### Wind farm characteristics

| Dimensions        | Enter your values here | Record comments or assumptions here | Uncertainties
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of turbines</td>
<td>150</td>
<td></td>
<td>Min  Max</td>
</tr>
<tr>
<td>Life time (years)</td>
<td>25</td>
<td></td>
<td>Min  Max</td>
</tr>
<tr>
<td>Performance</td>
<td></td>
<td></td>
<td>Min  Max</td>
</tr>
<tr>
<td>Turbine capacity</td>
<td>3.6</td>
<td>20 30</td>
<td></td>
</tr>
<tr>
<td>Capacity factor</td>
<td>45</td>
<td>27 34</td>
<td></td>
</tr>
<tr>
<td>Backup</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extra capacity</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Additional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emissions</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: The input parameters include some variables that can be specified by default values, but others that must be site specific. Variables that can be taken from defaults are marked with purple tags on left hand side.*

- **Input data**
  - Min: Minimum value, Max: Maximum value

- **Wind farm characteristics**
  - No. of turbines: 150
  - Life time: 25 years
  - Turbine capacity: 3.6 MW
  - Capacity factor: 45%
  - Extra capacity required for backup: 5%
  - Additional emissions due to reduced thermal efficiency: 10%
  - Carbon dioxide emissions from turbine life: (e.g., manufacture, construction, decommissioning)

- **Backup**
  - Extra capacity required for backup: 5%
  - Additional emissions due to reduced thermal efficiency: 10%

- **Carbon dioxide emissions from turbine life**
  - Total CO₂ emission from turbine life (tCO₂ wind farm⁻¹)

- **Characteristics of peatland before wind farm development**
  - Type of peatland: Acid bog
  - Average air temperature at site: 7°C
  - Average depth of peat at site: 1.60 m
  - C Content of dry peat: 55%
  - Average extent of drainage around drainage features at site: 50 m
  - Average water table depth at site: 0.75 m
  - Dry soil bulk density: 0.60 g cm⁻³
  - Average soil pH: 4.0

- **Characteristics of bog plants**
  - Time required for regeneration of bog plants after restoration: 10 years
  - Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha⁻¹ yr⁻¹)

- **Forestry Plantation Characteristics**
  - Area of forestry plantation to be felled (ha)
  - Average rate of carbon sequestration in timber (tC ha⁻¹ yr⁻¹)

- **Counterfactual emission factors**

*Note: Capacity factor. The average capacity factor between 1998 and 2004 for Scotland was 30% (DTI, 2006, Energy Trends, March 2006). We recommend that a site-specific capacity factor site should be used (as measured during planning stage). However, if this is unknown, the best (34%) and worst case capacity factors for Scotland (27%) should be used to determine the likely range of the results.*

*Note: Extra capacity required for backup. If 20% of national electricity is generated by wind energy, the extra capacity required for backup is 5% of the rated capacity of the wind plant (Dale et al. 2004, Energy Policy, 32, 1949-56). We suggest this should be 5% of the actual output. If it is assumed that less than 20% of national electricity is generated by wind energy, a lower percentage should be entered.*

*Note: Extra emissions due to reduced thermal efficiency of the reserve power generation = 10% (Dale et al. 2004, Energy Policy, 32, 1949-56).*

*Note: Emissions from turbine life. Note, if total emissions for the windfarm are unknown, emissions will be calculated according to turbine capacity. The normal range of CO₂ emissions is 394 to 8147 t CO₂ MW⁻¹ (White & Kulcinski, 2000, Fusion Eng. Des. 48, 473-48; White, 2007, Natural Resources Research. 15, 271 - 281).*

*Note: Time required for regeneration of previous habitat. It is suggested that loss of fixation should be assumed to be over lifetime of windfarm only. This time could longer if plants do not regenerate. The requirements for after-use planning include the provision of suitable refugia for peat forming vegetation, the removal of structures, or an assessment of the impact of leaving them in situ. Methods used to reinstatement the site will affect to likely time for regeneration of the previous habitat. This time could also be shorter if plants regenerate during lifetime of windfarm. If so, enter number of years estimated for regeneration.*

*Note: Carbon fixation by bog plants. Apparent C accumulation rate in peatland is 0.12 to 0.31 tC ha⁻¹ yr⁻¹ (Turunen et al., 2001, Global Biogeochemical Cycles, 15, 285-296; Botch et al. 1995, Global Biogeochemical Cycles, 9, 37-46). The SNH guidance uses a value of 0.25 tC ha⁻¹ yr⁻¹.*

*Note: Area of forestry plantation to be felled. If the forestry...*
### Input data

**Coal-fired plant emission factor (t CO\(_2\) MWh\(^{-1}\))**

| Coal-fired plant emission factor (t CO\(_2\) MWh\(^{-1}\)) | 0.86 |

**Grid-mix emission factor (t CO\(_2\) MWh\(^{-1}\))**

| Grid-mix emission factor (t CO\(_2\) MWh\(^{-1}\)) | 0.43 |

**Fossil fuel- mix emission factor (t CO\(_2\) MWh\(^{-1}\))**

| Fossil fuel- mix emission factor (t CO\(_2\) MWh\(^{-1}\)) | 0.607 |

### Borrow pits

<table>
<thead>
<tr>
<th>Number of borrow pits</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average length of pits (m)</td>
<td>97</td>
</tr>
<tr>
<td>Average width of pits (m)</td>
<td>126</td>
</tr>
<tr>
<td>Average depth of peat removed from pit (m)</td>
<td>1.60</td>
</tr>
</tbody>
</table>

### Wind turbine foundations

| Average length of turbine foundations (m) | 25 |
| Average width of turbine foundations(m) | 25 |
| Average depth of peat removed from turbine foundations(m) | 1.6 |

### Hard-standing area associated with each turbine

| Average length of hard-standing (m) | 43.06 |
| Average width of hard-standing (m) | 43.06 |
| Average depth of peat removed from hard-standing (m) | 1.6 |

### Access tracks

| Total length of access track (m) | 117520 |
| Existing track length (m) | 0 |
| Length of access track that is floating road (m) | 86010 |
| Floating road width (m) | 9.25 |
| Floating road depth (m) | 0.5 |
| Length of floating road that is drained (m) | 43005 |
| Average depth of drains associated with floating roads (m) | 0.5 |
| Length of access track that is excavated road (m) | 31510 |
| Excavated road width (m) | 9.25 |
| Excavated road depth (m) | 1 |
| Length of access track that is rock filled road (m) | 0 |
| Rock-filled road width (m) | 0 |
| Rock-filled road depth (m) | 0 |
| Length of rock-filled road that is drained (m) | 0 |
| Average depth of drains associated with rock-filled roads (m) | 0 |

### Cable Trenches

| Length of any cable trench that does not follow access tracks and is lined with a permeable medium (eg, sand) (m) | 5876 |
| Depth of cable trench (m) | 0.5 |

### Note: Peat Landslide Hazard

| WebLink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments | 0 |

Note: Plantation carbon sequestration. This is dependent on the yield class of the forestry. The SNH technical guidance assumed yield class of 16 m\(^3\) ha\(^{-1}\) yr\(^{-1}\), compared to the value of 14 m\(^3\) ha\(^{-1}\) yr\(^{-1}\) provided by the Forestry Commission. Carbon sequestered for yield class 16 m\(^3\) ha\(^{-1}\) yr\(^{-1}\) = 3.6 t CO\(_2\) ha\(^{-1}\) yr\(^{-1}\) (Cannell, 1999, Forestry, 72, 238-247)


Note: Coal-Fired Plant and Grid Mix Emission Factors. Coal fired plant EF = 0.86 t CO\(_2\) MWh\(^{-1}\); Grid-Mix EF = 0.43 t CO\(_2\) MWh\(^{-1}\). Source = DEFRA, 2003. Guidelines for the measurement and reporting of emissions by Direct Participants in UK Emissions Trading Scheme (DEFRA/Oct 2002)

Note: Total length of access track. If areas of access track overlap with hardstanding area, exclude these from the total length of access track to avoid double counting of land area lost.

Note: Rock filled roads. Rock filled roads are assumed to be roads where no peat has been removed and rock has been placed on the surface and allowed to settle.

Note: Peat Landslide Hazard. It is assumed that measures have been taken to may limit damage (Scottish Executive, 2006, Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments, Scottish Executive, Edinburgh, pp. 34-35) so that C losses due to peat landslide can be assumed to be negligible. Link: http://www.scotland.gov.uk/Publications/2006/12/21162303/1
<table>
<thead>
<tr>
<th>Improvement of C sequestration at site by blocking drains, restoration of habitat etc</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement of degraded bog</td>
<td></td>
</tr>
<tr>
<td>Area of degraded bog to be improved (ha)</td>
<td>394</td>
</tr>
<tr>
<td>Water table depth in degraded bog before improvement (m)</td>
<td>0.75</td>
</tr>
<tr>
<td>Water table depth in degraded bog after improvement (m)</td>
<td>0.75</td>
</tr>
<tr>
<td>Time required for hydrology and habitat of bog to return to its previous state on improvement (years)</td>
<td>10</td>
</tr>
<tr>
<td>Improvement of felled plantation land</td>
<td></td>
</tr>
<tr>
<td>Area of felled plantation to be improved (ha)</td>
<td>0</td>
</tr>
<tr>
<td>Water table depth in felled area before improvement (m)</td>
<td>0.00</td>
</tr>
<tr>
<td>Water table depth in felled area after improvement (m)</td>
<td>0.00</td>
</tr>
<tr>
<td>Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)</td>
<td>0</td>
</tr>
<tr>
<td>Restoration of peat removed from borrow pits</td>
<td></td>
</tr>
<tr>
<td>Area of borrow pits to be restored (ha)</td>
<td>15.19</td>
</tr>
<tr>
<td>Water table depth in borrow pit after restoration (m)</td>
<td>0.75</td>
</tr>
<tr>
<td>Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)</td>
<td>10</td>
</tr>
<tr>
<td>Removal of drainage from foundations and hardstanding</td>
<td></td>
</tr>
<tr>
<td>Water table depth around foundations and hardstanding after restoration (m)</td>
<td>0.75</td>
</tr>
<tr>
<td>Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)</td>
<td>25</td>
</tr>
</tbody>
</table>

**Note:** Restoration of site: If the water table at the site is returned to its original level or higher on decommissioning, and habitat at the site is restored, it is assumed that C losses continue only over the lifetime of the windfarm. Otherwise, C losses from drained peat are assumed to be 100%.

**Note:** Choice of methodology for calculating emission factors: The IPPC default methodology is the internationally accepted standard (IPCC, 1997, Revised 1996 IPCC guidelines for national greenhouse gas inventories, Vol 3, table 5-13). However, it is stated in IPCC (1997) that these are rough estimates, and "these rates and production periods can be used if countries do not have more appropriate estimates". Therefore, we have developed more site specific estimates for use here based on work from the SEERAD funded ECOSSE project (Smith et al, 2007. ECOSSE: Estimating Carbon in Organic Soils - Sequestration and Emissions. Final Report. SEERAD Report. ISBN 0 7559 1498 2. 166pp.)

**Appendix 16.3 intermediate scenario.xls**
Payback Time

Note: The carbon payback time of the wind farm is calculated by comparing the loss of C from the site due to windfarm development with the carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or Grid-mix.

1. Wind farm CO₂ emission saving

<table>
<thead>
<tr>
<th>Carbon dioxide saving (t CO₂ yr⁻¹)</th>
<th>...coal-fired electricity generation</th>
<th>...grid-mix of electricity generation</th>
<th>...fossil fuel-mix of electricity generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1830658</td>
<td>915332</td>
<td>1292109</td>
</tr>
</tbody>
</table>

Total CO₂ losses due to wind farm

<table>
<thead>
<tr>
<th>Carbon dioxide losses (t CO₂ eq.)</th>
<th>Payback time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>...coal-fired electricity generation</td>
<td>...grid-mix of electricity generation</td>
</tr>
<tr>
<td>2. Losses due to turbine life (eg. manufacture, construction, decommissioning)</td>
<td>175140</td>
</tr>
<tr>
<td>3. Losses due to backup</td>
<td>358919</td>
</tr>
<tr>
<td>4. Losses due to reduced carbon fixing potential</td>
<td>90366</td>
</tr>
<tr>
<td>5. Losses from soil organic matter</td>
<td>3520798</td>
</tr>
<tr>
<td>6. Losses due to DOC &amp; POC leaching</td>
<td>696821</td>
</tr>
<tr>
<td>7. Losses due to felling forestry</td>
<td>0</td>
</tr>
<tr>
<td>Total losses of carbon dioxide</td>
<td>4842043</td>
</tr>
</tbody>
</table>

Total CO₂ gains due to improvement of site

<table>
<thead>
<tr>
<th>Carbon dioxide gains (t CO₂ eq.)</th>
<th>Reduction in payback time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>...coal-fired electricity generation</td>
<td>...grid-mix of electricity generation</td>
</tr>
<tr>
<td>8. Gains due to improvement of degraded logs</td>
<td>106687</td>
</tr>
<tr>
<td>8. Gains due to improvement of felled forestry</td>
<td>0</td>
</tr>
<tr>
<td>8. Gains due to restoration of peat from borrow pits</td>
<td>7529</td>
</tr>
<tr>
<td>8. Gains due to removal of drainage from foundations &amp; hardstanding</td>
<td>0</td>
</tr>
<tr>
<td>Total gains</td>
<td>114216</td>
</tr>
</tbody>
</table>

Net emissions of carbon dioxide (t CO₂ eq.) | 4727827

Payback time
### Payback Time

<table>
<thead>
<tr>
<th>Fuel Mix</th>
<th>Total payback time of windfarm (yr)</th>
<th>Total payback time of windfarm (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired</td>
<td>2.6</td>
<td>31</td>
</tr>
<tr>
<td>Grid-mix</td>
<td>5.2</td>
<td>62</td>
</tr>
<tr>
<td>Fossil fuel-mix</td>
<td>3.7</td>
<td>44</td>
</tr>
</tbody>
</table>

### Carbon Payback Time using Fossil Fuel Mix as the Counterfactual

<table>
<thead>
<tr>
<th>Activity</th>
<th>Carbon Payback Time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine life</td>
<td>175</td>
</tr>
<tr>
<td>Backup</td>
<td>140</td>
</tr>
<tr>
<td>Bog plants</td>
<td>1.6</td>
</tr>
<tr>
<td>Forest felling</td>
<td>3.3</td>
</tr>
<tr>
<td>Soil organic carbon</td>
<td>0.8</td>
</tr>
<tr>
<td>Dissolved and particulate organic carbon</td>
<td>0.0</td>
</tr>
<tr>
<td>Improved degraded bogs</td>
<td>32.7</td>
</tr>
<tr>
<td>Improved degraded forestry</td>
<td>0.0</td>
</tr>
<tr>
<td>Restored borrow pits</td>
<td>0.1</td>
</tr>
</tbody>
</table>

### Greenhouse Gas Emissions associated with Wind Farm Development

- **Turbine life**: -500000 t CO₂ eq.
- **Backup**: 0 t CO₂ eq.
- **Bog plants**: 0 t CO₂ eq.
- **Forest felling**: 0 t CO₂ eq.
- **Soil organic carbon**: 0 t CO₂ eq.
- **Dissolved and particulate organic carbon**: 0 t CO₂ eq.
- **Improved degraded bogs**: 0 t CO₂ eq.
- **Improved degraded forestry**: 0 t CO₂ eq.
- **Restored borrow pits**: 0 t CO₂ eq.

Appendix 16.3 intermediate scenario.xls
1. Windfarm CO2 emission saving

Note: The total emission savings are given by estimating the total possible electrical output of the windfarm multiplied by the emission factor for the counterfactual case (coal-fire generation and electricity from grid)

<table>
<thead>
<tr>
<th>Power Generation Characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of turbines</td>
<td>150</td>
</tr>
<tr>
<td>Turbine capacity (MW)</td>
<td>3.6</td>
</tr>
<tr>
<td>Power of wind farm (MW)</td>
<td>540</td>
</tr>
<tr>
<td>Capacity factor (percentage efficiency)</td>
<td>45</td>
</tr>
<tr>
<td>Annual energy output from wind farm (MWh yr⁻¹)</td>
<td>2128680</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Counterfactual emission factors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired plant emission factor (t CO₂ MWh⁻¹)</td>
<td>0.86</td>
</tr>
<tr>
<td>Grid-mix emission factor (t CO₂ MWh⁻¹)</td>
<td>0.43</td>
</tr>
<tr>
<td>Fossil fuel- mix emission factor (t CO₂ MWh⁻¹)</td>
<td>0.607</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind farm CO₂ emission saving over...</th>
<th>Carbon Dioxide Saving (tCO₂ yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>...coal-fired electricity generation</td>
<td>1830665</td>
</tr>
<tr>
<td>...grid-mix of electricity generation</td>
<td>915332</td>
</tr>
<tr>
<td>...fossil fuel - mix of electricity generation</td>
<td>1292109</td>
</tr>
</tbody>
</table>
2. CO2 loss due to turbine life

Note: The carbon payback time of the wind farm due to turbine life (e.g., manufacture, construction, decommissioning) is calculated by comparing the emissions due to turbine life with carbon savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or grid-mix.

<table>
<thead>
<tr>
<th>Method used to estimate CO2 emissions from turbine life (e.g., manufacture, construction, decommissioning)?</th>
<th>Calculate wrt installed capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct input of emissions due to turbine life (t CO2 wind farm−1)</td>
<td>0</td>
</tr>
<tr>
<td>Calculation of emissions due to turbine life from energy output</td>
<td></td>
</tr>
<tr>
<td>CO2 emissions due to turbine life (tCO2 turbine−1)</td>
<td>1168</td>
</tr>
<tr>
<td>No. of turbines</td>
<td>150</td>
</tr>
<tr>
<td>Total calculated CO2 emission of the wind farm due to turbine life (t CO2 wind farm−1)</td>
<td>175140</td>
</tr>
<tr>
<td>Selected value for emissions due to turbine life (t CO2 wind farm−1)</td>
<td>175140</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional CO2 payback time of wind farm due to turbine life (e.g., manufacture, construction, decommissioning)</th>
<th>Additional payback time (yr)</th>
<th>Additional payback time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired electricity generation</td>
<td>0.10</td>
<td>1.1</td>
</tr>
<tr>
<td>Grid-mix of electricity generation</td>
<td>0.19</td>
<td>2.3</td>
</tr>
<tr>
<td>Fossil fuel - mix of electricity generation</td>
<td>0.14</td>
<td>1.8</td>
</tr>
</tbody>
</table>

| Uncertainty due to estimated CO2 emissions due to turbine life | 39% | 0.6 |

Defensible figures for the specific wind farm should be used wherever possible, but if these are unavailable, carbon dioxide emissions due to the turbine life, $L_{\text{life}}$, can be estimated from the turbine capacity, $c_{\text{turb}}$ (MW), using the following equation. This equation was derived using data from 18 European sites with a highly significant fit ($P=0.95$).

$$L_{\text{life}} = 138 + (286 \times c_{\text{turb}})$$

Evaluation against independent data indicates that using this equation instead of site specific measurements will introduce an average error in estimated carbon dioxide emissions of 39%. However, the uncertainty in estimated carbon payback time introduced by this error is small and decreases with turbine capacity: uncertainty is less than 6 months for a turbine capacity under 0.5 MW; less than 1.5 months for a turbine capacity between 0.5 and 1 MW, and approximately 1 month for a turbine capacity over 1 MW. Note that inclusion of a life cycle figure for wind farms would ideally require that equivalent life cycle costs for conventional power sources are included in the carbon emission savings figure. However, in the absence of comparative figures for coal and gas generating plants, it should be noted that this is an over-estimate of the life cycle costs of a wind farm. A comprehensive life cycle assessment of a modern UK wind farm would provide more robust figures.

Evaluation of equation against independent data

Carbon Dioxide Saving (tCO2 yr−1)
- Coal-fired electricity generation: 1830665
- Grid-mix of electricity generation: 915332
- Fossil fuel - mix of electricity generation: 1292109

Appendix 16.3 intermediate scenario.xls
Note: CO2 loss due to back up is calculated from the extra capacity required for backup of the wind farm given in the input data.

### Reserve capacity required for backup

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of turbines</td>
<td>150</td>
</tr>
<tr>
<td>Turbine capacity (MW)</td>
<td>3.6</td>
</tr>
<tr>
<td>Power of wind farm (MW h⁻¹)</td>
<td>540</td>
</tr>
<tr>
<td>Rated capacity (MW yr⁻¹)</td>
<td>4730400</td>
</tr>
<tr>
<td>Extra capacity required for backup (%)</td>
<td>5</td>
</tr>
<tr>
<td>Additional emissions due to reduced thermal efficiency of the reserve generation (%)</td>
<td>10</td>
</tr>
<tr>
<td>Reserve capacity (MWh yr⁻¹)</td>
<td>23652</td>
</tr>
</tbody>
</table>

### Carbon dioxide emissions due to backup power generation

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired plant emission factor (t CO₂ MWh⁻¹)</td>
<td>0.86</td>
</tr>
<tr>
<td>Grid-mix emission factor (t CO₂ MWh⁻¹)</td>
<td>0.43</td>
</tr>
<tr>
<td>Fossil fuel- mix emission factor (t CO₂ MWh⁻¹)</td>
<td>0.607</td>
</tr>
<tr>
<td>Annual emissions due to backup from...</td>
<td></td>
</tr>
<tr>
<td>...coal-fired electricity generation</td>
<td>20340.72</td>
</tr>
<tr>
<td>...grid-mix of electricity generation</td>
<td>10170.36</td>
</tr>
<tr>
<td>...fossil fuel - mix of electricity generation</td>
<td>14356.764</td>
</tr>
<tr>
<td>Total emissions due to backup from...</td>
<td></td>
</tr>
<tr>
<td>...coal-fired electricity generation</td>
<td>508518</td>
</tr>
<tr>
<td>...grid-mix of electricity generation</td>
<td>254259</td>
</tr>
<tr>
<td>...fossil fuel - mix of electricity generation</td>
<td>358919</td>
</tr>
</tbody>
</table>

### Wind farm CO₂ emission saving over...

<table>
<thead>
<tr>
<th></th>
<th>Carbon Dioxide Saving (tCO₂ yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>...coal-fired electricity generation</td>
<td>1830665</td>
</tr>
<tr>
<td>...grid-mix of electricity generation</td>
<td>915332</td>
</tr>
<tr>
<td>...fossil fuel - mix of electricity generation</td>
<td>1292109</td>
</tr>
</tbody>
</table>

### Additional CO₂ payback time of wind farm due to backup

<table>
<thead>
<tr>
<th></th>
<th>Additional payback time (yr)</th>
<th>Additional payback time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired electricity generation</td>
<td>0.20</td>
<td>2.4</td>
</tr>
<tr>
<td>Grid-mix of electricity generation</td>
<td>0.39</td>
<td>4.7</td>
</tr>
<tr>
<td>Fossil fuel-mix of electricity generation</td>
<td>0.28</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Assumption: Backup assumed to be by fossil-fuel-mix of electricity generation. Note that hydroelectricity may also be used for backup, so this assumption may make the value for backup generation too high. These assumptions should be revisited as technology develops.
4. Loss of CO2 fixing pot.

Note: Annual C fixation by the site is calculated by multiplying area of the wind farm by the annual C accumulation due to bog plant fixation

<table>
<thead>
<tr>
<th>Area where carbon accumulation by bog plants is lost</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area of land lost due to wind farm construction (m²)</td>
<td>1630043</td>
</tr>
<tr>
<td>Total area affected by drainage due to wind farm construction (m²)</td>
<td>26533296</td>
</tr>
<tr>
<td>Total area where fixation by plants is lost (m²)</td>
<td>28163339</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total loss of carbon accumulation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon accumulation in undrained peats (tC ha⁻¹ yr⁻¹)</td>
<td>0.25</td>
</tr>
<tr>
<td>Life time of wind farm (years)</td>
<td>25</td>
</tr>
<tr>
<td>Time required for regeneration of bog plants after restoration (years)</td>
<td>10</td>
</tr>
<tr>
<td>Carbon accumulation up to time of restoration (tCO₂ eq. ha⁻¹)</td>
<td>32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total loss of carbon accumulation by bog plants</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area where fixation by plants is lost (ha)</td>
<td>2816</td>
</tr>
<tr>
<td>Carbon accumulation over lifetime of wind farm (tCO₂ eq. ha⁻¹)</td>
<td>32</td>
</tr>
<tr>
<td>Total loss of carbon fixation by plants at the site (t CO₂)</td>
<td>90366</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Windfarm CO₂ emission saving over...</th>
<th>Carbon Dioxide Saving (tCO₂ yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>...coal-fired electricity generation</td>
<td>1830665</td>
</tr>
<tr>
<td>...grid-mix of electricity generation</td>
<td>915332</td>
</tr>
<tr>
<td>...fossil fuel - mix of electricity generation</td>
<td>1292109</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional CO₂ payback time of windfarm due to loss of CO₂ fixation</th>
<th>Additional payback time (years)</th>
<th>Additional payback time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired electricity generation</td>
<td>0.049</td>
<td>0.6</td>
</tr>
<tr>
<td>Grid-mix of electricity generation</td>
<td>0.099</td>
<td>1.2</td>
</tr>
<tr>
<td>Fossil fuel - mix of electricity generation</td>
<td>0.070</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Assumptions:
1. Bog plants are 100% lost from the area where peat is removed for construction.
2. Bog plants are 100% lost from the area where peat is drained.
3. The recovery of carbon accumulation by plants on restoration of land is as given in inputs

Appendix 16.3 intermediate scenario.xls
5. Loss of soil CO2

Note: Loss of C stored in peatland is estimated from % site lost by peat removal (sheet 5a), CO2 loss from removed peat (sheet 5b), % site affected by drainage (sheet 5c), and the CO2 loss from drained peat (sheet 5d).

<table>
<thead>
<tr>
<th>CO2 loss due to wind farm construction</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 loss from removed peat (t CO2 equiv)</td>
<td>1885395</td>
</tr>
<tr>
<td>CO2 loss from drained peat (t CO2 equiv)</td>
<td>1635403</td>
</tr>
<tr>
<td><strong>Total CO2 loss from peat (removed+ drained) (t CO2 equiv)</strong></td>
<td><strong>3520798</strong></td>
</tr>
</tbody>
</table>

Appendix 16.3 intermediate scenario.xls
5a. Volume of peat removed

Note: % site lost by peat removal is estimated from peat removed in borrow pits, turbine foundations, hard-standing and access tracks.
If peat is removed for any other reason, this must be added in to the volume of peat removed, area of land lost and % site lost at the bottom of this worksheet.

### Peat removed from borrow pits

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of borrow pits</td>
<td>14</td>
</tr>
<tr>
<td>Average length of pits (m)</td>
<td>97</td>
</tr>
<tr>
<td>Average width of pits (m)</td>
<td>126</td>
</tr>
<tr>
<td>Average depth of peat removed from pit (m)</td>
<td>1.6</td>
</tr>
<tr>
<td>Area of land lost in borrow pits (m²)</td>
<td>171108</td>
</tr>
<tr>
<td>Volume of peat removed from borrow pits (m³)</td>
<td>272772.8</td>
</tr>
</tbody>
</table>

### Peat removed from turbine foundations

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of turbines</td>
<td>150</td>
</tr>
<tr>
<td>Average length of turbine foundations (m)</td>
<td>25</td>
</tr>
<tr>
<td>Average width of turbine foundations (m)</td>
<td>25</td>
</tr>
<tr>
<td>Average depth of peat removed from foundations (m)</td>
<td>1.6</td>
</tr>
<tr>
<td>Area of land lost in foundations (m²)</td>
<td>90750</td>
</tr>
<tr>
<td>Volume of peat removed from foundation area (m³)</td>
<td>150000</td>
</tr>
</tbody>
</table>

### Peat removed from hard-standing

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of turbines</td>
<td>150</td>
</tr>
<tr>
<td>Average length of hard-standing (m)</td>
<td>43.06</td>
</tr>
<tr>
<td>Average width of hard-standing (m)</td>
<td>43.06</td>
</tr>
<tr>
<td>Average depth of peat removed from hard-standing (m)</td>
<td>1.6</td>
</tr>
<tr>
<td>Area of land lost in hard-standing (m²)</td>
<td>278124.54</td>
</tr>
<tr>
<td>Volume of peat removed from hard-standing area (m³)</td>
<td>444999.264</td>
</tr>
</tbody>
</table>

### Peat removed from access tracks

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floating roads</td>
<td></td>
</tr>
<tr>
<td>Length of access track that is floating road (m)</td>
<td>86010</td>
</tr>
<tr>
<td>Floating road width (m)</td>
<td>9.25</td>
</tr>
<tr>
<td>Floating road depth (m)</td>
<td>0.5</td>
</tr>
<tr>
<td>Area of land lost in floating roads (m²)</td>
<td>795592.5</td>
</tr>
<tr>
<td>Volume of peat removed for floating roads</td>
<td>397796.25</td>
</tr>
<tr>
<td>Excavated roads</td>
<td></td>
</tr>
<tr>
<td>Length of access track that is excavated road (m)</td>
<td>31510</td>
</tr>
<tr>
<td>Excavated road width (m)</td>
<td>9.25</td>
</tr>
<tr>
<td>Excavated road depth (m)</td>
<td>1</td>
</tr>
<tr>
<td>Area of land lost in excavated roads (m²)</td>
<td>291467.5</td>
</tr>
<tr>
<td>Volume of peat removed for excavated roads</td>
<td>291467.5</td>
</tr>
<tr>
<td>Rock-filled roads</td>
<td></td>
</tr>
<tr>
<td>Length of access track that is rock filled road (m)</td>
<td>0</td>
</tr>
<tr>
<td>Rock-filled road width (m)</td>
<td>0</td>
</tr>
<tr>
<td>Rock-filled road depth (m)</td>
<td>0</td>
</tr>
<tr>
<td>Area of land lost in rock-filled roads (m²)</td>
<td>0</td>
</tr>
<tr>
<td>Volume of peat removed for rock-filled roads</td>
<td>0</td>
</tr>
<tr>
<td>Total area of land lost in access tracks (m²)</td>
<td>1067060</td>
</tr>
<tr>
<td>Total volume of peat removed due to access tracks (m³)</td>
<td>689263.75</td>
</tr>
</tbody>
</table>

Total volume of peat removed (m³) due to wind farm construction 1558035.814

Total area of land lost due to wind farm construction (m²) 1630042.54
5b. CO2 loss from removed peat

<table>
<thead>
<tr>
<th>CO2 loss from removed peat</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C Content of dry peat (% by weight)</td>
<td>55</td>
</tr>
<tr>
<td>Dry soil bulk density (g cm$^{-3}$)</td>
<td>0.60</td>
</tr>
<tr>
<td>% C contained in removed peat that is lost as CO$_2$</td>
<td>100</td>
</tr>
<tr>
<td>Total volume of peat removed (m$^3$) due to wind farm construction</td>
<td>1558035.814</td>
</tr>
<tr>
<td>CO2 loss from removed peat (t CO$_2$)</td>
<td>1885395</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CO2 loss from undrained peat left in situ</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area of land lost due to wind farm construction (ha)</td>
<td>163</td>
</tr>
<tr>
<td>CO2 loss from undrained peat left in situ (t CO$_2$ ha$^{-1}$)</td>
<td>32</td>
</tr>
<tr>
<td>CO2 loss from undrained peat left in situ (t CO$_2$)</td>
<td>5205</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CO2 loss attributable to peat removal only</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 loss from removed peat (t CO$_2$)</td>
<td>1885395</td>
</tr>
<tr>
<td>CO2 loss from undrained peat left in situ (t CO$_2$)</td>
<td>5205</td>
</tr>
<tr>
<td>CO2 loss attributable to peat removal only (t CO$_2$)</td>
<td>1880190</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind farm CO2 emission saving over…</th>
<th>Carbon Dioxide Saving (tCO$_2$ yr$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>…coal-fired electricity generation</td>
<td>1830665</td>
</tr>
<tr>
<td>…grid-mix of electricity generation</td>
<td>915332</td>
</tr>
<tr>
<td>…fossil fuel - mix of electricity generation</td>
<td>1292109</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional CO2 payback time of wind farm due to removal of peat during construction</th>
<th>Additional payback time (years)</th>
<th>Additional payback time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired electricity generation</td>
<td>1.03</td>
<td>12.4</td>
</tr>
<tr>
<td>Grid-mix of electricity generation</td>
<td>2.56</td>
<td>24.7</td>
</tr>
<tr>
<td>Fossil fuel - mix of electricity generation</td>
<td>1.46</td>
<td>17.5</td>
</tr>
</tbody>
</table>

Note: If peat is treated in such a way that it is permanently restored, so that less than 100% of the C is lost to the atmosphere, a lower percentage can be entered in cell C10.
### Extent of drainage around each metre of drainage ditch

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average extent of drainage around each feature at site (m)</td>
<td>50</td>
</tr>
</tbody>
</table>

### Peat affected by drainage around borrow pits

<table>
<thead>
<tr>
<th>Borrow Pits</th>
<th>Number of Pits</th>
<th>Average Length of Pits (m)</th>
<th>Average Width of Pits (m)</th>
<th>Area of Pits (m^2)</th>
<th>Volume of Pits (m^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>97</td>
<td>126</td>
<td>32500</td>
<td>452200</td>
</tr>
</tbody>
</table>

### Peat affected by drainage around turbine foundation and hardstanding

<table>
<thead>
<tr>
<th>Foundation and Hardstanding</th>
<th>Number of Turbines</th>
<th>Average Length of Turbine Foundations (m)</th>
<th>Average Width of Turbine Foundations (m)</th>
<th>Average Depth of Peat Removed from Turbine Foundations (m)</th>
<th>Average Length of Hard-standing (m)</th>
<th>Average Width of Hard-standing (m)</th>
<th>Average Depth of Peat Removed from Hard-standing (m)</th>
<th>Area of Foundation and Hardstanding (m^2)</th>
<th>Volume of Foundation and Hardstanding (m^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150</td>
<td>25</td>
<td>25</td>
<td>2</td>
<td>43</td>
<td>43</td>
<td>16</td>
<td>68</td>
<td>23612</td>
</tr>
</tbody>
</table>

### Peat affected by drainage of access tracks

#### Floating Road

- Length of floating road that is drained (m): 43005
- Floating road width (m): 9.3
- Area of floating road (m^2): 407772.5
- Volume of floating road (m^3): 2349148

#### Excavated Road

- Length of access track that is excavated road (m): 31510
- Excavated road width (m): 9
- Excavated road depth (m): 1.0
- Area of excavated road (m^2): 283590
- Volume of excavated road (m^3): 315100

#### Rock-filled road

- Length of rock-filled road that is drained (m): 0
- Rock-filled road width (m): 0
- Area of rock-filled road (m^2): 0
- Volume of rock-filled road (m^3): 0

### Peat affected by drainage of cable trenches

<table>
<thead>
<tr>
<th>Cable Trench</th>
<th>Length of any cable trench that does not follow access tracks and is lined with a permeable medium (e.g. sand) (m)</th>
<th>Total area affected by drainage of cable trenches (m^2)</th>
<th>Total volume affected by drainage of cable trenches (m^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5876</td>
<td>14695000</td>
<td>7345000.00</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>5500148</td>
<td></td>
</tr>
</tbody>
</table>

### Total area and volume affected by drainage

<table>
<thead>
<tr>
<th>Feature</th>
<th>Area (m^2)</th>
<th>Volume (m^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area affected by drainage due to wind farm</td>
<td>26533296</td>
<td>19235488</td>
</tr>
</tbody>
</table>

**Note:** Extent of site affected by drainage is calculated assuming an average extent of drainage around each drainage feature as given in the input data.

**Appendix 16.3 Intermediate scenario.xls**
### Drained Land

- **Total area affected by drainage due to wind farm construction (ha):** 2653
- **Will the hydrology of the site be restored on decommissioning?** Yes
- **Will the habitat of the site be restored on decommissioning?** Yes

#### Calculations of C Loss from Drained Land if Site is NOT Restored after Decommissioning

<table>
<thead>
<tr>
<th>Total volume affected by drainage due to wind farm (m$^3$)</th>
<th>19235548</th>
</tr>
</thead>
<tbody>
<tr>
<td>C Content of dry peat (% by weight)</td>
<td>55</td>
</tr>
<tr>
<td>Dry soil bulk density (g cm$^{-3}$)</td>
<td>0.60</td>
</tr>
<tr>
<td><strong>Total GHG emissions from Drained Land (t CO$_2$ equiv.)</strong></td>
<td>23277129</td>
</tr>
<tr>
<td><strong>Total GHG Emissions from Undrained Land (t CO$_2$ equiv.)</strong></td>
<td>1146508</td>
</tr>
</tbody>
</table>

#### Calculations of C loss from Drained Land if Site IS Restored after Decommissioning

1. **Losses if Land is Drained**
   - **Flooded period (days year$^{-1}$):** 0
   - **Life time of wind farm (years):** 25
   - **Time required for regeneration of bog plants after restoration (years):** 10
   - **Methane Emissions from Drained Land**
     - **Annual rate of methane emission (t CH$_4$ ha$^{-1}$ yr$^{-1}$):** -0.55
     - **Conversion factor: CH$_4$ to CO$_2$ equivalents:** 30.67
   - **CH$_4$ emissions from drained land (t CO$_2$ equiv.)**: 0
   - **Carbon Dioxide Emissions from Drained Land**
     - **Annual rate of carbon dioxide emission (t CO$_2$ ha$^{-1}$ yr$^{-1}$):** 18.5
   - **CO$_2$ emissions from drained land (t CO$_2$ equiv.)**: 1720127
   - **Total GHG emissions from Drained Land (t CO$_2$ equiv.)**: 1720127

2. **Losses if Land is Undrained**
   - **Flooded period (days year$^{-1}$):** 178
   - **Life time of wind farm (years):** 25
   - **Time required for regeneration of bog plants after restoration (years):** 10
   - **Methane Emissions from Undrained Land**
     - **Annual rate of methane emission (t CH$_4$ ha$^{-1}$ yr$^{-1}$):** -0.59
     - **Conversion factor: CH$_4$ to CO$_2$ equivalents:** 30.67
   - **CH$_4$ emissions from undrained land (t CO$_2$ equiv.)**: -817561
   - **Carbon Dioxide Emissions from Undrained Land**
     - **Annual rate of carbon dioxide emission (t CO$_2$ ha$^{-1}$ yr$^{-1}$):** 19.0
   - **CO$_2$ emissions from undrained land (t CO$_2$ equiv.)**: 902285
   - **Total GHG Emissions from Undrained Land (t CO$_2$ equiv.)**: 84724

3. **CO$_2$ Losses due to Drainage**
   - **Total GHG emissions from Drained Land (t CO$_2$ equiv.)**: 1720127
   - **Total GHG Emissions from Undrained Land (t CO$_2$ equiv.)**: 84724
   - **Total CO$_2$ losses due to drainage (t CO$_2$ equiv.)**: 1635403

#### Wind farm CO$_2$ emission saving over coal-fired electricity generation

- **Carbon dioxide saving (t CO$_2$ yr$^{-1}$):** 1835865

#### Additional CO$_2$ payback time of wind farm due to drainage of peat

<table>
<thead>
<tr>
<th>CO$_2$ payback time due to drainage of peat</th>
<th>Additional payback time (years)</th>
<th>Additional payback time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired electricity generation</td>
<td>0.89</td>
<td>10.7</td>
</tr>
<tr>
<td>Grid-mix of electricity generation</td>
<td>1.79</td>
<td>21.4</td>
</tr>
<tr>
<td>Fossil fuel mix of electricity generation</td>
<td>1.37</td>
<td>16.2</td>
</tr>
</tbody>
</table>

---

**Note:** Conversion of CH$_4$ to CO$_2$ equivalents: $30.67$ CO$_2$ equiv. (CH$_4$)-1

**Assumption:** Losses of methane from drained and undrained land have the same proportion throughout the emission period.
5e. Emission rates from soils

Note: CO₂ losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been thoroughly tested against experimental data (see Nayak et al., 2008 - Final report).

### Calculations following IPCC default methodology

<table>
<thead>
<tr>
<th>Emission characteristics of acid bogs (IPCC, 1997)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of peatland: Acid Bog</td>
</tr>
<tr>
<td>Flooded period (days year⁻¹)</td>
</tr>
<tr>
<td>Annual rate of methane emission (t CH₄-C ha⁻¹ yr⁻¹)</td>
</tr>
<tr>
<td>Annual rate of carbon dioxide emission (t CO₂ ha⁻¹ yr⁻¹)</td>
</tr>
</tbody>
</table>

### Emission characteristics of fens (IPCC, 1997)

<table>
<thead>
<tr>
<th>Flooded period (days year⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual rate of methane emission (t CH₄-C ha⁻¹ yr⁻¹)</td>
</tr>
<tr>
<td>Annual rate of carbon dioxide emission (t CO₂ ha⁻¹ yr⁻¹)</td>
</tr>
</tbody>
</table>

### Selected emission characteristics (IPCC, 1997)

  - Annual rate of methane emission (t CH₄-C ha⁻¹ yr⁻¹) = 0.04015
  - Annual rate of carbon dioxide emission (t CO₂ ha⁻¹ yr⁻¹) = 35.2
- **Fens** based on the monthly mean temperature and the lengths of inundation (IPCC, 1997)
  - Annual rate of methane emission (t CH₄-C ha⁻¹ yr⁻¹) = 0.219
  - Annual rate of carbon dioxide emission (t CO₂ ha⁻¹ yr⁻¹) = 35.2

### Assumptions

- **Acid bogs**: The period of flooding is taken to be 178 days year⁻¹ for acid bogs and 169 days year⁻¹ based on the monthly mean temperature and the lengths of inundation (IPCC, 1997).
- **Fens**: The CH₄ emission rate is provided for acid bogs is 11 (1-38) mg CH₄-C m⁻² day⁻¹ x 365 days; and for fens is 60 (21-162) mg CH₄-C m⁻² day⁻¹ x 365 days (Aselmann & Crutzen, 1989).

### Calculations following ECOSSE based methodology

<table>
<thead>
<tr>
<th>Drained Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area affected by drainage due to wind farm construction (ha)</td>
</tr>
<tr>
<td>Total volume affected by drainage due to wind farm construction (m³)</td>
</tr>
</tbody>
</table>

### Soil Characteristics that Determine Emission Rates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annual air temperature at the site (°C)</td>
<td>7</td>
</tr>
<tr>
<td>Average depth of peat at site (m)</td>
<td>1.60</td>
</tr>
<tr>
<td>Average soil pH</td>
<td>4</td>
</tr>
<tr>
<td>Average water table depth at site (cm)</td>
<td>0.75</td>
</tr>
<tr>
<td>Average water table depth of drained land (m)</td>
<td>0.724958857</td>
</tr>
</tbody>
</table>

### Annual Emission Rates following ECOSSE based methodology

| Rate of carbon dioxide emission in drained soil (t CO₂ ha⁻¹ yr⁻¹) | 18.52 |
| Rate of carbon dioxide emission in undrained soil (t CO₂ ha⁻¹ yr⁻¹) | 18.96 |
| Rate of methane emission in drained soil ((t CH₄-C) ha⁻¹ yr⁻¹) | -0.55 |
| Rate of methane emission in undrained soil ((t CH₄-C) ha⁻¹ yr⁻¹) | -0.59 |

### Selected Emission Rates

| Rate of carbon dioxide emission in drained soil (t CO₂ ha⁻¹ yr⁻¹) | 18.52 |
| Rate of carbon dioxide emission in undrained soil (t CO₂ ha⁻¹ yr⁻¹) | 18.96 |
| Rate of methane emission in drained soil ((t CH₄-C) ha⁻¹ yr⁻¹) | -0.55 |
| Rate of methane emission in undrained soil ((t CH₄-C) ha⁻¹ yr⁻¹) | -0.59 |

**Note:** Equation derived by regression analysis against experimental data from 56 experiments. 41 cases were used and 9 included missing data values. The equation derived was $R_{CO2} = (3.667/1000) \times (58.4 + (3.11 \times T) + (16.7 \times pH) - (410 \times W))$, where $R_{CO2}$ is the annual rate of CO₂ emissions (t CO₂ ha⁻¹ yr⁻¹), $T$ is average annual air temperature (°C), $pH$ is the soil pH and $W$ is the water table depth (m). The equation has a $R^2$ value of 53.8%, $P < 0.0001$. By statistical convention, if $P<0.001$ this relationship can be considered to be highly significant.

**Note:** Equation derived by regression analysis against experimental data from 66 experiments. 40 cases were used and 26 included missing data values. The equation derived was $R_{CH4} = (3.667/1000) \times (547 + (71.7 \times T) + (322 \times D) + (4810 \times W))$, where $R_{CH4}$ is the annual rate of CH₄ emissions (t CH₄-C ha⁻¹ yr⁻¹). $T$ and $D$ are the average annual air temperature (°C) and the peat depth (m), and $W$ is the water table depth (m). The equation has a $R^2$ value of 52.7%, $P < 0.0001$. By statistical convention, if $P<0.001$ this relationship can be considered to be highly significant.

Appendix 16.3 intermediate scenario.xls
6. CO2 loss by DOC & POC loss

Note: CO2 losses from DOC are calculated using a simple approach derived from estimates of the total C loss leached as DOC and the percentage of leached DOC lost as CO2.

<table>
<thead>
<tr>
<th>Total C loss</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross CO2 loss from removed peat (t CO2)</td>
<td>1885395</td>
</tr>
<tr>
<td>Gross CO2 loss from drained land (t CO2)</td>
<td>817842</td>
</tr>
<tr>
<td>Gross CH4 loss from drained land (t CO2 equiv.)</td>
<td>817561</td>
</tr>
<tr>
<td>Gross CO2 loss from improved land (t CO2)</td>
<td>57386</td>
</tr>
<tr>
<td>Gross CH4 loss from flooded land (t CO2 equiv.)</td>
<td>0</td>
</tr>
<tr>
<td>Conversion factor: CH4-C to CO2 equivalents</td>
<td>30.6667</td>
</tr>
</tbody>
</table>

| % total soil C losses, lost as DOC | 10 |
| % DOC loss emitted as CO2 over the long term | 100 |
| % total soil C losses, lost as POC | 15 |
| % POC loss emitted as CO2 over the long term | 100 |

| Total gaseous loss of C (t C) | 761553 |
| Total C loss as DOC (t C) | 76155 |
| Total C loss as POC (t C) | 114233 |

| Total CO2 loss due to DOC leaching (t CO2) | 278728 |
| Total CO2 loss due to POC leaching (t CO2) | 418092 |
| Total CO2 loss due to DOC & POC leaching (t CO2) | 696821 |

<table>
<thead>
<tr>
<th>Wind farm CO2 emission saving over...</th>
<th>Carbon Dioxide Saving (tCO2 yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>...coal-fired electricity generation</td>
<td>1830665</td>
</tr>
<tr>
<td>...grid-mix of electricity generation</td>
<td>915332</td>
</tr>
<tr>
<td>...fossil fuel - mix of electricity generation</td>
<td>1292109</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional CO2 payback time of wind farm due to DOC and POC leaching</th>
<th>Additional payback time (years)</th>
<th>Additional payback time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired electricity generation</td>
<td>0.38</td>
<td>4.6</td>
</tr>
<tr>
<td>Grid-mix of electricity generation</td>
<td>0.76</td>
<td>9.1</td>
</tr>
<tr>
<td>Fossil fuel - mix of electricity generation</td>
<td>0.54</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Assumption: The export from temperate and boreal peatlands ranges between 10 and 500 kg DOC ha⁻¹ yr⁻¹ ([Dillon, P.J. and Molot, L.A. (1997) Water Resources Research 33, 2591–2600]), which typically represents around 10% of the total C release.

Assumption: In the long term, 100% of leached DOC is assumed to be lost as CO2.


Assumption: In the long term, 100% of leached DOC is assumed to be lost as CO2.

Appendix 16.3 intermediate scenario.xls
### Emissions due to forestry felling

| Area of forestry plantation to be felled (ha) | 0 |
| Carbon sequestered (tC ha\(^{-1}\) yr\(^{-1}\)) | 0 |
| Life time of wind farm (years) | 25 |
| Carbon sequestered over the lifetime of the wind farm (t C ha\(^{-1}\)) | 0 |
| **Total carbon loss due to felling of forestry (t CO\(_2\))** | 0 |

### Wind farm CO\(_2\) emission saving over…

<table>
<thead>
<tr>
<th>Carbon dioxide saving (tCO(_2) yr(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>…coal-fired electricity generation</td>
</tr>
<tr>
<td>…grid-mix of electricity generation</td>
</tr>
<tr>
<td>…fossil fuel - mix of electricity generation</td>
</tr>
</tbody>
</table>

### Additional CO\(_2\) payback time of wind farm due to felling of forestry

| Coal-fired electricity generation | 0.00 | 0.0 |
| Grid-mix of electricity generation | 0.00 | 0.0 |
| Fossil fuel - mix of electricity generation | 0.00 | 0.0 |

Note: Emissions due to forestry felling are calculated from the reduced carbon sequestered per crop rotation. If the forestry was due to be removed before the planned development, this C loss is not attributable to the wind farm and so the area of forestry to be felled should be entered as zero.
### Choice of methodology for calculating emission factors

The choice of methodology for calculating emission factors can significantly impact the results. Site-specific equations have been used in this project, as they provide more accurate estimates compared to the IPCC default methodology. These site-specific equations have been thoroughly tested against experimental data (see Nayak et al., 2008 - Final report).

<table>
<thead>
<tr>
<th>Improvement of...</th>
<th>Degraded Bog</th>
<th>Felled Forestry</th>
<th>Borrow Pits</th>
<th>Foundations &amp; Hardstanding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Description of site</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life time of wind farm (years)</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Area to be improved (ha)</td>
<td>394</td>
<td>0</td>
<td>15.19</td>
<td>354</td>
</tr>
<tr>
<td>Average air temperature at site (°C)</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Average soil pH</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Average depth of peat at site (m)</td>
<td>1.60</td>
<td>1.60</td>
<td>1.60</td>
<td>1.60</td>
</tr>
<tr>
<td>Water table depth before improvement (m)</td>
<td>0.75</td>
<td>0.00</td>
<td>1.60</td>
<td>1.60</td>
</tr>
<tr>
<td>Water table depth after improvement (m)</td>
<td>0.75</td>
<td>0.00</td>
<td>0.75</td>
<td>0.75</td>
</tr>
</tbody>
</table>

| **2. Losses with Improvement** | | | | |
| Flooded period (days year⁻¹) | 178 | 178 | 178 | 178 |
| Time required for hydrology and habitat to return to its previous state on restoration (years) | 10 | 0 | 10 | 25 |
| Improved period (years) | 15 | 25 | 15 | 0 |

**Site-specific annual rate of methane emission (t CO₂ ha⁻¹ yr⁻¹)**

-18.05

**IPCC annual rate of methane emission (t CO₂ ha⁻¹ yr⁻¹)**

1.23

**Selected annual rate of methane emission (t CO₂ ha⁻¹ yr⁻¹)**

-18.05

**CH₄ emissions from improved land (t CO₂ equiv.)**

-52029

**Carbon dioxide emissions from improved land**

-57421

**Total GHG emissions from improved land (t CO₂ equiv.)**

5392

| **3. Losses without Improvement** | | | | |
| Flooded period (days year⁻¹) | 0 | 0 | 0 | 0 |
| Time required for hydrology and habitat to return to its previous state on restoration (years) | 10 | 0 | 10 | 25 |
| Improved period (years) | 15 | 25 | 15 | 0 |

**Site-specific annual rate of methane emission (t CO₂ ha⁻¹ yr⁻¹)**

-18.05

**IPCC annual rate of methane emission (t CO₂ ha⁻¹ yr⁻¹)**

1.23

**Selected annual rate of methane emission (t CO₂ ha⁻¹ yr⁻¹)**

-18.05

**CH₄ emissions from unimproved land (t CO₂ equiv.)**

0

**Carbon dioxide emissions from unimproved land**

112079

**Total GHG emissions from unimproved land (t CO₂ equiv.)**

112079

| **4. Reduction in GHG emissions due to improvement of site** | | | | |
| Total GHG emissions from improved land (t CO₂ equiv.) | 5392 | 0 | 208 | 0 |
| Total GHG emissions from unimproved land (t CO₂ equiv.) | 112079 | 0 | 7737 | 0 |
| Reduction in GHG emissions due to improvement (t CO₂ equiv.) | 106687 | 0 | 7529 | 0 |

### Reduction in CO₂ payback time of wind farm due to improvement of site

<table>
<thead>
<tr>
<th>Wind farm CO₂ emission saving over...</th>
<th>Carbon Dioxide Saving (tCO₂ yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>...coal-fired electricity generation</td>
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<tr>
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<td>1292109</td>
</tr>
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</table>

### Reduction in CO₂ payback time of wind farm due improvement of site

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<thead>
<tr>
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<th>Borrow Pits</th>
<th>Foundations &amp; Hardstanding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduction in CO₂ payback time (years)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal-fired electricity generation</td>
<td>0.06</td>
<td>0.00</td>
<td>0.00</td>
<td>0.06</td>
</tr>
<tr>
<td>Grid-mix of electricity generation</td>
<td>0.12</td>
<td>0.00</td>
<td>0.01</td>
<td>0.12</td>
</tr>
<tr>
<td>Fossil fuel - mix of electricity generation</td>
<td>0.05</td>
<td>0.00</td>
<td>0.01</td>
<td>0.09</td>
</tr>
</tbody>
</table>

### Reduction in CO₂ payback time (months)

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Degraded Bog</th>
<th>Felled Forestry</th>
<th>Borrow Pits</th>
<th>Foundations &amp; Hardstanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired electricity generation</td>
<td>0.70</td>
<td>0.00</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Grid-mix of electricity generation</td>
<td>1.14</td>
<td>0.00</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Fossil fuel - mix of electricity generation</td>
<td>0.99</td>
<td>0.00</td>
<td>0.07</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Appendix 16.3 intermediate scenario.xls