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Appendix 18.1 Carbon Calculator Input and Results

Page 4-19 Lower expected Capacity (5.7 MW) Turbines

Page 20-35 Higher expected Capacity (7.2 MW) Turbines

Carbon Calculator Available at:

<https://informatics.sepa.org.uk/CarbonCalculator/>

Software Version 1.8.1



The Scottish
Government
Riaghaltas na h-Alba

[Start Carbon Calculator](#)

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This tool calculates payback time for windfarm sited on peatlands using methods given in Nayak et al, 2008 (<http://www.gov.scot/Publications/2008/06/25114657/0>) and revised equations for GHG emissions (Nayak, D.R., Miller, D., Nolan, A., Smith, P. and Smith, J.U., 2010, Calculating carbon budgets of wind farms on Scottish peatland. Mires and Peat 4: Art. 9. Online: <http://mires-and-peat.net/pages/volumes/map04/map0409.php>)

- Will the site be drained on construction of the windfarm?
- Is the soil at the site highly organic?
- Does windfarm construction require a significant amount of deforestation?
i.e. is removal in excess of keyholing the turbines within the forest boundary?

[New application](#)

If you already have an Application Reference, type it here (or paste it in the first box):

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Carbon Payback Results – MEC 5.7 MW

Payback Time and CO₂ emissions

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	Exp.	Min.	Max.
1. Windfarm CO2 emission saving over...			
...coal-fired electricity generation (t CO ₂ / yr)	82,575	80,216	84,934
...grid-mix of electricity generation (t CO ₂ / yr)	18,088	17,571	18,605
...fossil fuel-mix of electricity generation (t CO ₂ / yr)	37,050	35,991	38,108
Energy output from windfarm over lifetime (MWh)	3,058,335	2,970,954	3,145,716

	Exp.	Min.	Max.
Total CO2 losses due to wind farm (tCO₂ eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decommissioning)	25,796	25,795	25,796
3. Losses due to backup	18,525	18,525	18,525
4. Losses due to reduced carbon fixing potential	906	469	1,624
5. Losses from soil organic matter	5,044	50	8,618
6. Losses due to DOC & POC leaching	4,036	553	10,163
7. Losses due to felling forestry	4,347	4,222	4,473
Total losses of carbon dioxide	58,654	49,615	69,199

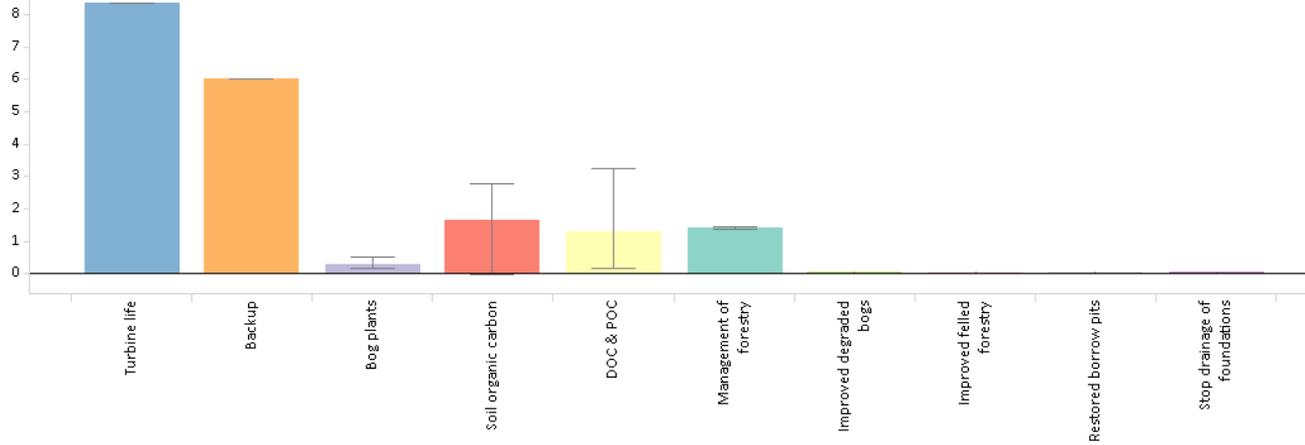
	Exp.	Min.	Max.
8. Total CO2 gains due to improvement of site (t CO₂ eq.)			
8a. Change in emissions due to improvement of degraded bogs	0	0	0
8b. Change in emissions due to improvement of felled forestry	0	0	0
8c. Change in emissions due to restoration of peat from borrow pits	0	0	0
8d. Change in emissions due to removal of drainage from foundations & hardstanding	0	0	0
Total change in emissions due to improvements	0	0	0

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO₂ eq.)	58,654	49,615	69,199
Carbon Payback Time			
...coal-fired electricity generation (years)	0.7	0.6	0.9
...grid-mix of electricity generation (years)	3.2	2.7	3.9
...fossil fuel-mix of electricity generation (years)	1.6	1.3	1.9
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	No gains!	No gains!	No gains!
Ratio of CO₂ eq. emissions to power generation (g/kWh) (for info. only)	19.18	15.77	23.29

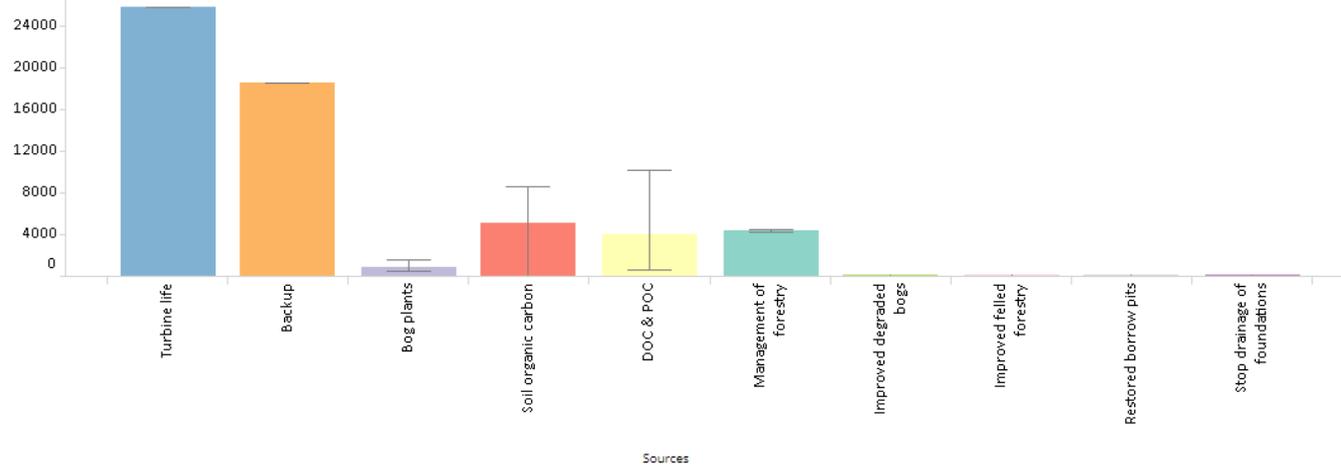
Carbon Payback Results - MEC 5.7 MW

Payback Time and CO₂ emissions

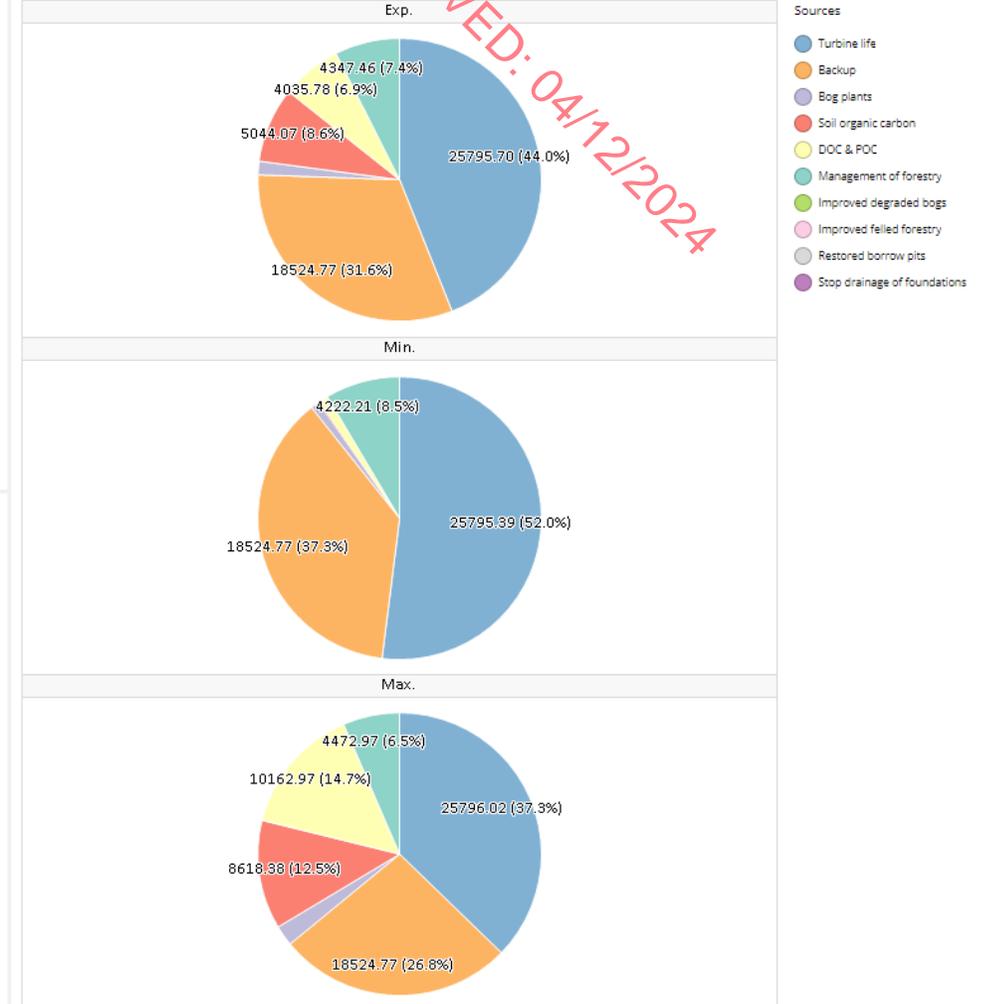
Carbon payback time (months) using fossil-fuel mix as counterfactual



Greenhouse gas emissions (t CO₂ eq.)



Proportions of greenhouse gas emissions from different sources



Input Data - MEC 5.7 MW

View Input Data

Print this page

Carbon Calculator v1.8.1

Kellystown WF

Location: 53.791995 -6.36523

EDF Renewables Ireland Ltd

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
<u>Dimensions</u>				
No. of turbines	5	5	5	Chapter 2: Description of the proposed development
Duration of consent (years)	35	35	35	Chapter 2: Description of the proposed development
<u>Performance</u>				
Power rating of 1 turbine (MW)	5.7	5.7	5.7	Chapter 2: Description of the proposed development
Capacity factor	35	34	36	Chapter 18: Air Quality & Climate
<u>Backup</u>				
Fraction of output to backup (%)	5	5	5	SNH Calculator Guidance
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO2 emission from turbine life (tCO2 MW ⁻¹) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	
Characteristics of peatland before windfarm development				
Type of peatland	Fen	Fen	Fen	Chapter 6: Biodiversity
Average annual air temperature at site (°C)	9.7	9.6	9.8	Chapter 18: Air Quality & Climate
Average depth of peat at site (m)	0.1	0.09	0.11	Chapter 10: Soils & Geology
C Content of dry peat (% by weight)	55	50	60	Default Value
Average extent of drainage around drainage features at site (m)	10	5	15	Chapter 11: Hydrology & Hydrogeology
Average water table depth at site (m)	1	0.99	1	Chapter 10: Soils & Geology
Dry soil bulk density (g cm ⁻³)	0.1	0.09	0.11	Default Value
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	10	5	15	Best Practise in Bog Restoration Ireland
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha ⁻¹ yr ⁻¹)	0.25	0.24	0.26	Default Value
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	9.41	9.4	9.42	Chapter 2: Description of the proposed development
Average rate of carbon sequestration in timber (tC ha ⁻¹ yr ⁻¹)	3.6	3.5	3.7	Cannell, 1999
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh ⁻¹)	0.945	0.945	0.945	
Grid-mix emission factor (t CO2 MWh ⁻¹)	0.207	0.207	0.207	
Fossil fuel-mix emission factor (t CO2 MWh ⁻¹)	0.424	0.424	0.424	
Borrow pits				
Number of borrow pits	0	0	0	Chapter 2: Description of the proposed development
Average length of pits (m)	0	0	0	
Average width of pits (m)	0	0	0	
Average depth of peat removed from pit (m)	0	0	0	

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Input Data - MEC 5.7 MW

Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	27.5	27.4	27.6	Chapter 2: Description of the proposed development
Average width of turbine foundations (m)	27.5	27.4	27.6	Chapter 2: Description of the proposed development
Average depth of peat removed from turbine foundations(m)	0.1	0.1	0.1	Chapter 10: Soils & Geology
Average length of hard-standing (m)	80	80	80	Chapter 2: Description of the proposed development
Average width of hard-standing (m)	56	56	56	Chapter 2: Description of the proposed development
Average depth of peat removed from hard-standing (m)	0.1	0.1	0.1	Chapter 10: Soils & Geology
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m ³)	4761	4760	4762	Chapter 16: Traffic & Transport
Access tracks				
Total length of access track (m)	6330	6000	6500	Chapter 2: Description of the proposed development
Existing track length (m)	0	0	0	Chapter 2: Description of the proposed development
<u>Length of access track that is floating road (m)</u>	0	0	0	na
Floating road width (m)	5	5	5	na
Floating road depth (m)	0	0	0	na
Length of floating road that is drained (m)	0	0	0	na
Average depth of drains associated with floating roads (m)	0	0	0	na
<u>Length of access track that is excavated road (m)</u>	6330	6000	6500	Chapter 2: Description of the proposed development
Excavated road width (m)	5	5	10	Chapter 2: Description of the proposed development
Average depth of peat excavated for road (m)	0.1	0.1	0.1	na
<u>Length of access track that is rock filled road (m)</u>	0	0	0	na
Rock filled road width (m)	5	5	5	na
Rock filled road depth (m)	0	0	0	na
Length of rock filled road that is drained (m)	0	0	0	na
Average depth of drains associated with rock filled roads (m)	0	0	0	na
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	708	707	709	na
Average depth of peat cut for cable trenches (m)	0.1	0.1	0.1	na
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m ³)	0	0	0	na
Area of additional peat excavated (m ²)	0	0	0	na
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	negligible	negligible	Fixed

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Input Data - MEC 5.7 MW

<u>Improvement of C sequestration at site by blocking drains, restoration of habitat etc</u>				
<u>Improvement of degraded bog</u>				
Area of degraded bog to be improved (ha)	0	0	0	na
Water table depth in degraded bog before improvement (m)	0	0	0	na
Water table depth in degraded bog after improvement (m)	0	0	0	na
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	2	2	2	Chapter 2: Description of the proposed development
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	2	2	2	Chapter 2: Description of the proposed development
<u>Improvement of felled plantation land</u>				
Area of felled plantation to be improved (ha)	0	0	0	na
Water table depth in felled area before improvement (m)	0	0	0	na
Water table depth in felled area after improvement (m)	0	0	0	na
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2	2	2	Chapter 2: Description of the proposed development
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	2	2	2	Chapter 2: Description of the proposed development
<u>Restoration of peat removed from borrow pits</u>				
Area of borrow pits to be restored (ha)	0	0	0	na
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	na
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0	0	0	na
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	2	2	2	Chapter 2: Description of the proposed development
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	2	2	2	Chapter 2: Description of the proposed development
<u>Early removal of drainage from foundations and hardstanding</u>				
Water table depth around foundations and hardstanding before restoration (m)	0	0	0	na
Water table depth around foundations and hardstanding after restoration (m)	0	0	0	na
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0.1	0.1	0.1	na
<u>Restoration of site after decommissioning</u>				
<u>Will the hydrology of the site be restored on decommissioning?</u>	Yes	Yes	Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	n/a	n/a	n/a	na
Will you attempt to block all artificial ditches and facilitate rewetting?	n/a	n/a	n/a	na
<u>Will the habitat of the site be restored on decommissioning?</u>	Yes	Yes	Yes	
Will you control grazing on degraded areas?	n/a	n/a	n/a	na
Will you manage areas to favour reintroduction of species	n/a	n/a	n/a	na
<u>Methodology</u>				
Choice of methodology for calculating emission factors	IPCC default			

Forestry input data

N/A

Construction input data

N/A

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Carbon Calculations - MEC 5.7 MW

1. Windfarm CO₂ emission saving

Emissions due to turbine life

The carbon payback time of the windfarm due to turbine life (eg. 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.

Capacity factor calculated from forestry data

Area name	Value type	Capacity factor (%)	Wind speed ratio	Average site windspeed (m/s)	Annual theoretical energy output (MW / turbine yr)

Capacity factor - Direct input

Capacity factor (%)	Exp.	Min.	Max.
	35.0	34.0	36.0

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	Exp.	Min.	Max.
Annual energy output from windfarm (MW/yr)			
RESULTS			
Emissions saving over coal-fired electricity ge...	82,575	80,216	84,934
Emissions saving over grid-mix of electricity g...	18,088	17,571	18,605
Emissions saving over fossil fuel - mix of elect...	37,050	35,991	38,108

Carbon Calculations - MEC 5.7 MW

2. CO₂ loss due to turbine life

Emissions due to turbine life

The carbon payback time of the windfarm due to turbine life (eg. 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.

Calculation of emissions with relation to installed capacity

	Exp.	Min.	Max.
Emissions due to turbine frome energy output (t CO ₂)	4858	4858	4858
Emissions due to cement used in construction (t CO ₂)	1504	1504	1505

Direct input of emissions due to turbine life

	Exp.	Min.	Max.
Emissions due to turbine life (tCO ₂ /windfarm)			

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RESULTS

	Exp.	Min.	Max.
Losses due to turbine life (manufacture, construction, etc.) (t CO ₂)	25796	25795	25796
Additional CO₂ payback time of windfarm due to turbine life			
...coal-fired electricity generation (months)	4	4	4
...grid-mix of electricity generation (months)	17	18	17
...fossil fuel - mix of electricity generation (months)	8	9	8

Carbon Calculations - MEC 5.7 MW

3. CO₂ loss due to backup

Emissions due to backup power generation

CO₂ loss due to back up is calculated from the extra capacity required for backup of the windfarm given in the input data.

Wind generated electricity is inherently variable, providing unique challenges to the electricity generating industry for provision of a supply to meet consumer demand (Netz, 2004). Backup power is required to accompany wind generation to stabilise the supply to the consumer. This backup power will usually be obtained from a fossil fuel source. At a high level of wind power penetration in the overall generating mix, and with current grid management techniques, the capacity for fossil fuel backup may become strained because it is being used to balance the fluctuating consumer demand with a variable and highly unpredictable output from wind turbines (White, 2007). The Carbon Trust (Carbon Trust/DTI, 2004) concluded that increasing levels of intermittent generation do not present major technical issues at the percentages of renewables expected by 2010 and 2020, but the UK renewables target at the time of that report was only 20%. When national reliance on wind power is low (less than ~20%), the additional fossil fuel generated power requirement can be considered to be insignificant and may be obtained from within the spare generating capacity of other power sectors (Dale et al. 2004). However, as the national supply from wind power increases above 20%, without improvements in grid management techniques, emissions due to backup power generation may become more significant. The extra capacity needed for backup power generation is currently estimated to be 5% of the rated capacity of the wind plant if wind power contributes more than 20% to the national grid (Dale et al 2004). Moving towards the SG target of 50% electricity generation from renewable sources, more short-term capacity may be required in terms of pumped-storage hydro-generated power, or a better mix of offshore and onshore wind generating capacity. Grid management techniques are anticipated to reduce this extra capacity, with improved demand side management, smart meters, grid reinforcement and other developments. However, given current grid management techniques, it is suggested that 5% extra capacity should be assumed for backup power generation if wind power contributes more than 20% to the national grid. At lower contributions, the extra capacity required for backup should be assumed to be zero. These assumptions should be revisited as technology improves.

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.

	Exp.	Min.	Max.
Reserve energy (MWh/yr)	12,483	12,483	12,483
Annual emissions due to backup from fossil fuel-mix of electricity generati...	529	529	529
RESULTS			
Total emissions due to backup from fossil fuel-mix of electricity generatio...	18,525	18,525	18,525

4. Loss of CO₂ fixing potential

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Emissions due to loss of bog plants

Annual C fixation by the site is calculated by multiplying area of the windfarm by the annual C accumulation due to bog plant fixation.

	Exp.	Min.	Max.
Area where carbon accumulation by bog plants is lost (ha)	21.97	13.33	34.07
Total loss of carbon accumulation up to time of restoration (tCO₂ eq./ha)	41	35	48
RESULTS			
Total loss of carbon fixation by plants at the site (t CO₂)	906	469	1624
Additional CO₂ payback time of windfarm due to loss of CO₂ fixing potential			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	1	0	1
...fossil fuel - mix of electricity generation (months)	0	0	1

Carbon Calculations - MEC 5.7 MW

5. Loss of soil CO₂ (a, b)

Emissions due to loss of soil organic carbon

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

5. Loss of soil CO ₂	Exp.	Min.	Max.
CO ₂ loss from removed peat (t CO ₂ equiv.)	-4562.02	-4017.58	-7830.95
CO ₂ loss from drained peat (t CO ₂ equiv.)	9606.09	4067.85	16449.33
RESULTS			
Total CO ₂ loss from peat (removed + drained) (t CO ₂ e...)	5044.07	50.28	8618.38
Additional CO ₂ payback time of windfarm due to loss ...			
...coal-fired electricity generation (months)	0.73	0.01	1.22
...grid-mix of electricity generation (months)	3.35	0.03	5.56
...fossil fuel - mix of electricity generation (months)	1.63	0.02	2.71

CO₂ loss from removed peats

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.

5b. CO ₂ loss from removed peat	Exp.	Min.	Max.
CO ₂ loss from removed peat (t CO ₂)	1166.27	926.55	2207.27
CO ₂ loss from undrained peat left in situ (t CO ₂)	5728.29	4944.12	10038.22
RESULTS			
CO ₂ loss attributable to peat removal only (t CO ₂)	-4562.02	-4017.58	-7830.95

Volume of Peat Removed

% 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 as additional peat excavated in the core input data entry.

5a. Volume of peat removed	Exp.	Min.	Max.
Peat removed from borrow pits			
Area of land lost in borrow pits (m ²)	0	0	0
Volume of peat removed from borrow pits (m ³)	0	0	0
Peat removed from turbine foundations			
Area of land lost in foundation (m ²)	3781.25	3753.8	3808.8
Volume of peat removed from foundation area (m ³)	378.13	375.38	380.88
Peat removed from hard-standing			
Area of land lost in hard-standing (m ²)	22400	22400	22400
Volume of peat removed from hard-standing area (m ³)	2240	2240	2240
Peat removed from access tracks			
Area of land lost in floating roads (m ²)	0	0	0
Volume of peat removed from floating roads (m ³)	0	0	0
Area of land lost in excavated roads (m ²)	31650	30000	65000
Volume of peat removed from excavated roads (m ³)	3165	3000	6500
Area of land lost in rock-filled roads (m ²)	0	0	0
Volume of peat removed from rock-filled roads (m ³)	0	0	0
Total area of land lost in access tracks (m ²)	31650	30000	65000
Total volume of peat removed due to access tracks (m ³)	3165	3000	6500
RESULTS			
Total area of land lost due to windfarm construction (m ²)	57831.25	56153.8	91208.8
Total volume of peat removed due to windfarm constructio...	5783.13	5615.38	9120.88

Carbon Calculations - MEC 5.7 MW

5. Loss of soil CO₂ (c, d, e)

Volume of peat drained

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

5c. Volume of peat drained

	Exp.	Min.	Max.
Total area affected by drainage around borrow pits (m2)	0	0	0
Total volume affected by drainage around borrow pits (m3)	0	0	0
Peat affected by drainage around turbine foundation and hardst...			
Total area affected by drainage of foundation and hardstanding ...	21100	10040	33180
Total volume affected by drainage of foundation and hardstandi...	1055	502	1659
Peat affected by drainage of access tracks			
Total area affected by drainage of access track(m2)	126600	60000	195000
Total volume affected by drainage of access track(m3)	6330	3000	9750
Peat affected by drainage of cable trenches			
Total area affected by drainage of cable trenches(m2)	14160	7070	21270
Total volume affected by drainage of cable trneches(m3)	708	353.5	1063.5
Drainage around additional peat excavated			
Total area affected by drainage (m2)	0	0	0
Total volume affected by drainage (m3)	0	0	0
RESULTS			
Total area affected by drainage due to windfarm (m2)	161860	77110	249450
Total volume affected by drainage due to windfarm (m3)	8093	3855.5	12472.5

CO₂ loss due to drainage

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 derived directly from experimental data for acid bogs and fens (see Nayak et al, 2008 - Final report).

5d. CO₂ loss from drained peat

	Exp.	Min.	Max.
Calculations of C Loss from Drained Land if Site is NOT Restored after De...			
Total GHG emissions from Drained Land (t CO ₂ equiv.)	1632.1	636.16	3019.37
Total GHG emissions from Undrained Land (t CO ₂ equiv.)	1020.6	397.81	1887.41
Calculations of C Loss from Drained Land if Site IS Restored after Decomi...			
Losses if Land is Drained			
CH ₄ emissions from drained land (t CO ₂ equiv.)	0	0	0
CO ₂ emissions from drained land (t CO ₂)	25638.62	10857.09	43903.2
Total GHG emissions from Drained Land (t CO ₂ equiv.)	25638.62	10857.09	43903.2
Losses if Land is Undrained			
CH ₄ emissions from undrained land (t CO ₂ equiv.)	2264.94	959.13	3878.45
CO ₂ emissions from undrained land (t CO ₂)	13767.59	5830.11	23575.42
Total GHG emissions from Undrained Land (t CO ₂ equiv.)	16032.53	6789.23	27453.87
RESULTS			
Total GHG emissions due to drainage (t CO ₂ equiv.)	9606.09	4067.85	16449.33

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).

Carbon Calculations - MEC 5.7 MW

5e. Emission rates from soils

	Exp.	Min.	Max.
Calculations following IPCC default methodology			
Flooded period (days/year)	169	169	169
Annual rate of methane emission (t CH ₄ -C/ha year)	0.22	0.22	0.22
Annual rate of carbon dioxide emission (t CO ₂ /ha year)	35.2	35.2	35.2
Calculations following ECOSSE based methodology			
Total area affected by drainage due to wind farm construction (ha)	16.19	7.71	24.95
Average water table depth of drained land (m)	1	1	0.99
Selected emission characteristics following site specific methodology			
Rate of carbon dioxide emission in drained soil (t CO ₂ /ha year)	64.74	64.69	64.78
Rate of carbon dioxide emission in undrained soil (t CO ₂ /ha year)	64.74	64.69	64.78
Rate of methane emission in drained soil (t CH ₄ -C/ha year)	0	0	0
Rate of methane emission in undrained soil (t CH ₄ -C/ha year)	0	0	0
RESULTS			
Selected rate of carbon dioxide emission in drained soil (t CO ₂ /ha year)	35.2	35.2	35.2
Selected rate of carbon dioxide emission in undrained soil (t CO ₂ /ha year)	0	0	0
Selected rate of methane emission in drained soil (t CH ₄ -C/ha year)	0	0	0
Selected rate of methane emission in undrained soil (t CH ₄ -C/ha year)	0.22	0.22	0.22

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Carbon Calculations - MEC 5.7 MW

6. CO₂ loss by DOC & POC loss

Emissions due to loss of DOC and POC

Note, CO₂ losses from DOC and POC are calculated using a simple approach derived from generic estimates of the percentage of the total CO₂ loss that is due to DOC or POC leaching.

No POC losses for bare soil included yet. If extensive areas of bare soil is present at site need modified calculation (Birnie et al, 1991)

	Exp.	Min.	Max.
Gross CO ₂ loss from restored drained land (t CO ₂)	11871.03	5026.98	20327.78
Gross CH ₄ loss from restored drained land (t CO ₂ equiv.)	0.00	0.00	0.00
Gross CO ₂ loss from improved land (t CO ₂)	0.00	0.00	0.00
Gross CH ₄ loss from improved land (t CO ₂ equiv.)	0.00	0.00	0.00
Total gaseous loss of C (t C)	3237.23	1370.86	5543.39
Total C loss as DOC (t C)	841.68	95.96	2217.35
Total C loss as POC (t C)	258.98	54.83	554.34
RESULTS			
Total CO ₂ loss due to DOC leaching (t CO ₂)	3086.19	351.86	8130.37
Total CO ₂ loss due to POC leaching (t CO ₂)	949.60	201.06	2032.59
Total CO ₂ loss due to DOC & POC leaching (t CO ₂)	4035.78	552.92	10162.97
Additional CO₂ payback time of windfarm due to DOC & POC			
...coal-fired electricity generation (months)	1	0	1
...grid-mix of electricity generation (months)	3	0	7
...fossil fuel - mix of electricity generation (months)	1	0	3

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7. Forestry CO₂ loss

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CO₂ loss from forests - calculation using detailed management information

Forest carbon calculator (Perks et al, 2009)

Total potential carbon sequestration loss due to felling of forestry for the wind ...
Total emissions due to cleared land (t CO ₂)
Emissions due to harvesting operations (t CO ₂)
Fossil fuel equivalent saving from use of felled forestry as biofuel (t CO ₂)
Fossil fuel equivalent saving from use of replanted forestry as biofuel (t CO ₂)
RESULTS
Total carbon loss associated with forest management(t CO ₂)

Emissions due to forest felling - calculation using simple management data

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.

	Exp.	Min.	Max.
Area of forestry plantation to be felled (ha)	9.41	9.4	9.42
Carbon sequestered (t C ha-1 yr-1)	3.6	3.5	3.7
Lifetime of windfarm (years)	35	35	35
Carbon sequestered over the lifetime of the windfarm (t C ha-1)	126	122.5	129.5
RESULTS			
Total carbon loss due to felling of forestry (t CO ₂)	4347.46	4222.21	4472.97
Additional CO ₂ payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	0.63	0.63	0.63
...grid-mix of electricity generation (months)	2.88	2.88	2.89
...fossil fuel - mix of electricity generation (months)	1.41	1.41	1.41

Carbon Calculations - MEC 5.7 MW

8. CO₂ gain - site improvement

Gains due to site improvement

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).

Degraded Bog			
	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha	25.7	25.7	25.7

Borrow Pits			
	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0

Felled Forestry			
	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha	25.7	25.7	25.7

Foundations & Hardstanding			
	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	34.9	34.9	34.9
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	34.9	34.9	34.9
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0

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Carbon Calculations - MEC 5.7 MW

8. CO₂ gain - site improvement

Gains due to site improvement

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).

Degraded Bog			
	Exp.	Min.	Max.
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-1 yr-1)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-1 yr-1)	35.2	35.2	35.2
CO ₂ emissions from unimproved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO ₂ equiv.)	0	0	0

Borrow Pits			
	Exp.	Min.	Max.
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-1 yr-1)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-1 yr-1)	35.2	35.2	35.2
CO ₂ emissions from unimproved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO ₂ equiv.)	0	0	0

Felled Forestry			
	Exp.	Min.	Max.
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-1 yr-1)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-1 yr-1)	35.2	35.2	35.2
CO ₂ emissions from unimproved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO ₂ equiv.)	0	0	0

Foundations & Hardstanding			
	Exp.	Min.	Max.
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-1 yr-1)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	34.9	34.9	34.9
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-1 yr-1)	35.2	35.2	35.2
CO ₂ emissions from unimproved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO ₂ equiv.)	0	0	0

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Carbon Payback Results - MEC 7.2 MW

Payback Time and CO₂ emissions

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1. Windfarm CO ₂ emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO ₂ / yr)	104,305	101,325	107,285
...grid-mix of electricity generation (t CO ₂ / yr)	22,848	22,195	23,501
...fossil fuel-mix of electricity generation (t CO ₂ / yr)	46,799	45,462	48,137
Energy output from windfarm over lifetime (MWh)	3,863,160	3,752,784	3,973,536

Total CO ₂ losses due to wind farm (tCO ₂ eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (eg. manufacture, construction, decommissioning)	32,803	32,803	32,804
3. Losses due to backup	23,400	23,400	23,400
4. Losses due to reduced carbon fixing potential	906	469	1,624
5. Losses from soil organic matter	5,044	50	8,618
6. Losses due to DOC & POC leaching	4,036	553	10,163
7. Losses due to felling forestry	4,347	4,222	4,473
Total losses of carbon dioxide	70,537	61,497	81,081

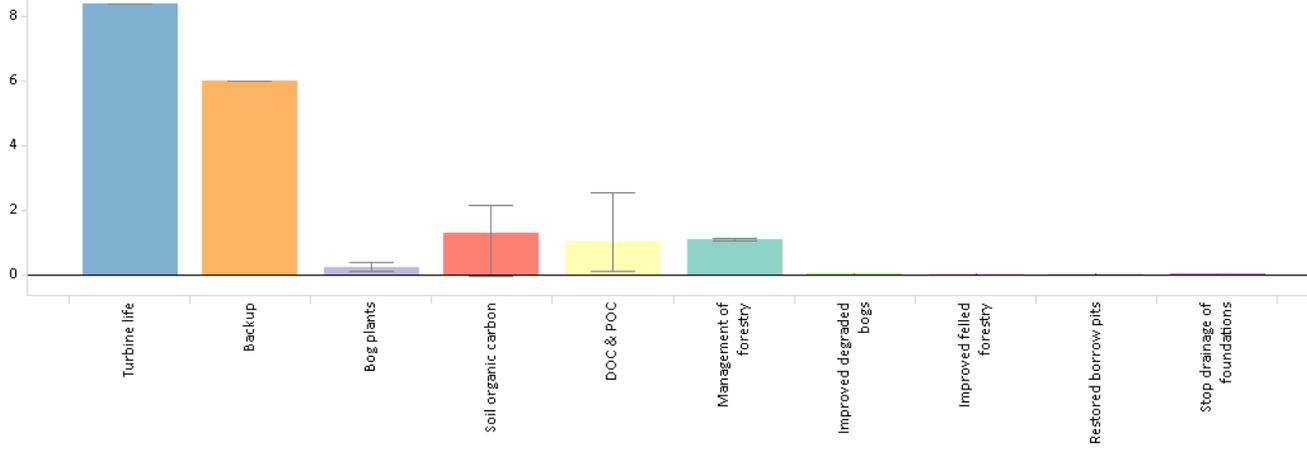
8. Total CO ₂ gains due to improvement of site (t CO ₂ eq.)	Exp.	Min.	Max.
8a. Change in emissions due to improvement of degraded bogs	0	0	0
8b. Change in emissions due to improvement of felled forestry	0	0	0
8c. Change in emissions due to restoration of peat from borrow pits	0	0	0
8d. Change in emissions due to removal of drainage from foundations & hardstanding	0	0	0
Total change in emissions due to improvements	0	0	0

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO ₂ eq.)	70,537	61,497	81,081
Carbon Payback Time			
...coal-fired electricity generation (years)	0.7	0.6	0.8
...grid-mix of electricity generation (years)	3.1	2.6	3.7
...fossil fuel-mix of electricity generation (years)	1.5	1.3	1.8
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	No gains!	No gains!	No gains!
Ratio of CO ₂ eq. emissions to power generation (g/kWh) (for info. only)	18.26	15.48	21.61

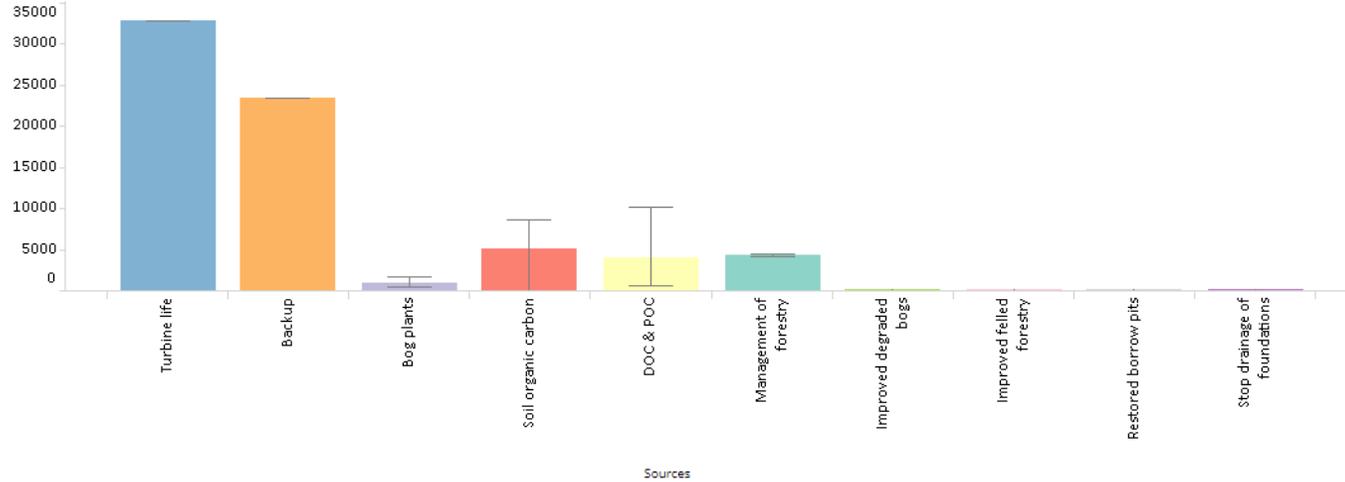
Carbon Payback Results - MEC 7.2 MW

Payback Time and CO₂ emissions

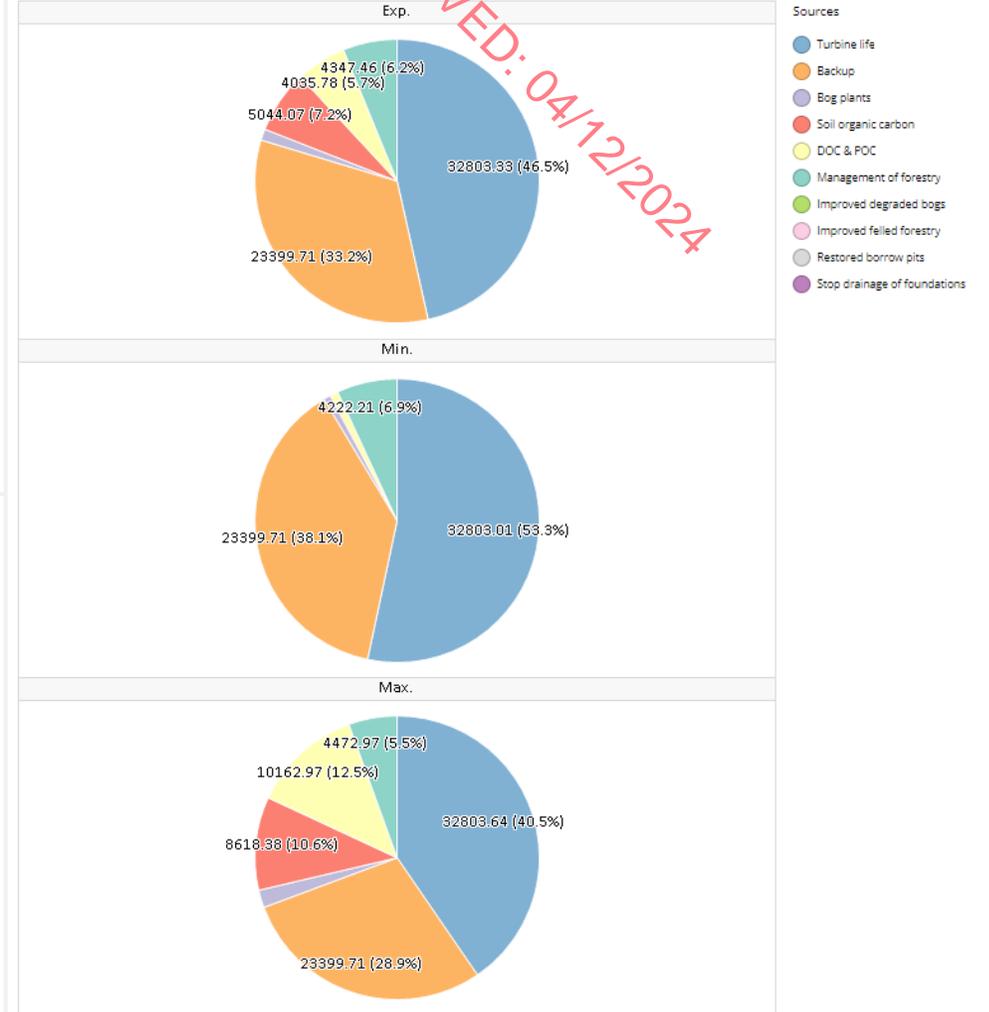
Carbon payback time (months) using fossil-fuel mix as counterfactual



Greenhouse gas emissions (t CO₂ eq.)



Proportions of greenhouse gas emissions from different sources



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Input Data - MEC 7.2 MW

View Input Data

Print this page

Carbon Calculator v1.8.1

Kellystown WF

Location: 53.791995 -6.36523

EDF Renewables Ireland Ltd

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
<u>Dimensions</u>				
No. of turbines	5	5	5	Chapter 2: Description of the proposed development
Duration of consent (years)	35	35	35	Chapter 2: Description of the proposed development
<u>Performance</u>				
Power rating of 1 turbine (MW)	7.2	7.2	7.2	Chapter 2: Description of the proposed development
Capacity factor	35	34	36	Chapter 18: Air Quality & Climate
<u>Backup</u>				
Fraction of output to backup (%)	5	5	5	SNH Calculator Guidance
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO2 emission from turbine life (tCO2 MW ⁻¹) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	
Characteristics of peatland before windfarm development				
<u>Type of peatland</u>				
Average annual air temperature at site (°C)	Fen	Fen	Fen	Chapter 6: Biodiversity
Average depth of peat at site (m)	9.7	9.6	9.8	Chapter 18: Air Quality & Climate
C Content of dry peat (% by weight)	0.1	0.09	0.11	Chapter 10: Soils & Geology
Average extent of drainage around drainage features at site (m)	55	50	60	Default Value
Average water table depth at site (m)	10	5	15	Chapter 11: Hydrology & Hydrogeology
Dry soil bulk density (g cm ⁻³)	1	0.99	1	Chapter 10: Soils & Geology
<u>Characteristics of bog plants</u>				
Time required for regeneration of bog plants after restoration (years)	0.1	0.09	0.11	Default Value
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha ⁻¹ yr ⁻¹)	10	5	15	Best Practise in Bog Restoration Ireland
<u>Forestry Plantation Characteristics</u>				
Area of forestry plantation to be felled (ha)	0.25	0.24	0.26	Default Value
Average rate of carbon sequestration in timber (tC ha ⁻¹ yr ⁻¹)	9.41	9.4	9.42	Chapter 2: Description of the proposed development
Counterfactual emission factors	3.6	3.5	3.7	Cannell, 1999
<u>Coal-fired plant emission factor (t CO2 MWh⁻¹)</u>				
Coal-fired plant emission factor (t CO2 MWh ⁻¹)	0.945	0.945	0.945	
<u>Grid-mix emission factor (t CO2 MWh⁻¹)</u>				
Grid-mix emission factor (t CO2 MWh ⁻¹)	0.207	0.207	0.207	
<u>Fossil fuel-mix emission factor (t CO2 MWh⁻¹)</u>				
Fossil fuel-mix emission factor (t CO2 MWh ⁻¹)	0.424	0.424	0.424	
<u>Borrow pits</u>				
Number of borrow pits	0	0	0	Chapter 2: Description of the proposed development
Average length of pits (m)	0	0	0	
Average width of pits (m)	0	0	0	
Average depth of peat removed from pit (m)	0	0	0	

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Input Data - MEC 7.2 MW

Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	27.5	27.4	27.6	Chapter 2: Description of the proposed development
Average width of turbine foundations (m)	27.5	27.4	27.6	Chapter 2: Description of the proposed development
Average depth of peat removed from turbine foundations(m)	0.1	0.1	0.1	Chapter 10: Soils & Geology
Average length of hard-standing (m)	80	80	80	Chapter 2: Description of the proposed development
Average width of hard-standing (m)	56	56	56	Chapter 2: Description of the proposed development
Average depth of peat removed from hard-standing (m)	0.1	0.1	0.1	Chapter 10: Soils & Geology
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m ³)	4761	4760	4762	Chapter 16: Traffic & Transport
Access tracks				
Total length of access track (m)	6330	6000	6500	Chapter 2: Description of the proposed development
Existing track length (m)	0	0	0	Chapter 2: Description of the proposed development
<u>Length of access track that is floating road (m)</u>	0	0	0	na
Floating road width (m)	5	5	5	na
Floating road depth (m)	0	0	0	na
Length of floating road that is drained (m)	0	0	0	na
Average depth of drains associated with floating roads (m)	0	0	0	na
<u>Length of access track that is excavated road (m)</u>	6330	6000	6500	Chapter 2: Description of the proposed development
Excavated road width (m)	5	5	10	Chapter 2: Description of the proposed development
Average depth of peat excavated for road (m)	0.1	0.1	0.1	na
<u>Length of access track that is rock filled road (m)</u>	0	0	0	na
Rock filled road width (m)	5	5	5	na
Rock filled road depth (m)	0	0	0	na
Length of rock filled road that is drained (m)	0	0	0	na
Average depth of drains associated with rock filled roads (m)	0	0	0	na
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	708	707	709	na
Average depth of peat cut for cable trenches (m)	0.1	0.1	0.1	na
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m ³)	0	0	0	na
Area of additional peat excavated (m ²)	0	0	0	na
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	negligible	negligible	Fixed

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Input Data - MEC 7.2 MW

<u>Improvement of C sequestration at site by blocking drains, restoration of habitat etc</u>				
<u>Improvement of degraded bog</u>				
Area of degraded bog to be improved (ha)	0	0	0	na
Water table depth in degraded bog before improvement (m)	0	0	0	na
Water table depth in degraded bog after improvement (m)	0	0	0	na
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	2	2	2	Chapter 2: Description of the proposed development
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	2	2	2	Chapter 2: Description of the proposed development
<u>Improvement of felled plantation land</u>				
Area of felled plantation to be improved (ha)	0	0	0	na
Water table depth in felled area before improvement (m)	0	0	0	na
Water table depth in felled area after improvement (m)	0	0	0	na
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2	2	2	Chapter 2: Description of the proposed development
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	2	2	2	Chapter 2: Description of the proposed development
<u>Restoration of peat removed from borrow pits</u>				
Area of borrow pits to be restored (ha)	0	0	0	na
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	na
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0	0	0	na
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	2	2	2	Chapter 2: Description of the proposed development
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	2	2	2	Chapter 2: Description of the proposed development
<u>Early removal of drainage from foundations and hardstanding</u>				
Water table depth around foundations and hardstanding before restoration (m)	0	0	0	na
Water table depth around foundations and hardstanding after restoration (m)	0	0	0	na
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0.1	0.1	0.1	na
<u>Restoration of site after decommissioning</u>				
<u>Will the hydrology of the site be restored on decommissioning?</u>	Yes	Yes	Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	n/a	n/a	n/a	na
Will you attempt to block all artificial ditches and facilitate rewetting?	n/a	n/a	n/a	na
<u>Will the habitat of the site be restored on decommissioning?</u>	Yes	Yes	Yes	
Will you control grazing on degraded areas?	n/a	n/a	n/a	na
Will you manage areas to favour reintroduction of species	n/a	n/a	n/a	na
<u>Methodology</u>				
Choice of methodology for calculating emission factors	IPCC default			

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Forestry input data

N/A

Construction input data

N/A

Carbon Calculations - MEC 7.2 MW

1. Windfarm CO₂ emission saving

Emissions due to turbine life

The carbon payback time of the windfarm due to turbine life (eg. 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.

Capacity factor calculated from forestry data

Area name	Value type	Capacity factor (%)	Wind speed ratio	Average site windspeed (m/s)	Annual theoretical energy output (MW / turbine yr)
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Capacity factor - Direct input

	Exp.	Min.	Max.
Capacity factor (%)	35.0	34.0	36.0

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	Exp.	Min.	Max.
Annual energy output from windfarm (MW/yr)			
RESULTS			
Emissions saving over coal-fired electricity ge...	104,305	101,325	107,285
Emissions saving over grid-mix of electricity g...	22,848	22,195	23,501
Emissions saving over fossil fuel - mix of elect...	46,799	45,462	48,137

Carbon Calculations - MEC 7.2 MW

2. CO₂ loss due to turbine life

Emissions due to turbine life

The carbon payback time of the windfarm due to turbine life (eg. 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.

Calculation of emissions with relation to installed capacity

	Exp.	Min.	Max.
Emissions due to turbine frome energy output (t CO ₂)	6260	6260	6260
Emissions due to cement used in construction (t CO ₂)	1504	1504	1505

Direct input of emissions due to turbine life

	Exp.	Min.	Max.
Emissions due to turbine life (tCO ₂ /windfarm)			

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RESULTS

	Exp.	Min.	Max.
Losses due to turbine life (manufacture, construction, etc.) (t CO ₂)	32803	32803	32804
Additional CO₂ payback time of windfarm due to turbine life			
...coal-fired electricity generation (months)	4	4	4
...grid-mix of electricity generation (months)	17	18	17
...fossil fuel - mix of electricity generation (months)	8	9	8

Carbon Calculations - MEC 7.2 MW

3. CO₂ loss due to backup

Emissions due to backup power generation

CO₂ loss due to back up is calculated from the extra capacity required for backup of the windfarm given in the input data.

Wind generated electricity is inherently variable, providing unique challenges to the electricity generating industry for provision of a supply to meet consumer demand (Netz, 2004). Backup power is required to accompany wind generation to stabilise the supply to the consumer. This backup power will usually be obtained from a fossil fuel source. At a high level of wind power penetration in the overall generating mix, and with current grid management techniques, the capacity for fossil fuel backup may become strained because it is being used to balance the fluctuating consumer demand with a variable and highly unpredictable output from wind turbines (White, 2007). The Carbon Trust (Carbon Trust/DTI, 2004) concluded that increasing levels of intermittent generation do not present major technical issues at the percentages of renewables expected by 2010 and 2020, but the UK renewables target at the time of that report was only 20%. When national reliance on wind power is low (less than ~20%), the additional fossil fuel generated power requirement can be considered to be insignificant and may be obtained from within the spare generating capacity of other power sectors (Dale et al. 2004). However, as the national supply from wind power increases above 20%, without improvements in grid management techniques, emissions due to backup power generation may become more significant. The extra capacity needed for backup power generation is currently estimated to be 5% of the rated capacity of the wind plant if wind power contributes more than 20% to the national grid (Dale et al 2004). Moving towards the SG target of 50% electricity generation from renewable sources, more short-term capacity may be required in terms of pumped-storage hydro-generated power, or a better mix of offshore and onshore wind generating capacity. Grid management techniques are anticipated to reduce this extra capacity, with improved demand side management, smart meters, grid reinforcement and other developments. However, given current grid management techniques, it is suggested that 5% extra capacity should be assumed for backup power generation if wind power contributes more than 20% to the national grid. At lower contributions, the extra capacity required for backup should be assumed to be zero. These assumptions should be revisited as technology improves.

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.

	Exp.	Min.	Max.
Reserve energy (MWh/yr)	15,768	15,768	15,768
Annual emissions due to backup from fossil fuel-mix of electricity generati...	669	669	669
RESULTS			
Total emissions due to backup from fossil fuel-mix of electricity generatio...	23,400	23,400	23,400

4. Loss of CO₂ fixing potential

Emissions due to loss of bog plants

Annual C fixation by the site is calculated by multiplying area of the windfarm by the annual C accumulation due to bog plant fixation.

	Exp.	Min.	Max.
Area where carbon accumulation by bog plants is lost (ha)	21.97	13.33	34.07
Total loss of carbon accumulation up to time of restoration (tCO ₂ eq./ha)	41	35	48
RESULTS			
Total loss of carbon fixation by plants at the site (t CO ₂)	906	469	1624
Additional CO ₂ payback time of windfarm due to loss of CO ₂ fixing potential			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	1
...fossil fuel - mix of electricity generation (months)	0	0	0

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Carbon Calculations - MEC 7.2 MW

5. Loss of soil CO₂ (a, b)

Emissions due to loss of soil organic carbon

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

5. Loss of soil CO ₂	Exp.	Min.	Max.
CO ₂ loss from removed peat (t CO ₂ equiv.)	-4562.02	-4017.58	-7830.95
CO ₂ loss from drained peat (t CO ₂ equiv.)	9606.09	4067.85	16449.33
RESULTS			
Total CO ₂ loss from peat (removed + drained) (t CO ₂ e...)	5044.07	50.28	8618.38
Additional CO ₂ payback time of windfarm due to loss ...			
...coal-fired electricity generation (months)	0.58	0.01	0.96
...grid-mix of electricity generation (months)	2.65	0.03	4.4
...fossil fuel - mix of electricity generation (months)	1.29	0.01	2.15

CO₂ loss from removed peats

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.

5b. CO ₂ loss from removed peat	Exp.	Min.	Max.
CO ₂ loss from removed peat (t CO ₂)	1166.27	926.55	2207.27
CO ₂ loss from undrained peat left in situ (t CO ₂)	5728.29	4944.12	10038.22
RESULTS			
CO ₂ loss attributable to peat removal only (t CO ₂)	-4562.02	-4017.58	-7830.95

Volume of Peat Removed

% 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 as additional peat excavated in the core input data entry.

5a. Volume of peat removed	Exp.	Min.	Max.
Peat removed from borrow pits			
Area of land lost in borrow pits (m ²)	0	0	0
Volume of peat removed from borrow pits (m ³)	0	0	0
Peat removed from turbine foundations			
Area of land lost in foundation (m ²)	3781.25	3753.8	3808.8
Volume of peat removed from foundation area (m ³)	378.13	375.38	380.88
Peat removed from hard-standing			
Area of land lost in hard-standing (m ²)	22400	22400	22400
Volume of peat removed from hard-standing area (m ³)	2240	2240	2240
Peat removed from access tracks			
Area of land lost in floating roads (m ²)	0	0	0
Volume of peat removed from floating roads (m ³)	0	0	0
Area of land lost in excavated roads (m ²)	31650	30000	65000
Volume of peat removed from excavated roads (m ³)	3165	3000	6500
Area of land lost in rock-filled roads (m ²)	0	0	0
Volume of peat removed from rock-filled roads (m ³)	0	0	0
Total area of land lost in access tracks (m ²)	31650	30000	65000
Total volume of peat removed due to access tracks (m ³)	3165	3000	6500
RESULTS			
Total area of land lost due to windfarm construction (m ²)	57831.25	56153.8	91208.8
Total volume of peat removed due to windfarm constructio...	5783.13	5615.38	9120.88

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5. Loss of soil CO₂ (c, d, e)

Volume of peat drained

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

5c. Volume of peat drained

	Exp.	Min.	Max.
Total area affected by drainage around borrow pits (m2)	0	0	0
Total volume affected by drainage around borrow pits (m3)	0	0	0
Peat affected by drainage around turbine foundation and hardst...			
Total area affected by drainage of foundation and hardstanding ...	21100	10040	33180
Total volume affected by drainage of foundation and hardstandi...	1055	502	1659
Peat affected by drainage of access tracks			
Total area affected by drainage of access track(m2)	126600	60000	195000
Total volume affected by drainage of access track(m3)	6330	3000	9750
Peat affected by drainage of cable trenches			
Total area affected by drainage of cable trenches(m2)	14160	7070	21270
Total volume affected by drainage of cable trneches(m3)	708	353.5	1063.5
Drainage around additional peat excavated			
Total area affected by drainage (m2)	0	0	0
Total volume affected by drainage (m3)	0	0	0
RESULTS			
Total area affected by drainage due to windfarm (m2)	161860	77110	249450
Total volume affected by drainage due to windfarm (m3)	8093	3855.5	12472.5

CO₂ loss due to drainage

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 derived directly from experimental data for acid bogs and fens (see Nayak et al, 2008 - Final report).

5d. CO₂ loss from drained peat

	Exp.	Min.	Max.
Calculations of C Loss from Drained Land if Site is NOT Restored after De...			
Total GHG emissions from Drained Land (t CO ₂ equiv.)	1632.1	636.16	3010.37
Total GHG emissions from Undrained Land (t CO ₂ equiv.)	1020.6	397.81	1887.41
Calculations of C Loss from Drained Land if Site IS Restored after Decomi...			
Losses if Land is Drained			
CH ₄ emissions from drained land (t CO ₂ equiv.)	0	0	0
CO ₂ emissions from drained land (t CO ₂)	25638.62	10857.09	43903.2
Total GHG emissions from Drained Land (t CO ₂ equiv.)	25638.62	10857.09	43903.2
Losses if Land is Undrained			
CH ₄ emissions from undrained land (t CO ₂ equiv.)	2264.94	959.13	3878.45
CO ₂ emissions from undrained land (t CO ₂)	13767.59	5830.11	23575.42
Total GHG emissions from Undrained Land (t CO ₂ equiv.)	16032.53	6789.23	27453.87
RESULTS			
Total GHG emissions due to drainage (t CO ₂ equiv.)	9606.09	4067.85	16449.33

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).

Carbon Calculations - MEC 7.2 MW

5e. Emission rates from soils

	Exp.	Min.	Max.
Calculations following IPCC default methodology			
Flooded period (days/year)	169	169	169
Annual rate of methane emission (t CH ₄ -C/ha year)	0.22	0.22	0.22
Annual rate of carbon dioxide emission (t CO ₂ /ha year)	35.2	35.2	35.2
Calculations following ECOSSE based methodology			
Total area affected by drainage due to wind farm construction (ha)	16.19	7.71	24.95
Average water table depth of drained land (m)	1	1	0.99
Selected emission characteristics following site specific methodology			
Rate of carbon dioxide emission in drained soil (t CO ₂ /ha year)	64.74	64.69	64.78
Rate of carbon dioxide emission in undrained soil (t CO ₂ /ha year)	64.74	64.69	64.78
Rate of methane emission in drained soil (t CH ₄ -C/ha year)	0	0	0
Rate of methane emission in undrained soil (t CH ₄ -C/ha year)	0	0	0
RESULTS			
Selected rate of carbon dioxide emission in drained soil (t CO ₂ /ha year)	35.2	35.2	35.2
Selected rate of carbon dioxide emission in undrained soil (t CO ₂ /ha year)	0	0	0
Selected rate of methane emission in drained soil (t CH ₄ -C/ha year)	0	0	0
Selected rate of methane emission in undrained soil (t CH ₄ -C/ha year)	0.22	0.22	0.22

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6. CO₂ loss by DOC & POC loss

Emissions due to loss of DOC and POC

Note, CO₂ losses from DOC and POC are calculated using a simple approach derived from generic estimates of the percentage of the total CO₂ loss that is due to DOC or POC leaching.

No POC losses for bare soil included yet. If extensive areas of bare soil is present at site need modified calculation (Birnie et al, 1991)

	Exp.	Min.	Max.
Gross CO ₂ loss from restored drained land (t CO ₂)	11871.03	5026.98	20327.78
Gross CH ₄ loss from restored drained land (t CO ₂ equiv.)	0.00	0.00	0.00
Gross CO ₂ loss from improved land (t CO ₂)	0.00	0.00	0.00
Gross CH ₄ loss from improved land (t CO ₂ equiv.)	0.00	0.00	0.00
Total gaseous loss of C (t C)	3237.23	1370.86	5543.39
Total C loss as DOC (t C)	841.68	95.96	2217.35
Total C loss as POC (t C)	258.98	54.83	554.34
RESULTS			
Total CO₂ loss due to DOC leaching (t CO₂)	3086.19	351.86	8130.37
Total CO₂ loss due to POC leaching (t CO₂)	949.60	201.06	2032.59
Total CO₂ loss due to DOC & POC leaching (t CO₂)	4035.78	552.92	10162.97
Additional CO₂ payback time of windfarm due to DOC & POC			
...coal-fired electricity generation (months)	0	0	1
...grid-mix of electricity generation (months)	2	0	5
...fossil fuel - mix of electricity generation (months)	1	0	3

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7. Forestry CO₂ loss

CO₂ loss from forests - calculation using detailed management information

Forest carbon calculator (Perks et al, 2009)

Total potential carbon sequestration loss due to felling of forestry for the wind ...
Total emissions due to cleared land (t CO ₂)
Emissions due to harvesting operations (t CO ₂)
Fossil fuel equivalent saving from use of felled forestry as biofuel (t CO ₂)
Fossil fuel equivalent saving from use of replanted forestry as biofuel (t CO ₂)
RESULTS
Total carbon loss associated with forest management(t CO ₂)

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Emissions due to forest felling - calculation using simple management data

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.

	Exp.	Min.	Max.
Area of forestry plantation to be felled (ha)	9.41	9.4	9.42
Carbon sequestered (t C ha-1 yr-1)	3.6	3.5	3.7
Lifetime of windfarm (years)	35	35	35
Carbon sequestered over the lifetime of the windfarm (t C ha-1)	126	122.5	129.5
RESULTS			
Total carbon loss due to felling of forestry (t CO ₂)	4347.46	4222.21	4472.97
Additional CO ₂ payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	0.5	0.5	0.5
...grid-mix of electricity generation (months)	2.28	2.28	2.28
...fossil fuel - mix of electricity generation (months)	1.11	1.11	1.12

Carbon Calculations - MEC 7.2 MW

8. CO₂ gain - site improvement

Gains due to site improvement

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).

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Degraded Bog			
	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...)	25.7	25.7	25.7

Felled Forestry			
	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...)	25.7	25.7	25.7

Borrow Pits			
	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0

Foundations & Hardstanding			
	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	34.9	34.9	34.9
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha-...)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	34.9	34.9	34.9
Selected annual rate of methane emissions (t CH ₄ -C ha-1 yr-1)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0

Carbon Calculations - MEC 7.2 MW

8. CO₂ gain - site improvement

Gains due to site improvement

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).

Degraded Bog			
	Exp.	Min.	Max.
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha ⁻¹ yr ⁻¹)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2
CO ₂ emissions from unimproved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO ₂ equiv.)	0	0	0

Borrow Pits			
	Exp.	Min.	Max.
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha ⁻¹ yr ⁻¹)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2
CO ₂ emissions from unimproved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO ₂ equiv.)	0	0	0

Felled Forestry			
	Exp.	Min.	Max.
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha ⁻¹ yr ⁻¹)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2
CO ₂ emissions from unimproved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO ₂ equiv.)	0	0	0

Foundations & Hardstanding			
	Exp.	Min.	Max.
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha ⁻¹ yr ⁻¹)	0	0	0
CO ₂ emissions from improved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	34.9	34.9	34.9
Selected annual rate of methane emissions (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0	0	0
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2
CO ₂ emissions from unimproved land (t CO ₂ equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO ₂ equiv.)	0	0	0

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