


# Cover

CARBON CALCULATOR TOOL v . . .

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 The Scottish Government  
Application Status Control  
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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>)

# Admin

CARBON CALCULATOR TOOL v . . . - APPLICATION STATUS CONTROL

Help

Reference Code:

Windfarm Name	Version	Methodology used for calculating emission factors	Status Date	Status
No data available in table				

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Selected:

# Start

CARBON CALCULATOR TOOL v . . .

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

# CoreInput

Core input data  
1. Windfarm characteristics 2. Peatland 3. Bog plants 4. Forestry Plantation 5. Emission factors 6. Borrow pits 7. Foundations and hard-standing 8. Access tracks 9. Cable trenches 10. Additional peat 11. Improvement actions 12. Restoration after decommissioning 13. Methodology & application details  
Forestry input data  
Construction input data

Signed off for submission

Note: Results are only available once ALL data are correct and complete, and a new version will be created.

Ref: **MPRJ-W5M3-2KPG** v

MENU

Windfarm characteristics Page 1 of 12

## Expected values

### Dimensions

Number of Turbines

Duration of consent (years)

### Performance

Power rating of 1 turbine (MW)

### Capacity factor

### Backup

Fraction of output to backup (%)

# Payback Time

Payback Time  
 Payback Time - ChartsInput Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

	Exp.	Min.	Max.
1. Windfarm CO2 emission saving over...			
...coal-fired electricity generation (t CO2 / yr)	86,020	83,562	104,277
...grid-mix of electricity generation (t CO2 / yr)	16,601	16,127	20,125
...fossil fuel-mix of electricity generation (t CO2 / yr)	37,086	36,027	44,958
Energy output from windfarm over lifetime (MWh)	3,004,680	2,918,832	3,642,408

	Exp.	Min.	Max.
Total CO2 losses due to wind farm (tCO2 eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decommissioning)	25,341	25,246	30,329
3. Losses due to backup	18,543	18,543	21,854
4. Losses due to reduced carbon fixing potential	731	498	1,003
5. Losses from soil organic matter	14,691	3,801	32,121
6. Losses due to DOC & POC leaching	2,216	416	4,875
7. Losses due to felling forestry	11,074	10,331	11,396
Total losses of carbon dioxide	72,597	58,834	101,578

	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	-5,709	0	-7,612
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	-5,709	0	-7,612

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	66,888	51,222	101,578

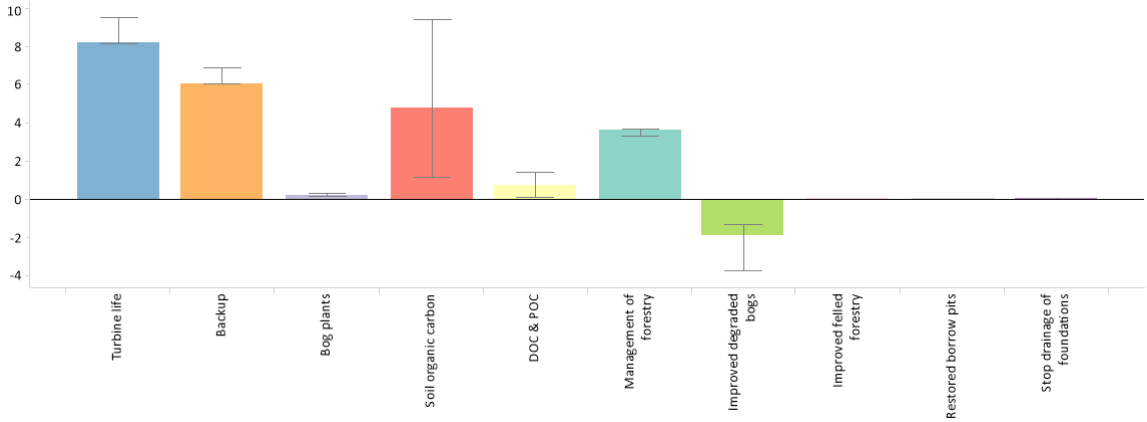
Carbon Payback Time			
...coal-fired electricity generation (years)	0.8	0.5	1.2
...grid-mix of electricity generation (years)	4.0	2.5	6.3
...fossil fuel-mix of electricity generation (years)	1.8	1.1	2.8

Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	2.96	0.55	No gains!
Ratio of CO2 eq. emissions to power generation (g/kWh) (for info. only)	22.26	14.06	34.80

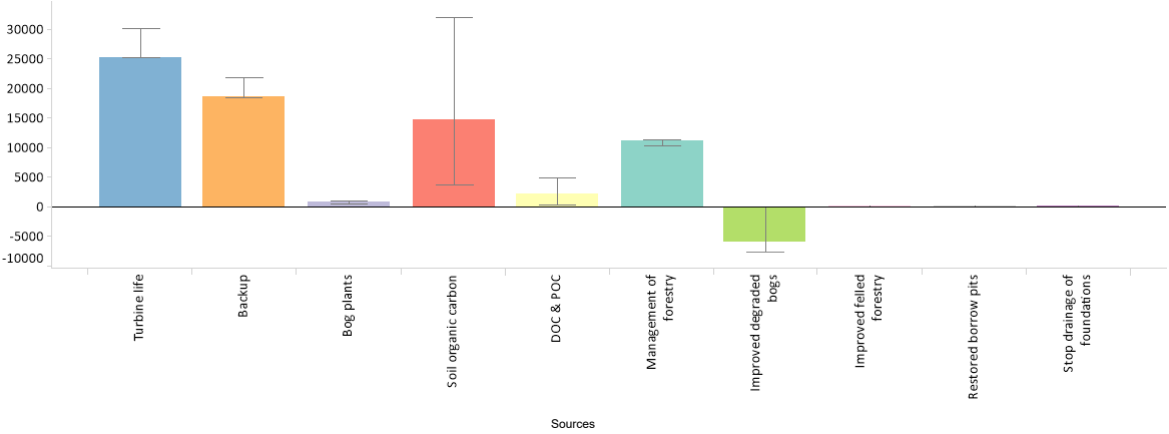
# Payback Time - Charts

Payback Time  
 Payback Time - Charts Input Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

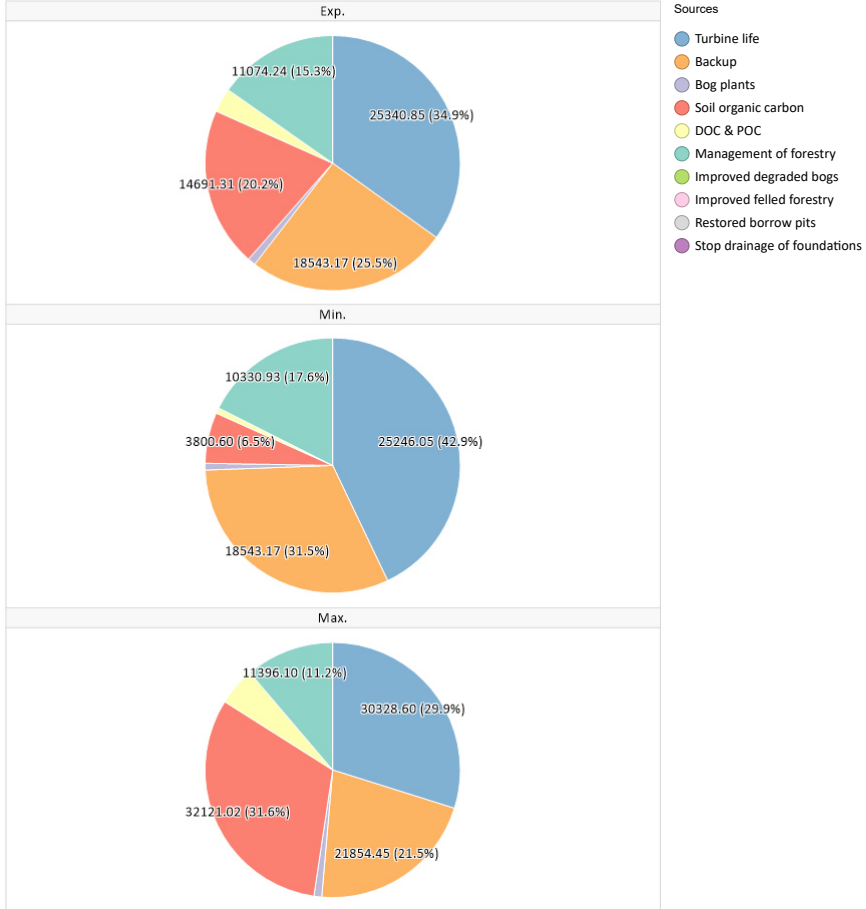
Carbon payback time (months) using fossil-fuel mix as counterfactual



Greenhouse gas emissions (t CO2 eq.)



Proportions of greenhouse gas emissions from different sources



# View

[Payback Time](#)  
[Payback Time - Charts](#)  
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Carbon Calculator v1.7.0

Inchamore Wind Farm Location: 51.949379 -9.269362

Inchamore Wind DAC

## Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
<b>Windfarm characteristics</b>				
<b>Dimensions</b>				
No. of turbines	5	5	5	Chapter 2 Project Description
Duration of consent (years)	35	35	35	Chapter 2 Project Description
<b>Performance</b>				
Power rating of 1 turbine (MW)	5.6	5.6	6.6	Chapter 2 Project Description
Capacity factor	35	34	36	Chapter 10 Air and Climate
<b>Backup</b>				
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 <sup>-1</sup> ) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity Calculate wrt installed capacity Calculate wrt installed capacity			
<b>Characteristics of peatland before windfarm development</b>				
<b>Type of peatland</b>				
Average annual air temperature at site (°C)	Acid bog	Acid bog	Acid bog	Chapter 5: Biodiversity
Average depth of peat at site (m)	9.975	9.7	10	Chapter 10 Air and Climate
C Content of dry peat (% by weight)	0.53	0	1.4	Chapter 8 Soils & Geology
Average extent of drainage around drainage features at site (m)	55	50	60	Default Value
Average water table depth at site (m)	7.5	5	10	Chapter 9 Hydrology and Hydrogeology
Dry soil bulk density (g cm <sup>-3</sup> )	0.5	0.1	1	Chapter 9 Hydrology & Hydrogeology
Characteristics of bog plants	0.1	0.09	0.11	Default Values
<b>Time required for regeneration of bog plants after restoration (years)</b>				
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha <sup>-1</sup> yr <sup>-1</sup> )	10	5	15	Best Practice from Bog Restoraton Ireland
Forestry plantation Characteristics	0.25	0.24	0.26	Default Values
<b>Forestry plantation Characteristics</b>				
Area of forestry plantation to be felled (ha)	<b>Expected value</b>	<b>Minimum value</b>	<b>Maximum value</b>	<b>Source of data</b>
Average rate of carbon sequestration in timber (tC ha <sup>-1</sup> yr <sup>-1</sup> )	23.97	23	24	Chapter 2 Project Description
Counterfactual emission factors	3.6	3.5	3.7	Cannell, 1999
<b>Coal-fired plant emission factor (t CO2 MWh<sup>-1</sup>)</b>				
Grid-mix emission factor (t CO2 MWh <sup>-1</sup> )	1.002	1.002	1.002	
Fossil fuel-mix emission factor (t CO2 MWh <sup>-1</sup> )	0.19338	0.19338	0.19338	
Borrow pits	0.432	0.432	0.432	
<b>Borrow pits</b>				
Number of borrow pits	1	1	1	Chapter 2: Project Description
Average length of pits (m)	414	413	415	Chapter 2: Project Description
Average width of pits (m)	93.41	92	93.41	Chapter 2: Project Description

## 5. Loss of soil CO2 (a, b)

Payback Time  
 Payback Time - ChartsInput Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

### 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 CO2

	Exp.	Min.	Max.
CO2 loss from removed peat (t CO2 equiv.)	8408.28	154.75	22723.5
CO2 loss from drained peat (t CO2 equiv.)	6283.03	3645.85	9397.52
<b>RESULTS</b>			
Total CO2 loss from peat (removed + drained) (t CO2 equiv.)	14691.31	3800.6	32121.02
<b>Additional CO2 payback time of windfarm due to loss of soil C...</b>			
...coal-fired electricity generation (months)	2.05	0.55	3.7
...grid-mix of electricity generation (months)	10.62	2.83	19.15
...fossil fuel - mix of electricity generation (months)	4.75	1.27	8.57

### CO<sub>2</sub> 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. CO2 loss from removed peat

	Exp.	Min.	Max.
CO2 loss from removed peat (t CO2)	16204.00	6598.90	31756.41
CO2 loss from undrained peat left in situ (t CO2)	7795.72	6444.16	9032.91
<b>RESULTS</b>			
CO2 loss attributable to peat removal only (t CO2)	8408.28	154.75	22723.50

### 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.
<b>Peat removed from borrow pits</b>			
Area of land lost in borrow pits (m2)	38671.74	37996	38765.15
Volume of peat removed from borrow pits (m3)	48339.68	18998	77530.3
<b>Peat removed from turbine foundations</b>			
Area of land lost in foundation (m2)	1890	1760	2167.5
Volume of peat removed from foundation area (m3)	567	176	1083.75
<b>Peat removed from hard-standing</b>			
Area of land lost in hard-standing (m2)	23700	18000	23750
Volume of peat removed from hard-standing area (m3)	14220	3600	33250
<b>Peat removed from access tracks</b>			
Area of land lost in floating roads (m2)	0	0	0
Volume of peat removed from floating roads (m3)	0	0	0
Area of land lost in excavated roads (m2)	17775	17770	21336
Volume of peat removed from excavated roads (m3)	10665	10662	12801.6
Area of land lost in rock-filled roads (m2)	0	0	0
Volume of peat removed from rock-filled roads (m3)	0	0	0
Total area of land lost in access tracks (m2)	17775	17770	21336
Total volume of peat removed due to access tracks (m3)	10665	10662	12801.6
<b>RESULTS</b>			
Total area of land lost due to windfarm construction (m2)	92966.74	86455	96948.65
Total volume of peat removed due to windfarm construction (m3)	80349.68	39993	131223.65

## 5. Loss of soil CO2 (c,d,e)

Payback Time  
 Payback Time - ChartsInput Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

### 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)	7836.15	5150	10568.2
Total volume affected by drainage around borrow pits (m3)	4897.59	1287.5	10568.2
Peat affected by drainage around turbine foundation and hardstanding			
Total area affected by drainage of foundation and hardstanding area (m2)	20167.5	12400	27750
Total volume affected by drainage of foundation and hardstanding area (m3)	6050.25	1240	19425
Peat affected by drainage of access tracks			
Total area affected by drainage of access track(m2)	53325	35540	71120
Total volume affected by drainage of access track(m3)	15997.5	10662	21336
Peat affected by drainage of cable trenches			
Total area affected by drainage of cable trenches(m2)	0	0	0
Total volume affected by drainage of cable trenches(m3)	0	0	0
Drainage around additional peat excavated			
Total area affected by drainage (m2)	2956.28	1931.5	4020.24
Total volume affected by drainage (m3)	1773.77	1158.72	2412.37
<b>RESULTS</b>			
Total area affected by drainage due to windfarm (m2)	84284.93	55021.5	113458.44
Total volume affected by drainage due to windfarm (m3)	28719.11	14348.22	53741.57

### 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.
<b>Calculations of C Loss from Drained Land if Site is NOT Restored after Decommissioning</b>			
Total GHG emissions from Drained Land (t CO2 equiv.)	5791.74	2367.48	13005.58
Total GHG emissions from Undrained Land (t CO2 equiv.)	3066.07	1253.31	6884.98
<b>Calculations of C Loss from Drained Land if Site IS Restored after Decommissioning</b>			
<b>Losses if Land is Drained</b>			
CH4 emissions from drained land (t CO2 equiv.)	0	0	0
CO2 emissions from drained land (t CO2)	13350.73	7747.03	19968.69
Total GHG emissions from Drained Land (t CO2 equiv.)	13350.73	7747.03	19968.69
<b>Losses if Land is Undrained</b>			
CH4 emissions from undrained land (t CO2 equiv.)	227.74	132.15	340.63
CO2 emissions from undrained land (t CO2)	6839.96	3969.02	10230.53
Total GHG emissions from Undrained Land (t CO2 equiv.)	7067.71	4101.18	10571.16
<b>RESULTS</b>			
Total GHG emissions due to drainage (t CO2 equiv.)	6283.03	3645.85	9397.52

### 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).

#### 5e. Emission rates from soils

	Exp.	Min.	Max.
<b>Calculations following IPCC default methodology</b>			
Flooded period (days/year)	178	178	178
Annual rate of methane emission (t CH4-C/ha year)	0.04	0.04	0.04
Annual rate of carbon dioxide emission (t CO2/ha year)	35.2	35.2	35.2
<b>Calculations following ECOSSE based methodology</b>			
Total area affected by drainage due to wind farm construction (ha)	8.43	5.5	11.35

## 7. Forestry CO2 loss

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### CO<sub>2</sub> 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 farm (t CO2)
Total emissions due to cleared land (t CO2)
Emissions due to harvesting operations (t CO2)
Fossil fuel equivalent saving from use of felled forestry as biofuel (t CO2)
Fossil fuel equivalent saving from use of replanted forestry as biofuel (t CO2)
<b>RESULTS</b>
Total carbon loss associated with forest management(t CO2)

### 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)	23.97	23	24
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
<b>RESULTS</b>			
Total carbon loss due to felling of forestry (t CO2)	11074.24	10330.93	11396.1
Additional CO2 payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	1.54	1.48	1.31
...grid-mix of electricity generation (months)	8	7.69	6.8
...fossil fuel - mix of electricity generation (months)	3.58	3.44	3.04

## 8. CO2 gain - site improvement

Payback Time  
 Payback Time - ChartsInput Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 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.
<b>1. Description of site</b>			
Area to be improved (ha)	11	0	11
Depth of peat above water table before improvement (m)	0.16	0	0.25
Depth of peat above water table after improvement (m)	0.1	0	0.05
<b>2. Losses with improvement</b>			
Improved period (years)	15	20	5
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.04	0.04	0.04
CH4 emissions from improved land (t CO2 equiv.)	99.075	0	132.1
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0	0	0
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 equiv.)	99.075	0	132.1
<b>3. Losses without improvement</b>			
Improved period (years)	15	20	5
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0	0	0
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	35.2	35.2	35.2
CO2 emissions from unimproved land (t CO2 equiv.)	5808	0	7744

#### Borrow Pits

	Exp.	Min.	Max.
<b>1. Description of site</b>			
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
<b>2. Losses with improvement</b>			
Improved period (years)	24	29	18
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.04	0.04	0.04
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0	0	0
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 equiv.)	0	0	0
<b>3. Losses without improvement</b>			
Improved period (years)	24	29	18
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0	0	0
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	35.2	35.2	35.2
CO2 emissions from unimproved land (t CO2 equiv.)	0	0	0

#### Felled Forestry

	Exp.	Min.	Max.
<b>1. Description of site</b>			
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
<b>2. Losses with improvement</b>			
Improved period (years)	15	25	0
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.04	0.04	0.04
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0	0	0
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 equiv.)	0	0	0
<b>3. Losses without improvement</b>			
Improved period (years)	15	25	0
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0	0	0
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	35.2	35.2	35.2
CO2 emissions from unimproved land (t CO2 equiv.)	0	0	0

#### Foundations & Hardstanding

	Exp.	Min.	Max.
<b>1. Description of site</b>			
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
<b>2. Losses with improvement</b>			
Improved period (years)	32.5	34.9	30
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.04	0.04	0.04
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0	0	0
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 equiv.)	0	0	0
<b>3. Losses without improvement</b>			
Improved period (years)	32.5	34.9	30
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0	0	0
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	35.2	35.2	35.2
CO2 emissions from unimproved land (t CO2 equiv.)	0	0	0

### 3. CO2 loss backup

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**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)	12,264	12,264	14,454
Annual emissions due to backup from fossil fuel-mix of electricity generation (tCO2/yr)	530	530	624
<b>RESULTS</b>			
Total emissions due to backup from fossil fuel-mix of electricity generation (tCO2)	18,543	18,543	21,854

# 1. CO2 emission saving

Payback Time  
 Payback Time - Charts  
 Input Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

## 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

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

	Exp.	Min.	Max.
Annual energy output from windfarm (MW/yr)			
<b>RESULTS</b>			
Emissions saving over coal-fired electricity generatio...	86,020	83,562	104,277
Emissions saving over grid-mix of electricity generati...	16,601	16,127	20,125
Emissions saving over fossil fuel - mix of electricity g...	37,086	36,027	44,958

## 2. CO2 loss turbine life

Payback Time

Payback Time - ChartsInput Data

1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

### 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 from energy output (t CO2)	4765	4765	5699
Emissions due to cement used in construction (t CO2)	1517	1422	1833

Direct input of emissions due to turbine life

	Exp.	Min.	Max.
Emissions due to turbine life (tCO2/windfarm)			

### RESULTS

	Exp.	Min.	Max.
Losses due to turbine life (manufacture, construction, etc.) (t CO2)	25341	25246	30329
Additional CO2 payback time of windfarm due to turbine life			
...coal-fired electricity generation (months)	4	4	3
...grid-mix of electricity generation (months)	18	19	18
...fossil fuel - mix of electricity generation (months)	8	8	8

## 4. Loss CO2 fixing pot.

Payback Time  
Payback Time - ChartsInput Data  
1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

### 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)	17.73	14.15	21.04
Total loss of carbon accumulation up to time of restoration (tCO2 eq./ha)	41	35	48
<b>RESULTS</b>			
Total loss of carbon fixation by plants at the site (t CO2)	731	498	1003
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	0

## 6. CO2 loss DOC & POC

Payback Time  
 Payback Time - ChartsInput Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

### 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 CO2 loss from restored drained land (t CO2)	6510.77	3778.00	9738.15
Gross CH4 loss from restored drained land (t CO2 equiv.)	0.00	0.00	0.00
Gross CO2 loss from improved land (t CO2)	0.00	0.00	0.00
Gross CH4 loss from improved land (t CO2 equiv.)	99.07	0.00	132.10
Total gaseous loss of C (t C)	1777.91	1030.26	2658.83
Total C loss as DOC (t C)	462.26	72.12	1063.53
Total C loss as POC (t C)	142.23	41.21	265.88
<b>RESULTS</b>			
Total CO2 loss due to DOC leaching (t CO2)	1694.96	264.44	3899.65
Total CO2 loss due to POC leaching (t CO2)	521.52	151.11	974.91
Total CO2 loss due to DOC & POC leaching (t CO2)	2216.48	415.54	4874.56
<b>Additional CO2 payback time of windfarm due to DOC &amp; POC</b>			
...coal-fired electricity generation (months)	0	0	1
...grid-mix of electricity generation (months)	2	0	3
...fossil fuel - mix of electricity generation (months)	1	0	1

# Cover

CARBON CALCULATOR TOOL v . . .

[Help](#) [About...](#)

Scottish Government and SEPA users only:

 The Scottish Government  
Application Status Control  
Enter password  
[Sign in](#)  
[Start Carbon Calculator](#)

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>)

# Admin

CARBON CALCULATOR TOOL v . . . - APPLICATION STATUS CONTROL

Help

Reference Code:

Windfarm Name	Version	Methodology used for calculating emission factors	Status Date	Status
No data available in table				

[Previous](#)[Next](#)

Selected:

# Start

CARBON CALCULATOR TOOL v . . .

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

Search

New application

# CoreInput

Core input data  
1. Windfarm characteristics 2. Peatland 3. Bog plants 4. Forestry Plantation 5. Emission factors 6. Borrow pits 7. Foundations and hard-standing 8. Access tracks 9. Cable trenches 10. Additional peat 11. Improvement actions 12. Restoration after decommissioning 13. Methodology & application details  
Forestry input data  
Construction input data

Signed off for submission

Note: Results are only available once ALL data are correct and complete, and a new version will be created.

Ref: **MPRJ-W5M3-2KPG** v

MENU

Windfarm characteristics Page 1 of 12

Expected values	Minimum	Maximum
<b>Dimensions</b>		
Number of Turbines <input type="text" value="5"/>		
<input type="text" value="Chapter 2 Project Description"/>	<input type="text" value="5"/>	<input type="text" value="5"/>
Duration of consent (years) <input type="text" value="35"/>		
<input type="text" value="Chapter 2 Project Description"/>	<input type="text" value="35"/>	<input type="text" value="35"/>
<b>Performance</b>		
Power rating of 1 turbine (MW) <input type="text" value="6.6"/>		
<input type="text" value="Chapter 2 Project Description"/>	<input type="text" value="5.6"/>	<input type="text" value="6.6"/>
<b>Capacity factor</b>		
<input type="text" value="35"/> <input type="button" value="Direct input (% estimated capacity factor) v"/>	<input type="text" value="34"/> <input type="button" value="Direct input (% estimated capacity factor) v"/>	<input type="text" value="36"/> <input type="button" value="Direct input (% estimated capacity factor) v"/>
<input type="text" value="Chapter 10 Air and Climate"/>		
<b>Backup</b>		
Fraction of output to backup (%) <input type="text" value="5"/>		

# Payback Time

Payback Time

Payback Time - ChartsInput Data

1. Windfarm CO2 emission saving over... 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 6. Loss of soil CO2 (c,d,e) 7. CO2 loss by DOC & POC loss 8. Foresty CO2 loss 9. CO2 gain - site improvement

1. Windfarm CO2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	101,380	83,562	104,277
...grid-mix of electricity generation (t CO2 / yr)	19,566	16,127	20,125
...fossil fuel-mix of electricity generation (t CO2 / yr)	43,709	36,027	44,958
Energy output from windfarm over lifetime (MWh)	3,541,230	2,918,832	3,642,408

Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (eg. manufacture, construction, decommissioning)	30,013	25,246	30,329
3. Losses due to backup	21,854	18,543	21,854
4. Losses due to reduced carbon fixing potential	731	498	1,003
5. Losses from soil organic matter	14,691	3,801	32,121
6. Losses due to DOC & POC leaching	2,216	416	4,875
7. Losses due to felling forestry	11,074	10,331	11,396
Total losses of carbon dioxide	80,580	58,834	101,578

8. Total CO2 gains due to improvement of site (t CO2 eq.)	Exp.	Min.	Max.
8a. Change in emissions due to improvement of degraded bogs	-5,709	0	-7,612
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	-5,709	0	-7,612

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	74,871	51,222	101,578

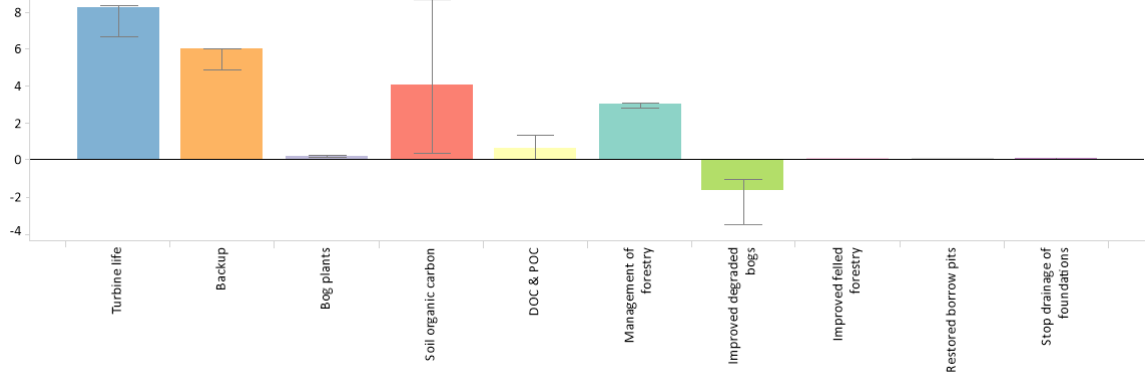
Carbon Payback Time	Exp.	Min.	Max.
...coal-fired electricity generation (years)	0.7	0.5	1.2
...grid-mix of electricity generation (years)	3.8	2.5	6.3
...fossil fuel-mix of electricity generation (years)	1.7	1.1	2.8

Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	2.96	0.55	No gains!
Ratio of CO2 eq. emissions to power generation (g/kWh) (for info. only)	21.14	14.06	34.80

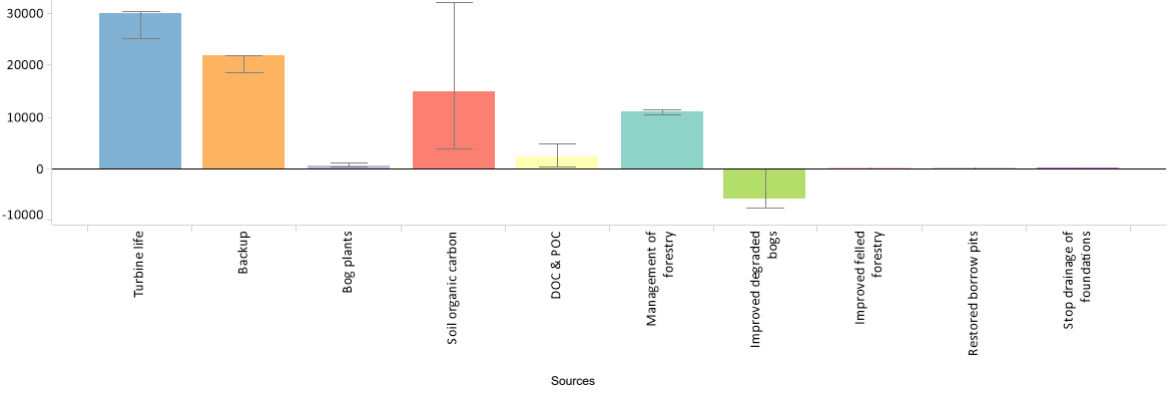
# Payback Time - Charts

Payback Time  
 Payback Time - ChartsInput Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a.b) 6. Loss of soil CO2 (c.d) 7. CO2 loss by DOC & POC loss 8. Forestry CO2 loss 9. CO2 sink - soils improvement

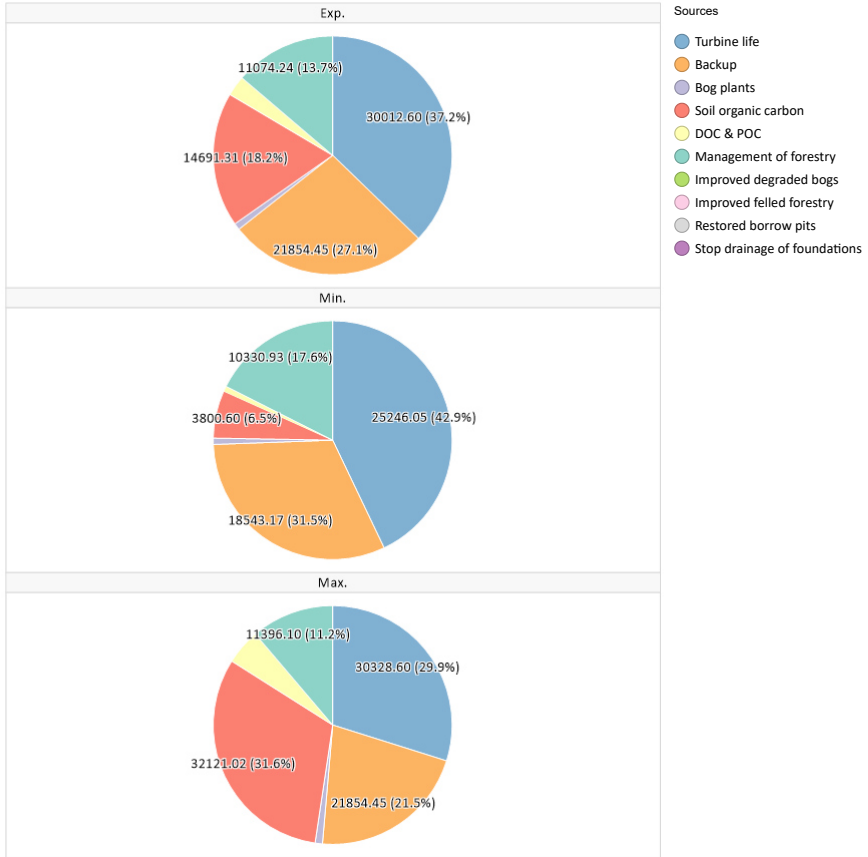
Carbon payback time (months) using fossil-fuel mix as counterfactual



Greenhouse gas emissions (t CO2 eq.)



Proportions of greenhouse gas emissions from different sources



# View

[Payback Time](#)  
[Payback Time - Charts](#)  
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[1. Windfarm CO2 emission saving](#) [2. CO2 loss due to turbine life](#) [3. CO2 loss due to backup](#) [4. Loss of CO2 fixing potential](#) [5. Loss of soil CO2 \(a.b\)](#) [6. Loss of soil CO2 \(c.d\)](#) [7. CO2 loss by DOC & DOC loss](#) [8. Foresty CO2 loss](#) [9. CO2 soil - site improvement](#)

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Carbon Calculator v1.7.0

Inchamore Wind Farm Location: 51.949379 -9.269362

Inchamore Wind DAC

## Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
<b>Windfarm characteristics</b>				
<b>Dimensions</b>				
No. of turbines	5	5	5	Chapter 2 Project Description
Duration of consent (years)	35	35	35	Chapter 2 Project Description
<b>Performance</b>				
Power rating of 1 turbine (MW)	6.6	5.6	6.6	Chapter 2 Project Description
Capacity factor	35	34	36	Chapter 10 Air and Climate
<b>Backup</b>				
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 <sup>-1</sup> ) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity Calculate wrt installed capacity Calculate wrt installed capacity			
<b>Characteristics of peatland before windfarm development</b>				
<b>Type of peatland</b>				
Average annual air temperature at site (°C)	9.975	9.7	10	Chapter 10 Air and Climate
Average depth of peat at site (m)	0.53	0	1.4	Chapter 8 Soils & Geology
C Content of dry peat (% by weight)	55	50	60	Default Value
Average extent of drainage around drainage features at site (m)	7.5	5	10	Chapter 9 Hydrology and Hydrogeology
Average water table depth at site (m)	0.5	0.1	1	Chapter 9 Hydrology & Hydrogeology
Dry soil bulk density (g cm <sup>-3</sup> )	0.1	0.09	0.11	Default Values
<b>Characteristics of bog plants</b>				
Time required for regeneration of bog plants after restoration (years)	10	5	15	Best Practice from Bog Restoraton Ireland
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha <sup>-1</sup> yr <sup>-1</sup> )	0.25	0.24	0.26	Default Values
<b>Forestry Plantation Characteristics</b>				
<b>Input data</b>				
Area of forestry plantation to be felled (ha)	23.97	23	24	Chapter 2 Project Description
Average rate of carbon sequestration in timber (tC ha <sup>-1</sup> yr <sup>-1</sup> )	3.6	3.5	3.7	Cannell, 1999
<b>Counterfactual emission factors</b>				
Coal-fired plant emission factor (t CO2 MWh <sup>-1</sup> )	1.002	1.002	1.002	
Grid-mix emission factor (t CO2 MWh <sup>-1</sup> )	0.19338	0.19338	0.19338	
Fossil fuel-mix emission factor (t CO2 MWh <sup>-1</sup> )	0.432	0.432	0.432	
<b>Borrow pits</b>				
Number of borrow pits	4	4	4	Chapter 2 Project Description

## 5. Loss of soil CO2 (a, b)

Payback Time  
 Payback Time - ChartsInput Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

### 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 CO2

	Exp.	Min.	Max.
CO2 loss from removed peat (t CO2 equiv.)	8408.28	154.75	22723.5
CO2 loss from drained peat (t CO2 equiv.)	6283.03	3645.85	9397.52
<b>RESULTS</b>			
<b>Total CO2 loss from peat (removed + drained) (t CO2 equiv.)</b>	<b>14691.31</b>	<b>3800.6</b>	<b>32121.02</b>
Additional CO2 payback time of windfarm due to loss of soil C...			
...coal-fired electricity generation (months)	1.74	0.55	3.7
...grid-mix of electricity generation (months)	9.01	2.83	19.15
...fossil fuel - mix of electricity generation (months)	4.03	1.27	8.57

### CO<sub>2</sub> 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. CO2 loss from removed peat

	Exp.	Min.	Max.
CO2 loss from removed peat (t CO2)	16204.00	6598.90	31756.41
CO2 loss from undrained peat left in situ (t CO2)	7795.72	6444.16	9032.91
<b>RESULTS</b>			
<b>CO2 loss attributable to peat removal only (t CO2)</b>	<b>8408.28</b>	<b>154.75</b>	<b>22723.50</b>

### 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.
<b>Peat removed from borrow pits</b>			
Area of land lost in borrow pits (m2)	38671.74	37996	38765.15
Volume of peat removed from borrow pits (m3)	48339.68	18998	77530.3
<b>Peat removed from turbine foundations</b>			
Area of land lost in foundation (m2)	1890	1760	2167.5
Volume of peat removed from foundation area (m3)	567	176	1083.75
<b>Peat removed from hard-standing</b>			
Area of land lost in hard-standing (m2)	23700	18000	23750
Volume of peat removed from hard-standing area (m3)	14220	3600	33250
<b>Peat removed from access tracks</b>			
Area of land lost in floating roads (m2)	0	0	0
Volume of peat removed from floating roads (m3)	0	0	0
Area of land lost in excavated roads (m2)	17775	17770	21336
Volume of peat removed from excavated roads (m3)	10665	10662	12801.6
Area of land lost in rock-filled roads (m2)	0	0	0
Volume of peat removed from rock-filled roads (m3)	0	0	0
Total area of land lost in access tracks (m2)	17775	17770	21336
Total volume of peat removed due to access tracks (m3)	10665	10662	12801.6
<b>RESULTS</b>			
<b>Total area of land lost due to windfarm construction (m2)</b>	<b>92966.74</b>	<b>86455</b>	<b>96948.65</b>
<b>Total volume of peat removed due to windfarm construction (m3)</b>	<b>80349.68</b>	<b>39993</b>	<b>131223.65</b>

## 5. Loss of soil CO<sub>2</sub> (c,d,e)

Payback Time  
 Payback Time - ChartsInput Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

### 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)	7836.15	5150	10568.2
Total volume affected by drainage around borrow pits (m3)	4897.59	1287.5	10568.2
Peat affected by drainage around turbine foundation and hardstanding			
Total area affected by drainage of foundation and hardstanding area (m2)	20167.5	12400	27750
Total volume affected by drainage of foundation and hardstanding area (m3)	6050.25	1240	19425
Peat affected by drainage of access tracks			
Total area affected by drainage of access track(m2)	53325	35540	71120
Total volume affected by drainage of access track(m3)	15997.5	10662	21336
Peat affected by drainage of cable trenches			
Total area affected by drainage of cable trenches(m2)	0	0	0
Total volume affected by drainage of cable trenches(m3)	0	0	0
Drainage around additional peat excavated			
Total area affected by drainage (m2)	2956.28	1931.5	4020.24
Total volume affected by drainage (m3)	1773.77	1158.72	2412.37
<b>RESULTS</b>			
Total area affected by drainage due to windfarm (m2)	84284.93	55021.5	113458.44
Total volume affected by drainage due to windfarm (m3)	28719.11	14348.22	53741.57

### Emission rates from soils

Note, CO<sub>2</sub> 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).

#### 5e. Emission rates from soils

	Exp.	Min.	Max.
Calculations following IPCC default methodology			
Flooded period (days/year)	178	178	178
Annual rate of methane emission (t CH <sub>4</sub> -C/ha year)	0.04	0.04	0.04
Annual rate of carbon dioxide emission (t CO <sub>2</sub> /ha year)	35.2	35.2	35.2
Calculations following ECOSSE based methodology			

### CO<sub>2</sub> loss due to drainage

Note, CO<sub>2</sub> 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. CO<sub>2</sub> loss from drained peat

	Exp.	Min.	Max.
Calculations of C Loss from Drained Land if Site is NOT Restored after Decommissioning			
Total GHG emissions from Drained Land (t CO <sub>2</sub> equiv.)	5791.74	2367.48	13005.58
Total GHG emissions from Undrained Land (t CO <sub>2</sub> equiv.)	3066.07	1253.31	6884.98
Calculations of C Loss from Drained Land if Site IS Restored after Decommissioning			
Losses if Land is Drained			
CH <sub>4</sub> emissions from drained land (t CO <sub>2</sub> equiv.)	0	0	0
CO <sub>2</sub> emissions from drained land (t CO <sub>2</sub> )	13350.73	7747.03	19968.69
Total GHG emissions from Drained Land (t CO <sub>2</sub> equiv.)	13350.73	7747.03	19968.69
Losses if Land is Undrained			
CH <sub>4</sub> emissions from undrained land (t CO <sub>2</sub> equiv.)	227.74	132.15	340.63
CO <sub>2</sub> emissions from undrained land (t CO <sub>2</sub> )	6839.96	3969.02	10230.53
Total GHG emissions from Undrained Land (t CO <sub>2</sub> equiv.)	7067.71	4101.18	10571.16
<b>RESULTS</b>			
Total GHG emissions due to drainage (t CO <sub>2</sub> equiv.)	6283.03	3645.85	9397.52

## 7. Forestry CO2 loss

[Payback Time](#)  
[Payback Time - Charts](#)  
[Input Data](#)  
[1. Windfarm CO2 emission saving](#) [2. CO2 loss due to turbine life](#) [3. CO2 loss due to backup](#) [4. Loss of CO2 fixing potential](#) [5. Loss of soil CO2 \(a,b\)](#) [5. Loss of soil CO2 \(c,d,e\)](#) [6. CO2 loss by DOC & POC loss](#) [7. Forestry CO2 loss](#) [8. CO2 gain - site improvement](#)

### CO<sub>2</sub> 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 farm (t CO2)
Total emissions due to cleared land (t CO2)
Emissions due to harvesting operations (t CO2)
Fossil fuel equivalent saving from use of felled forestry as biofuel (t CO2)
Fossil fuel equivalent saving from use of replanted forestry as biofuel (t CO2)
<b>RESULTS</b>
Total carbon loss associated with forest management(t CO2)

### 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)	23.97	23	24
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
<b>RESULTS</b>			
Total carbon loss due to felling of forestry (t CO2)	11074.24	10330.93	11396.1
Additional CO2 payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	1.31	1.48	1.31
...grid-mix of electricity generation (months)	6.79	7.69	6.8
...fossil fuel - mix of electricity generation (months)	3.04	3.44	3.04

## 8. CO2 gain - site improvement

Payback Time  
 Payback Time - ChartsInput Data  
 1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 6. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 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.
<b>1. Description of site</b>			
Area to be improved (ha)	11	0	11
Depth of peat above water table before improvement (m)	0.16	0	0.25
Depth of peat above water table after improvement (m)	0.1	0	0.05
<b>2. Losses with improvement</b>			
Improved period (years)	15	20	5
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.04	0.04	0.04
CH4 emissions from improved land (t CO2 equiv.)	99.075	0	132.1
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0	0	0
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 eqiv.)	99.075	0	132.1
<b>3. Losses without improvement</b>			
Improved period (years)	15	20	5
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0	0	0
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	35.2	35.2	35.2

#### Borrow Pits

	Exp.	Min.	Max.
<b>1. Description of site</b>			
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
<b>2. Losses with improvement</b>			
Improved period (years)	24	29	18
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.04	0.04	0.04
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0	0	0
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 eqiv.)	0	0	0
<b>3. Losses without improvement</b>			
Improved period (years)	24	29	18
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0	0	0
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	35.2	35.2	35.2

#### Felled Forestry

	Exp.	Min.	Max.
<b>1. Description of site</b>			
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
<b>2. Losses with improvement</b>			
Improved period (years)	15	25	0
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.04	0.04	0.04
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0	0	0
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 eqiv.)	0	0	0
<b>3. Losses without improvement</b>			
Improved period (years)	15	25	0
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0	0	0
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	35.2	35.2	35.2

#### Foundations & Hardstanding

	Exp.	Min.	Max.
<b>1. Description of site</b>			
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
<b>2. Losses with improvement</b>			
Improved period (years)	32.5	34.9	30
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.04	0.04	0.04
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0	0	0
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 eqiv.)	0	0	0
<b>3. Losses without improvement</b>			
Improved period (years)	32.5	34.9	30
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0	0	0
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	35.2	35.2	35.2

### 3. CO2 loss backup

[Payback Time](#)  
[Payback Time - ChartsInput Data](#)  
[1. Windfarm CO2 emission saving](#) [2. CO2 loss due to turbine life](#) [3. CO2 loss due to backup](#) [4. Loss of CO2 fixing potential](#) [5. Loss of soil CO2 \(a.b\)](#) [5. Loss of soil CO2 \(c.d.e\)](#) [6. CO2 loss by DOC & POC loss](#) [7. Forestry CO2 loss](#) [8. CO2 gain - site improvement](#)

**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)	14,454	12,264	14,454
Annual emissions due to backup from fossil fuel-mix of electricity generation (tCO2/yr)	624	530	624
<b>RESULTS</b>			
Total emissions due to backup from fossil fuel-mix of electricity generation (tCO2)	21,854	18,543	21,854

# 1. CO2 emission saving

[Payback Time](#)  
[Payback Time - ChartsInput Data](#)  
[1\\_Windfarm CO2 emission saving](#)
[2\\_CO2 loss due to turbine life](#)
[3\\_CO2 loss due to backup](#)
[4\\_Loss of CO2 fixing potential](#)
[5\\_Loss of soil CO2 \(a,b\)](#)
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## 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

	Exp.	Min.	Max.
Annual energy output from windfarm (MW/yr)			
<b>RESULTS</b>			
Emissions saving over coal-fired electricity generatio...	101,380	83,562	104,277
Emissions saving over grid-mix of electricity generati...	19,566	16,127	20,125
Emissions saving over fossil fuel - mix of electricity g...	43,709	36,027	44,958

## 2. CO2 loss turbine life

[Payback Time](#)  
[Payback Time - Charts](#)
[Input Data](#)  
[1. Windfarm CO2 emission saving](#)
[2. CO2 loss due to turbine life](#)
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### 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 from energy output (t CO2)	5699	4765	5699
Emissions due to cement used in construction (t CO2)	1517	1422	1833

Direct input of emissions due to turbine life

	Exp.	Min.	Max.
Emissions due to turbine life (tCO2/windfarm)			

### RESULTS

	Exp.	Min.	Max.
Losses due to turbine life (manufacture, construction, etc.) (t CO2)	30013	25246	30329
<b>Additional CO2 payback time of windfarm due to turbine life</b>			
...coal-fired electricity generation (months)	4	4	3
...grid-mix of electricity generation (months)	18	19	18
...fossil fuel - mix of electricity generation (months)	8	8	8

## 4. Loss CO2 fixing pot.

Payback Time  
Payback Time - ChartsInput Data  
1. Windfarm CO2 emission saving 2. CO2 loss due to turbine life 3. CO2 loss due to backup 4. Loss of CO2 fixing potential 5. Loss of soil CO2 (a,b) 5. Loss of soil CO2 (c,d,e) 6. CO2 loss by DOC & POC loss 7. Forestry CO2 loss 8. CO2 gain - site improvement

### 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)	17.73	14.15	21.04
Total loss of carbon accumulation up to time of restoration (tCO2 eq./ha)	41	35	48
<b>RESULTS</b>			
Total loss of carbon fixation by plants at the site (t CO2)	731	498	1003
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)	0	0	1
...fossil fuel - mix of electricity generation (months)	0	0	0

## 6. CO2 loss DOC & POC

[Payback Time](#)  
[Payback Time - ChartsInput Data](#)  
[1. Windfarm CO2 emission saving](#) [2. CO2 loss due to turbine life](#) [3. CO2 loss due to backup](#) [4. Loss of CO2 fixing potential](#) [5. Loss of soil CO2 \(a,b\)](#) [5. Loss of soil CO2 \(c,d,e\)](#) [6. CO2 loss by DOC & POC loss](#) [7. Forestry CO2 loss](#) [8. CO2 gain - site improvement](#)

### 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 CO2 loss from restored drained land (t CO2)	6510.77	3778.00	9738.15
Gross CH4 loss from restored drained land (t CO2 equiv.)	0.00	0.00	0.00
Gross CO2 loss from improved land (t CO2)	0.00	0.00	0.00
Gross CH4 loss from improved land (t CO2 equiv.)	99.07	0.00	132.10
Total gaseous loss of C (t C)	1777.91	1030.26	2658.83
Total C loss as DOC (t C)	462.26	72.12	1063.53
Total C loss as POC (t C)	142.23	41.21	265.88
<b>RESULTS</b>			
Total CO2 loss due to DOC leaching (t CO2)	1694.96	264.44	3899.65
Total CO2 loss due to POC leaching (t CO2)	521.52	151.11	974.91
Total CO2 loss due to DOC & POC leaching (t CO2)	2216.48	415.54	4874.56
<b>Additional CO2 payback time of windfarm due to DOC &amp; POC</b>			
...coal-fired electricity generation (months)	0	0	1
...grid-mix of electricity generation (months)	1	0	3
...fossil fuel - mix of electricity generation (months)	1	0	1