government on the body to be responsible for evaluating carbon calculations. Comments received from SEPA and SNH in this regard are, as stated by those bodies, outside of their remit.

A number of consultation responses were received on the assessment of air quality undertaken in the 2009 ES. A summary of the consultation responses is provided in Appendix A1.1, and a brief commentary on the responses is provided in Table A16.1 below.

Table A16.1: Consultation Responses

Consultee	Response Summary
Air Quality	
Shetland Islands Council Environmental Health Service	• DEFRA Local Air Quality Management Technical Guidance TG (09) supersedes the 2003 version. TG (09) Table A.3 should be used in calculating vehicle emissions. • Short-lived construction sites do not normally need to be considered for

(SIC EHS)	LAQM purposes. • Dust from site haul routes will affect, and monitoring will be required at two properties in Valleyfield (Brae), one in Whinnea Lea (Nesting), and possibly at Setter House (Weisdale). • Some outlined mitigation for dust is not appropriate to Shetland, e.g. the use of trees. • Dust suppression Management Plan to be developed, agreed with SIC EHS and implemented pre-works. • Dust monitoring programme to be proposed and agreed with SIC EHS.
	Consultant's response: It is acknowledged that Local Air Quality management guidance was updated shortly before the submission of the original ES. The screening assessment methods and criteria are the same in both the revised and superseded documents. As discussed above it is acknowledged that the suggested mitigation for fugitive dust impact will not be suitable in all situations. Further detail of the proposed mitigation measures during the construction period are provided in the Site Environmental Management Plan (SEMP), Appendix A14.6. The SEMP also sets out VEP's commitment to development a management plan and monitoring programme.
RSPB	• Some mitigation outlined in Section 16.8.1 inappropriate. Additives in spray/wash water should not be used, and exposed peat surfaces should not be vegetated with quick growing plants. Restoration should instead use previously removed acrotelm turfs or native plant species.
	Consultant's response: It is acknowledged that the suggested mitigation for fugitive dust impact will not be suitable in all situations. Further detail of the proposed mitigation measures during the construction period are provided in the Site Environmental Management Plan, Appendix A14.6..

<table>
<tr><th colspan="2">Carbon Budget Appraisal</th></tr>
<tr><td rowspan="2">RSPB</td><td>• Object on basis that carbon balance of proposal is uncertain; ES underestimates indirect impacts on peat, no assessment of interconnector carbon budget, underestimated worst-case payback period, and possibility of negative contribution to climate change targets.
• Carbon budget must include interconnector and all associated infrastructure.
• Worst case payback period should be calculated based on 200m zone of drainage influence, occurrence of some peat slides, 25yr+ restoration period for hydrology and habitat, and carbon loss from excavated peats.
• Clarification required on prevention of peat drying and damage to blanket bog from storage of excavated peat.
• Mitigation provided for floating roads and drainage is inconsistent with earlier chapters.</td></tr>
<tr><td>Consultant's response: Whilst the interconnector and the wind farm are technically linked they are both subject to separate planning applications. Scottish Hydro Electric Transmission Ltd (SHETL) as the applicant for the permissions relating to the interconnector has prepared a carbon balance report for the convertor station at the Shetland end of the interconnector. This is available from SHETL or the Planning Authority.

The method of calculating carbon payback and the assumptions made in those calculations are summarised and justified in Section A16.4.

Details of the proposed method of storing excavated peat are provided in the Site Environmental Management Plan, Appendix A14.6, as are details of all proposed mitigation measures.</td></tr>
<tr><td rowspan="2">SEPA</td><td>• SEPA not currently in position to comment.
• Note inconsistency in carbon payback periods provided in different ES sections
• Interconnector has not been taken into account and is a material consideration.</td></tr>
<tr><td>Consultant's response: As discussed above, the effect of the interconnector on carbon emissions has been considered elsewhere.

The previous inconsistency in the carbon payback periods is noted and has been clarified within this ES chapter.</td></tr>
<tr><td rowspan="2">SNH</td><td>• No remit to advise on carbon calculation although advice on inconsistencies in ecological assessment is relevant and may help evaluate validity of input parameters.
• The development footprint is underestimated due to lack of consideration of associated infrastructure.
• Impacts on peat are underestimated.
• Development footprint cannot be measured until inconsistency in ES, in terms of operational and construction track widths, crane pad dimensions and habitat loss are resolved.
• Assessment based on full adoption of mitigation measures denies assessment of worst-case scenario and evaluation of mitigation effectiveness. A more transparent approach should be adopted.</td></tr>
<tr><td>Consultant's response:
The comments of SNH are noted and have been incorporated into the revised assessment of carbon emissions.</td></tr>
</table>

A16.3 CHANGES IN THE POLICY CONTEXT

A16.3.1 Air Quality

Since the 2009 assessment was undertaken the Scottish Government has issued revised Local Air Quality Management (LAQM) Policy Guidance. The Policy Guidance places a greater emphasis on the role of development and transport planning in improving air quality. The guidance also sets out the revised assessment and reporting framework for local authorities.

This assessment takes cognisance of the revised policy guidance and its accompanying technical guidance.

A16.3.2 Carbon emissions

A single Scottish Planning Policy (SPP) was published in February 2010 and includes various topic areas including wind farms and various environmental subject areas. The Planning Policy overrides the previous individual planning policies including Scottish Planning Policy SPP6 [Scottish Government, 2007]. As with SPP6 the policy recognises the reduction of carbon emissions as a key objective of renewable energy policy and identifies the need to consider the release of carbon stored in soils. The policy states that where peat and other carbon rich soils are present, applicants should assess the likely effects associated with any development.

Whilst the need to assess the likely effects of a development on carbon emissions is established, neither SPP nor the relevant planning advice note PAN 45 *Renewable Technologies* [Scottish Government, 2002] provides guidance on the method for doing so. Scottish Government, however, does encourage use of the document *Calculating carbon savings from wind farms on Scottish peatlands – A New Approach* [Nayak et al, 2008] to gauge the payback time for carbon emissions from a project. It is noted the document is pending further refinement, and as such it is recommended that the results of an assessment undertaking following the approach should be treated as indicative only.

A16.4 CHANGES IN METHODOLOGY

A16.4.1 Air Quality

The 2009 ES considered the air quality impacts in line with guidance contained within Local Air Quality Management (LAQM) Technical Guidance TG(03). As discussed in Section A16.2, in response to comments from Shetland Islands Council on the 2009 ES, this guidance has now been superseded with TG(09) [Scottish Government, 2009]. The method of assessment has not, however, changed between the two guidance documents.

The method of assessing dust nuisance, i.e. in accordance with Planning Advice Note PAN50 Annex B [The Scottish Office, 1998], is the same as that used in the 2009 ES.

A16.4.2 Carbon emissions

The 2009 ES calculated a carbon payback period for the proposed wind farm based on the method outlined in the guidance document *Calculating Carbon Savings from Wind Farms* *on Scottish Peat Lands – A New Approach* [Nayak et al, 2008] and the accompanying carbon calculator spreadsheet. The document and accompanying spreadsheet are hereafter referred to in this Chapter as the CCS Report or CCS Spreadsheet.

The CCS Report is unchanged since the 2009 ES. However, the CCS Spreadsheet has been amended, with the most recent version issued in December 2009. The most recent spreadsheet contains a number of corrections and amendments from the previous version of the spreadsheets. The calculations undertaken in this assessment have, therefore, followed the original 2008 CCS Report and the latest version of the spreadsheet.

The 2009 ES calculations considered a series of generic site data and/or general assumptions about conditions across the site. In reality, conditions across the site are heterogeneous, therefore using a generic dataset and/or assumption to calculate the carbon payback does not allow the carbon emissions associated with the development to be accurately calculated.

In response to comments from statutory consultees and in line with our improved understanding of the site the carbon payback calculations have been revised and refined wherever possible. The general method of assessment still follows that laid out in the CCS Report, however the calculations have been amended to more accurately capture the variability of conditions across the site, as well as the variety of features. To achieve this, the calculations have been undertaken following the method contained in the CCS Report rather than using the spreadsheet. The calculations are set out in a methodical way in Appendix A16.6.

The calculations undertaken to determine the carbon payback period of the wind farm can be divided into two categories, emissions relating to counterfactual emissions associated with the offset of fossil fuel combustion emissions and construction of the wind farm, and emissions caused by changes to hydrological conditions of peat. As discussed in Section A16.1.2, emissions associated with carbon offset and construction are calculated based on generic emissions factors based on an average of parameters measured/calculated at a UK level. Emissions associated with changes to the hydrological conditions of peat are more site specific and dependant on local assumptions and/or measurements.

The methods of calculating the emissions associated with each category are set out in the following sections. Overall, the calculations account for the following generating activities and emissions savings:

- Carbon emissions savings due to fossil fuel combustion offset;
- Loss of carbon due to wind farm lifecycle (production, transportation, erection, operation and decommissioning);
- Loss of carbon due to backup power generation requirements;
- Loss of carbon fixing potential of peatlands;
- Loss of carbon from soil removal;
- Loss of carbon due to changes in hydrodynamics (drying); and
- Carbon savings due to habitat improvement measures.

Some other factors have been specifically excluded. The study does not consider loss of carbon due to forestry clearance as this is not applicable to the Viking Wind Farm. The wind farm layout has been designed in such a way as to minimise peat slide risk (see Chapter 14 of the 2009 ES and Chapter A14 of this Addendum). As the peat slide risk has been assessed as "unlikely" (see the 2009 ES, Appendix 14.1, Peat Stability Assessment), assessment of potential emissions due to this cause has also been excluded.

Counterfactual emissions and carbon lifecycle

Carbon savings due to fossil fuel combustion offset

Electricity produced by the wind farm will off-set electricity produced by other sources and the carbon emissions associated with those sources.

The total electricity produced by the wind farm, on average, in a year is a product of the number of turbines, the generating capacity of each turbine and the calculated capacity factor of the turbine.

The emissions offset will depend on the electricity generation source displaced. As individual sources cannot be identified it is necessary to use average emissions factors for a range of electricity generating means to calculate the emissions offset by the electricity produced by the wind farm. These counterfactual emissions factors are specified for three electricity generating mixes:

- coal-fired plant emissions;
- typical grid mix emissions; and
- fossil-fuel mix emissions.

Coal fired plant emissions represent the carbon emissions associated with the combustion of coal in thermal power generation plants. The emissions factor represents the average CO_2 emission per mass weight of coal combusted in power generating plant. Coal fired power generation represents the most carbon-intensive method of generating electricity.

The typical grid mix represents the average carbon emission for electricity production across all electricity production types, including coal and gas fired combustion plant, nuclear and renewable energy sources. The emission factor is provided on the UK emissions factor database [NAEI, 2008] and represents the current relative contribution of each electricity generating source, and the associated emissions, to the UK grid.

The fossil-fuel mix represents the average carbon emissions associated with energy production from all fossil fuel, i.e. gas, coal and heavy fuel oil, combustion generated electricity.

As referenced in Appendix 2 of the CCS Report and reflecting national grid statistical data, electricity generated by renewable sources will typically offset emissions from fossil fuel sources. Nuclear power tends to provide the UK base load, as due to the difficulties in stopping and restarting nuclear power, nuclear power stations operate continuously. By contrast, fossil fuel combustion can be varied according to renewable energy output. It is, therefore, most appropriate to calculate carbon emission savings with reference to the fossil fuel mix emissions factors.

It should be noted that the fossil fuel mix emissions factor is a five year average emissions factor based on the period 2002-2006. As fossil fuel combustion efficiencies improve, and as old inefficient plant is decommissioned the fossil fuel emissions factor will be expected to decrease.

The carbon emissions offset from other electricity producing sources is, therefore, calculated by the following equation:

Emission saving ($t\ CO_2\ yr^{-1}$) = *Annual energy output of wind farm* ($MWh\ yr^{-1}$) *x Counterfactual emissions factor* ($t\ CO_2\ MWh^{-1}$)

Where the counterfactual emissions factor for fossil fuel grid mix is 0.607 $t\ CO_2\ MWh^{-1}$.

The study also considers a counterfactual emission based upon the grid mix emission factor of 0.43 $t\ CO_2\ MWh^{-1}$ to determine the sensitivity of the carbon payback period to the emissions factor assumed.

Carbon emissions due to wind farm lifecycle

The carbon lifecycle of wind turbines includes the carbon costs associated with the manufacturing of wind turbines, transportation, on-site construction, ongoing operation and decommissioning. The carbon emissions associated with a typical turbine have been evaluated by a number of companies as discussed in the CC Report. Based on the results of these studies an equation has been developed to estimate the carbon lifecycle of a turbine based on its generating capacity as follows:

$$L_{Life} = (934.35 \times c_{turb}) - 467.55$$

where L_{Life} is the carbon lifecycle loss (te CO_2 $turbine^{-1}$);

C_{turb} is the turbine capacity (MW)

It should be noted that the formula is taken from the most recent version of the CCS Spreadsheet and differs from that contained in the original CCS Report, reflecting the results of more recent manufacturer carbon lifecycle studies.

The total lifecycle emission of the development is a function of the turbine lifecycle emissions and the total number of turbines in the development.

Carbon savings due to backup power generation requirements

The inherent variability of wind means that the power generated by a wind farm in variable. In order to ensure a stable electricity supply to consumers the National Grid maintains a constant backup electricity supply. At present, the existing capacity of the generating network means that any variability in electricity produced by wind farms can be accommodated, however as the proportion of all electricity produced by wind increases the need for backup power generation becomes more important.

In Scotland, the capacity of hydropower and the ability to control its power generation means that little backup power generation is required. If, however, electricity generation is considered across the whole national grid (UK wide) it has been determined that additional backup capacity will be required when the proportion of total electricity produced in the UK from wind exceeds 20%.

The CCS Report identifies that where backup power generation is required a capacity of 5% of the rated capacity of the wind farm will be necessary. Due to the reduced efficiency of the thermal power generation by being on backup an increase in carbon emissions equivalent to 10% of the backup capacity will occur.

Based on the contribution of wind to the national grid currently it is anticipated that the proportion of electricity in the UK produced by wind will not exceed 20% until 2038. For the purposes of the calculations it has been assumed that the wind farm will be fully operational by 2016, and will remain operational until 2041. On the basis of these assumptions, a backup capacity of 5% of the rated output of the wind farm will, therefore, be required for the period 2038-2041.

Emissions due to changes to hydrological conditions

Changes to the hydrological conditions of the peatland on the site have the potential to alter the conditions of peat and accelerate or cause further erosion of the soil due to drying. The hydrodynamics of the site will vary according to local geology and topography, therefore it is not possible to determine the exact effects of the development on hydrological conditions. It is, therefore, necessary to make a number of assumptions regarding local site conditions in order to estimate likely carbon emissions.

Where assumptions are made in input data to a model there will be a potential variance on that input data, which will, in turn, lead to a variance in the model output

Loss of carbon fixing potential of peatlands

The carbon fixing potential of peatlands, i.e. the amount of CO_2 absorbed by vegetation on peat, varies depending on the quality of the peat and its vegetative state. Active blanket bog has a positive carbon fixing potential, i.e. it absorbs more CO_2 than it releases, however bare or exposed peat will have a negative carbon fixing potential. The Natural England report *England's Peatlands, Carbon Storage and Greenhouse Gases*, [Natural England, 2010] outlines carbon gas flux rates (carbon fixing potential rates) for differing peatland vegetations. The report identifies that bare peat, for example, has a positive carbon flux i.e. it emits low quantities of CO_2, whereas pristine, undamaged blanket bog has a high carbon fixing potential.

A vegetation survey (NVC survey) was undertaken on the Viking site as part of the ecological habitats assessment, the findings of which were reported in Chapter 10 of the 2009 ES. Based on these data the peatlands on the site have been categorised in accordance with the categories set out in the Natural England report. The data are set out in Table A16.2.

Table A16.2: Peatland vegetation and carbon flux rate

NVC Survey Category	Natural England Category	Carbon Flux Rate (tonnes CO_2 ha^{-1} yr^{-1})
Bare Peat	Bare Peat	0.06
Blanket Bog (BB)	Blanket bog/Hagged and gullied	-0.2
Blanket Bog (BB)	Blanket bog/Undamaged	-4.11
Acid grassland (AG)	Improved/shallow peaty soils	0.92
Acid dry dwarf shrub heath (ADH)	Improved/shallow peaty soils	0.92
Semi improved acid grassland (SI)	Improved/shallow peaty soils	0.92

NVC Survey Category	**Natural England Category**	**Carbon Flux Rate (tonnes CO_2 ha^{-1} yr^{-1})**
Improved grassland (I)	Improved/shallow peaty soils	0.92
Dry heath/acid grassland mosaic (DGM)	Improved/shallow peaty soils	0.92
Wet heath and wet heath/ acid grassland mosaic (WGM)	Improved/shallow peaty soils	0.92
Mesotrophic grassland (MG)	Improved/shallow peaty soils	0.92

It should be noted that the values assigned to the table reflect the carbon flux rates of peatlands in England, and that the situation in Shetland is different, not least due to the difference in ambient meteorological conditions. For the purposes of the study, therefore, it was assumed that non-pristine peat has no carbon fixing potential i.e. a carbon flux rate of zero, whilst only undamaged blanket bog and hagged and gullied bog have carbon fixing potential as per Table A16.2.

A GIS analysis was undertaken to determine the surface area around each feature (including drainage buffers) of each peat vegetation class. Using the surface area determined for each vegetation type and the assumed carbon flux rate a net CO_2 flux per year was calculated. The total net flux over the lifetime of the wind farm was then calculated. The calculations were undertaken to reflect the surface areas affected depending on the three drainage scenarios considered (see section on changes due to hydrodynamics below).

Loss of carbon from soil removal

The loss of carbon from removed soil (peat) is a function of the total volume of removed peat and the carbon content in peat.

The construction of the wind farm will require the removal of peat to allow the construction of various features, including:

- roads;
- cable trenches;
- turbine bases; and
- temporary and permanent hardstanding around turbine bases.

The total volume of removed peat from cut roads, turbine bases, temporary and permanent hardstanding has been calculated as part of the Site Materials and Reinstatement Plan. The volume of removed peat as determined by the peat balance calculation is summarised in Table A16.3. The calculated value, however, should not be regarded as definitive, but rather a realistic estimate of the volumes of peat to be excavated and re-used.

The calculations account for the total dimensions of each feature and the relative peat depth at each feature. The calculations also account for the re-use of peat for verge protection and support for turbine bases and permanent hardstanding.

Table A16.3: Peat extraction and re-use volumes

Peat details	**Volume of peat (m^3)**
Total volume of peat excavated	742,000
Total volume of peat re-used	434,000
Peat balance	308,000

It should be noted that removed peat for temporary hardstanding areas will be reinstated immediately following construction. Peat extracted from the turbine base areas will be stored on-site for re-instatement following the decommissioning of the wind farm. Further detail on peat extraction and re-use is provided in Appendices A14.4 and A14.6.

It is not, therefore, considered that this peat is lost and as such the removed peat from the turbine bases has not been included in the calculation for peat loss. Similarly, peat will be stored on-site for restoration of some permanent hardstanding and to restore areas of double track to single track following the construction phase of the development.

The total volume of peat permanently removed is, therefore, approximately 308,000 m^3. It is proposed that this peat will be used to restore the borrow pit areas on site. It may be considered that the peat is not entirely lost and given suitable restoration and planting of borrow pit areas may become active blanket bog, however for the purposes of calculating carbon emissions, and to present a worst case scenario, it is assumed that this volume of peat is lost.

The carbon loss associated with this loss of peat can be determined by the equation:

$$L_{removed} = (3.667/100) \times pC_{dry\ peat} \times BD_{dry\ soil} \times V_{direct}$$

Where $L_{removed}$ is the carbon loss (tCO_2)

$pC_{dry\ peat}$ is the carbon content of peat (%), assumed to be 50%

$BD_{dry\ soil}$ is the bulk density of dry soil (g/cm^3), assumed to be 0.1 g/cm^3

V_{direct} is the volume of soil lost

The calculations to determine the total emissions as a result of soil removal were undertaken based on the above equation and assuming a 50% carbon content of peat and an average bulk soil density of 0.1 g/cm^3.

Loss of carbon due to changes in hydrodynamics (drying)

Drainage of peat can result in a reduction in the water table level and can result in drying and decomposition causing carbon loss from accumulated peat. The introduction of artificial drains, in the form of structures such as roads and turbine bases or hardstanding, can, if not done correctly, create drainage pathways affecting the surrounding area.

The extent of drainage effects on peat is a critical parameter in assessing the disturbance to peat and hence carbon emissions. The 2008 CCS Report assessed the issue of hydraulic conductivity and referenced data from a number of studies over the last forty years. The studies referenced range from lowland fern peatland to upland blanket bog. One of the more recent studies referenced [Coulson et al, 1990] considered an upland blanket bog site, where rainfall levels are higher (as is the case on Shetland) and determined that extent of drainage around disturbance was minimal (1.5m).

Despite the fact that peatlands in the UK have been deliberately drained for land improvement for millennia the studies of drainage distance are limited. Studies of drainage for land improvement have indicated that a density of drains as low as 2m is required [Burke, 1967] to affect the water table depth.

No specific site measurements of hydraulic conductivity have been undertaken from which a specific drainage distance can be determined, therefore it is necessary to define this value based on published data. A review of reported hydraulic conductivity values for peat land sites in Scotland indicates a range in values from $0{\cdot}7 \times 10^{-6}$ cm s^{-1} to 1 mm $year^{-1}$. The CCS Report provides a regression equation which can be used to determine the extent of drainage around a disturbance based on the measured hydraulic connectivity of the peat. The equation is given as:

$$\text{Extent of drainage} = 11.958 \times \log(H) - 9.361$$

Where H is the hydraulic conductivity (mm d^{-1}).

Using the range of measured hydraulic connectivity taken from the various studies the extent of drainage calculated ranges from 0 – 21.3m. These drainage distances are in line with the values reported in the CCS Report.

Due to the uncertainty in the drainage distance it is considered appropriate to consider different drainage scenarios in the study to calculate a range of carbon emissions. Based on the findings of the various studies referenced in the CCS Report and the distances calculated above it was proposed to consider three scenarios in the study, in line with the 2009 ES. It is considered, however, the drying distances considered in the 2009 ES may have been overly conservative, and therefore three new scenarios have been considered:

- a low extent drainage scenario of 10m;
- an intermediate extent drainage scenario of 20m; and
- a high extent drainage scenario of 50m.

(In the 2009 ES the scenarios were 10m, 50m and 100m respectively.)

Using these drainage distances the volume of peat potentially affected by drainage was calculated using the equations outlined in the CCS Report, i.e. calculating the linear area alongside roads and area surrounding turbine bases and hardstandings. The calculations assumed a turbine base dimension of 22m by 22m, and a hardstanding dimension of 43m by 43m. The mean peat depth around turbine bases and hardstandings was determined from GIS analysis of the peat depth probes and found to be 1.6m.

If the site drainage is restored following the construction phase and/or decommissioning of the development then it is assumed that local hydrology will return to a stable state. The carbon lost by the peat will, therefore, be that leached over the period during which the drainage is in place.

Emissions of carbon from drained peat are calculated using the method outlined in Section A2.9.2 of the CCS Report, based on the calculated annual emission of methane and CO_2 and the number of years that the peat remains in the drained state.

The formulae and calculations are outlined in Appendix 1 of the CCS Report. The calculated emission rate for methane is a constant based on local environmental and ground conditions. The methane emission rate is corrected to a CO_2 equivalent emission rate. The CO_2 emission rate is a function of peat depth, therefore different emission rates have been calculated for each feature type.

Following the CCS Report calculation method, relevant CO_2 equivalent emissions factors for the Viking site were calculated based on local environmental and ground conditions.

The total emission over the period that the peat is drained was calculated as a product of the area of drained peat, the relevant emission factors and the time period over which the peat is drained. As a worst case it was assumed that the peat will remain drained for the 25 year lifetime of the wind farm.

Carbon savings due to habitat improvement measures

The baseline condition of peat across the development site is discussed in Section A16.5. Existing erosion of peat and the consequent loss of embedded carbon therein is a feature of the peat lands on Shetland at present.

The proposed habitat management plan (HMP) (Appendix A10.9), which is designed to offset adverse impacts to ecological habitats, including peatlands, and its effect on peat is described in Section A16.7. The HMP proposes an initial pilot area for habitat measures, to be implemented over a period of approximately five years, with successful measures then rolled out across the whole study area where possible.

The calculations to determine carbon savings from the habitat improvement measures assume that the erosion of peat across the pilot study area is arrested over the five year pilot study period. The volume of peat 'saved' is then calculated based on the amount of peat which would have been eroded over the further twenty years of the wind farm operation.

It is recognised that peat depths across the study area vary as does the quality of vegetation cover, and therefore so will the rate of erosion. It is considered, however, that by assuming the erosion of peat is arrested only, i.e. there is no enhancement of the peat, then this conservative assumption will over-ride any over-estimates of peat loss variability.

The carbon savings associated with the habitat improvement areas were calculated based on the savings in peat loss and following the method described above in the Loss of Carbon from Removed Soil section.

An additional key facet of the habitat management plan is to reduce the habitat loss due to over-grazing. The effect of over-grazing on blanket bog, and in Shetland in particular, has been studied by the Macaulay Institute [Hulme & Birnie, 1997]. The paper concludes that over-grazing has a direct effect on habitat degradation. The paper also suggests that there is potential to reverse degradation by sustainable grazing management.

Studies in support of developing sustainable grazing management [Milne, 1997] have identified that the annual dry matter production from a blanket mire community is in the order of 210 kg per hectare. It can, therefore, be assumed that by reducing grazing levels on the wind farm development boundary, an annual improvement in habitat production, and therefore carbon fixing, of up to 210 kg per hectare can be achieved.

The carbon savings due to habitat improvement from sustainable grazing assumed a saving of 210 kg ha^{-1} yr^{-1} on areas of bare or damaged peat.

A16.5 CHANGES IN BASELINE CONDITIONS

The assessment of air quality and climate effects in the 2009 ES included an assessment of baseline air quality levels and greenhouse gas emissions in a Shetland, Scotland and UK context.

Changes to baseline air quality and greenhouse gas emissions since the 2009 ES are noted in the following sections.

A16.5.1 Air Quality

In line with its statutory obligations under the Local Air Quality Management (LAQM) process, Shetland Islands Council undertakes an annual review and assessment of air quality in the Council area. The most recent assessment was undertaken in 2010, with an Annual Progress Report published in April 2010 [Shetland Islands Council, 2010]. The report considered local air quality monitoring data from 2009 and evaluated measured pollutant concentrations against the standards and objectives set out in the Air Quality (Scotland) Regulations 2000 and the 2002 amendment.

The report also considered new or proposed emission sources and evaluated the potential for these emission sources to have significant adverse impacts on local air quality.

The Progress Report concluded that air quality in Shetland is very good and that there are no existing or proposed emission sources that are likely to have a significant adverse impact on local air quality. It noted that there is no air quality monitoring undertaken within the proposed wind farm study area, although historically monitoring has been undertaken at Lang Kames near Sand Water.

In assessing the potential impact of the proposed wind farm, and in particular emissions associated with the construction phase of the development, it is necessary to consider the incremental increase in pollutant concentrations in relation to background or baseline concentrations. Background concentrations for the key pollutants to be considered, namely fine particulates (PM_{10}) and nitrogen dioxide (NO_2), as well as monitoring data from Lerwick, are presented in Table A16.4. The estimated background pollutant concentration data are taken from data provided by Defra and the Devolved Administrations.

Table A16.4 Air Quality Baseline Data

Pollutant	Average background concentration over study area ($\mu g/m^3$)	Measured annual mean 2009 concentration in Lerwick ($\mu g/m^3$)	Annual Mean Air Quality Objective Level ($\mu g/m^3$)
Fine particulates	9.5	Not measured	18

(PM_{10})			
Nitrogen dioxide (NO_2)	2 – 3	8.4	40

Based on the estimated background concentrations and measured concentrations in Lerwick it is evident that pollutant concentrations are substantially below air quality objective levels.

A16.5.2 Carbon emissions

The 2009 ES presented baseline greenhouse gas emission data for Shetland, emissions from fossil fuel electricity power generation in Scotland and across the whole of the UK. Whilst it is anticipated that there may be some small variation on the data for electricity generation for Scotland and the UK as a whole since 2009 it is not considered that any change will have a material effect on this assessment.

To allow emissions of greenhouse gases associated with the development to be placed into context it is appropriate to note total emissions of greenhouse gases for other major sources on Shetland and from the islands as a whole. The published emissions from other major CO_2 emitting sources are presented in Table A16.5.

Table A16.5 Annual CO2 emissions from major emission sources on Shetland

Emitter	Annual emissions CO_2 equivalent (te/year)	Data Source
Sullom Voe Oil Terminal	260,000	Scottish Pollution Release Inventory (2008 Returns)
Lerwick Power Station	83,347	Scottish Pollution Release Inventory (2008 Returns)
Lerwick Energy Recovery Plant	34,443	Scottish Pollution Release Inventory (2008 Returns)
Total Gas Processing Plant		
Operational*	Not quantified	Chapter 10 2009 ES
Construction	~105,000	Peat Disposal Study 2009
Overall Shetland (excluding above)	201,678	National Atmospheric Emissions Inventory (2008 data)

*Plant is not anticipated to be operational until 2014

Based on the emissions data it is evident that industrial emissions sources are the main emitters of greenhouse gases in Shetland. Operational emissions of greenhouse gases from the proposed Total plant have not yet been estimated, although it is anticipated that emissions will be of a similar magnitude to that for Lerwick Power Station.

It should be noted that the emissions data for Shetland overall exclude emissions from natural sources. Emissions of greenhouse gases from peat degradation are considered in the following section.

A16.5.3 Natural greenhouse gas emissions from peat degradation

Vegetation on blanket bogs across much of Shetland, and in particular areas of the development site, has been modified and subjected to damage. The result is that peat erosion is widespread and there are extensive areas of bare peat surfaces.

Historical studies examining peat erosion on Shetland and within the Kergord quadrant of the development [Birnie, 1993] have determined annual losses in the range of 10-40mm per annum.

A more recent site visit by Macaulay Scientific Consulting reviewed conditions on the development site and provided a report to Viking Energy Partnership [Birnie, 2010]. The report identified that peat erosion is widespread with extensive areas of bare peat surfaces, particularly in the Nesting quadrant. It further identified that none of the blanket bog within the wind farm site could be described as pristine, with losses in line with those measured and reported in 1993. The previously measured peat losses on the site were noted, by Birnie, to be in line with annual losses measured at other sites [Evans and Warburton, 2007].

If the rate of annual peat losses is extrapolated over the 25 year lifetime of the wind farm, then the peat loss will be between 0.25-1m.

The carbon loss associated with this loss of peat can be determined by the equation:

$$L_{removed} = (3.667/100) \times pC_{dry\ peat} \times BD_{dry\ soil} \times V_{direct}$$

Where $L_{removed}$ is the carbon loss (tCO_2)

$pC_{dry\ peat}$ is the carbon content of peat (%), assumed to be 50%

$BD_{dry\ soil}$ is the bulk density of dry soil (g/cm^3), assumed to be 0.1 g/cm^3

V_{direct} is the volume of soil lost

Per hectare, the carbon loss is determined to be between 458 – 1,833 tonnes of CO_2 over the lifetime of the wind farm.

The total area of the development site is 15,528ha. Whilst the entire site is not covered by peat, approximately 85% is. Overall, therefore, over the lifetime of the wind farm the total carbon loss due to existing peat erosion would be in the order of 6.4 – 25 Megatonnes CO_2.

It should be noted that this calculation is a simplified estimate of current carbon losses, as it does not account for the variability of peat loss over the site, nor does it account for the fact that current peat depths on some parts of the site are less than 1m, meaning all peat would be eroded prior to the end of the wind farms lifetime.

The calculation does, however, provide an indication of the levels of CO_2 currently leaching from what is non-pristine, modified blanket bog as would occur in the absence of the proposed Viking Wind Farm development under a ‘do nothing’ scenario. Measures which Viking Energy Partnership intends to put in place in order to compensate for habitat loss, which will in turn reduce the existing ongoing losses of CO_2 from the wind farm site are fully described in the Habitat Management Plan, Appendix A10.9.

A16.6 CHANGES IN THE PROPOSED WIND FARM

A16.6.1 Air Quality

The significance of the impact of the development on local air quality and nuisance potential is dependent on the number of emissions sources and their location in relation to the nearest receptors. It is considered unlikely that significant nuisance effects will occur beyond 1km from an emission source.

A reduction in the number of wind turbines and associated infrastructure means a reduction in the number of receptors potentially impacted upon by the development. Furthermore, there will be a reduction in construction plant and road traffic movements, which will again result in a reduction in air pollutant emissions.

The principal sources of dust emissions are considered to be borrow pits and turbine base locations. A reduction in the number of turbines and borrow pits means that the number of receptors potentially impacted upon has reduced. To determine whether the impact to receptors has changed a re-evaluation of the receptors potentially affected by each borrow pit has been undertaken.

A16.6.2 Carbon emissions

The changes to the proposed wind farm will have a number of effects on carbon emissions, some positive and some negative.

A reduction in the number of turbines proposed means an overall reduction in the generating capacity of the development, although it does lead to an increase in the efficiency of the remaining turbines. Overall, this would mean a reduction in CO_2 emissions offset from fossil fuel combustion.

As, however, the extent of the wind farm is reduced, with the number of turbine bases, tracks and hardstanding reduced accordingly, the volume of peat disturbed would be reduced substantially. This would mean a reduction in emissions associated with removal of peat or changes to the local hydrology.

A16.7 CHANGES IN AGREED MITIGATION

Restoring the hydrology and habitats on site remains a critical objective of the development in order to minimise the carbon losses associated with the development.

The critical component of restoration is to restore the hydrology on site following the relevant phase of the development. Following the construction phase temporary hardstanding will be removed and, where appropriate, drains around the turbine base and permanent hardstanding will be blocked in order to restore the local water table.

Peat extracted during the construction of the wind farm will be usefully utilised elsewhere on the site and maintained in an active condition. As detailed in Table A16.3, nearly all of extracted peat will be re-used on site. Further detail on extracted peat and storage is provided in the Site Materials and Reinstatement Plan.

Certain elements of the infrastructure such as turbine bases and access roads will likely be left in situ; it is expected that the site will re-establish equilibrium provided drains are blocked on decommissioning where necessary. Attempting to remove turbine foundations would likely cause more damage to the surrounding peat environments.

All calculations in the study have 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.

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 A10, Non-avian Ecology, and Appendix A10.9, Habitat Management Plan.

A16.8 CHANGES IN THE IMPACT ASSESSMENT

A16.8.1 Air Quality

Based on the revised area of search for proposed borrow pits, the distances to the closest receptors have been determined and receptors located within 1km of potential dust generating activities identified. A revised table of receptors and the distance to the nearest borrow pits is provided in Appendix A16.1. Changes to the distances since the 2009 ES are small, and cause no change to the 2009 assessment.

The overall reduction in the number of borrow pits means that there would now be eighteen fewer receptors located within 1km of a borrow pit.

Furthermore, five fewer receptors would be potentially impacted upon by multiple borrow pits. The receptors are Flamister, Whinnea Lea, South Newing, Clymlsa and Sandwater SSSI.

Overall, therefore, the potential for adverse dust impact remains unchanged at most receptors, with a reduction in the potential for adverse impacts predicted at the five receptors no longer affected by multiple borrow pits.

A16.8.2 Carbon Payback

The total carbon emissions associated with the wind farm development are presented in this section.

Counterfactual emissions

The net carbon balance associated with the construction of the wind farm and backup power generation is presented in Table A16.6.

Table A16.6: Calculated counterfactual CO_2 emissions

Source	Emission Rate (Mt CO_2)
Carbon lifecycle of manufacture, installation, maintenance and decommissioning	0.368
Backup power generation requirements	0.036

The total offset emissions from replacement of alternative electricity production sources are presented in Table A16.7.

Table A16.7: Calculated counterfactual CO_2 emissions

Source	Annual Emissions Saving (Mt CO_2)	Total Emissions Saving over Wind Farm Lifetime (Mt CO_2)
Fossil fuel mix	1.13	28.14
Grid mix	0.8	19.93

Emissions due to changes in hydrological conditions

The emissions due to the changes in hydrological conditions of peat were calculated as set out in Appendix A16.5. The most significant parameter in the calculation of carbon emissions due to changes in the hydrological conditions was the assumed drainage extent. The net carbon balance associated with the changes to the hydrological conditions of peat, for the three assumed drainage extents is presented in Table A16.8.

Table A16.8: Calculated CO_2 emissions due to changes in hydrological conditions

Source	Emission Rate (Mt CO_2)		
	10m Extent	20m Extent	50m extent
Loss of carbon fixing potential	0.002	0.003	0.007
Removed Peat	0.056	0.056	0.056
Drained Peat	0.069	0.138	0.551

Total	**0.127**	**0.197**	**0.614**

Carbon savings due to habitat improvement measures

The potential carbon saving associated with the habitat improvement measures in the pilot study area has been calculated to be between 380 -1520 kt.

Furthermore, reduction in grazing across the site could give rise to an additional 81kt of carbon fixing over the lifetime of the wind farm due to habitat re-growth, if sustainable grazing is introduced across the whole development site.

The Habitat Management Plan could achieve carbon savings of up to 1.6 Mt CO_2 based on the best case calculations, a figure which exceeds the total carbon loss associated with the development.

Overall carbon payback period

The overall carbon payback period of the wind farm is summarised in Table A16.9.

Table A16.9: Calculated Overall Carbon Payback Period

Source	Emission Rate (Mt CO_2)		
Total loss due to carbon lifecycle and backup power requirements	0.404		
Total loss due to changes in hydrological conditions of peat	0.127	0.197	0.614
Habitat management plan improvements	(0.38)		
Total loss	**0.151**	**0.221**	**0.638**
Annual CO_2 emissions offset (Mt CO_2)	**1.13**		
Payback period (years)	**0.13**	**0.20**	**0.56**

The total annual CO_2 offset of the wind farm was determined to be 1.13 Mt CO_2 per annum. Based on the calculated CO_2 emissions associated with the development of the wind farm the carbon payback time period will range from 2 months to 7 months depending on the drainage scenario considered.

If the annual CO_2 offset is amended to reflect a grid mix emission factor then the annual CO_2 offset will be reduced to 0.8 Mt, resulting in carbon payback periods ranging from 2 months to 10 months depending on the drainage scenario considered.

Where the best case habitat management improvements are assumed, the total emission loss would be negative for each scenario, i.e. the development will achieve higher carbon savings through habitat improvement than will be emitted through peat disturbance.

A16.9 SUMMARY AND CONCLUSIONS

The chapter considered the effect of the development on both local air quality and emissions of greenhouse gases.

A16.9.1 Air Quality

No emissions will be generated during the operation of the wind farm, therefore the assessment of impacts to local air quality considered the construction phase of the development only. The most significant emission source from the construction phase of the development was determined to be emissions of dust and fine particulate material from borrow pit quarrying operations and excavation for turbine foundations or hardstanding. It was determined that adverse impacts are unlikely to occur at distances beyond 1km of these construction activities.

The reduction in the extent of the wind farm development, including a reduction in the number of turbines and borrow pits, has reduced the number of receptors potentially affected by construction phase emissions. No new receptors have been identified. The amendment to the wind farm layout is considered likely to mean a reduction in emissions overall, and for those receptors still within the study area no change to the overall impact is predicted.

A16.9.2 Carbon emissions

Electricity produced by the wind farm will offset emissions from electricity produced by fossil fuel power stations, leading to a reduction in greenhouse gas emissions. The development of the wind farm will, however, result in emissions of greenhouse gases associated with the manufacture of turbines, the requirement for backup power generation, and through the disturbance of peat.

Peat contains a significant carbon store and any damage to peat will result in a release of embedded carbon. Analysis of baseline conditions on the development site, however, indicated that the peat bog is not in pristine condition and that it is currently subject to extensive erosion, with peat depths under currently bare peat surfaces estimated to reduce by up to 1m in depth over the lifetime of the wind farm assuming no attempts are made to mitigate the erosion. Even without the development the eroded peat across the development site will be a significant carbon emitter over the next 25 years, as high as major industrial sources on the Shetland.

Calculations were undertaken to quantify both the greenhouse gas emissions associated with the development and the emissions resulting from the development itself. One of the most crucial factors in the release of greenhouse gases from peat is the disturbance to local hydrology around features, known as the drainage extent. As specific details of the local effect could not be determined three different drainage extents were considered and emissions calculated for each scenario.

The calculations also accounted for the effects of the Habitat Management Plan in reducing peat erosion across the site. The calculations considered the effect of the improvement measures on the pilot study area only, however over time best practice in blanket bog improvement will be rolled out across the whole development site and beyond.

The CO_2 emissions associated with the development were determined to be in the order of 0.5-1.1 Mt CO_2 over the lifetime of the wind farm. These emissions are small in comparison to the likely emissions due to peat erosion and are substantially offset by the proposed habitat management measures.

Overall, it is estimated that any emissions associated with the development will be offset within the first year of the development. This carbon payback period is relatively low, and is a consequence of the high efficiency of the wind farm, the scale of the development and the potential of the habitat improvement measures to substantially improve existing habitats.

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