

Ballyfeeny Green Energy Project



Environmental Impact Assessment Report Volume III

Appendix 9.1 – Scottish Government – Carbon Calculation Input and output September 2025

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Scottish Government Windfarm Carbon Assessment Tool - Version 2.14.1

27/01/2023

This spreadsheet calculates payback time for windfarm sited on peatlands using methods given in Nayak et al, 2008 (<http://www.scotland.gov.uk/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://www.mires-and-peat.net/map04/map_04_09.htm))

Version 2.0.0 - Adapted to include detail of forestry management, Smith et al., 2011. <http://www.scotland.gov.uk/WindFarmsAndCarbon>

Version 2.14.0 - Corrections to calculation of peat removed for hardstanding plus corrections to emission factors and changes as detailed in previous worksheets

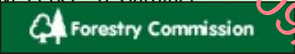
Revised by J.U.Smith to correct forestry and restoration sheets

Version 2.14.1 - Equivalent to version 2.14.0 but with worksheets unprotected for your own use. Do not use this version in planning applications.

INSTRUCTIONS

- A** There are 6 worksheets giving instructions, data entry and outputs, ...
- Instructions
 - Do I need to use this tool? Click here to find out [Click here](#)
 - Core input data Data needed in all calculations [Click here](#)
 - Forestry input data Extra details sometimes needed for forestry calculations
 - Construction input data Extra details sometimes needed for construction calculations
 - Payback time and CO₂ emissions [Click here](#)
 - ...and 8 numbered worksheets showing calculations:
 - 1. Windfarm CO₂ emission saving
 - 2. CO₂ loss due to turbine life
 - 3. CO₂ loss due to backup
 - 4. Loss of CO₂ Fixing Pot.
 - 5. Loss of soil CO₂
 - 5a. Volume of peat removed
 - 5b. CO₂ loss from removed peat
 - 5c. Volume of peat drained
 - 5d. CO₂ loss from drained peat
 - 5e. Emission rates
 - 6. CO₂ loss by DOC & POC loss
 - 7i. Forestry CO₂ loss - simple
 - 7ii. Forestry CO₂ loss - detailed
 - 7a. C sequest. in trees (3PG)
 - 7b. C seq. in soil under trees
 - 7c. Average stand data
 - 7d. Windspeed ratios
 - 8. CO₂ gain - site improvement
- In addition, there are spreadsheets containing references and requesting feedback.
- References
 - Frequently asked questions
- Notes on calculations are given in pale green text boxes.... [Click here to see example of Notes Box](#)
- Protocols for measurements are given in pale yellow comment boxes..... [Click here to see example of Protocol Box](#)
- Assumptions are given in pale blue text boxes.... [Click here to see example of Assumptions Box](#)

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Note on official version number

Version X.Y.Z

X refers to the release number
Y refers to released updates on release X
Z refers to unreleased updates on release X.Y

Officially released versions will always have Z=0

If you make changes of your own, please do not refer to your modified spreadsheet using the official version number.

The latest version is published at www.scotland.gov.uk/WindFarmsAndCarbon

Please check you are using the latest official version with Z=0 before submitting a planning application.

Do I need to use this tool?

1. Will the site be drained on construction of the windfarm?

No

2. Is the soil at the site highly organic?
i.e. is the soil organo-mineral or organic, (i.e. a peaty gley or peat)?

No

3. Does windfarm construction require a significant amount of deforestation?
i.e. is removal in excess of keyholing the turbines within the forest boundary?

Yes

You could use this tool to account for losses on deforestation.
To do this, move to the Core input data sheet and complete the pink cells in the form to obtain an estimate of C payback time

Click here to return to Instructions sheet

Click here

Click here to move on to Core input data sheet

Click here

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Core input data

ENTER INPUT DATA HERE! VALUES SHOULD ONLY BE CHANGED ON THIS SHEET. **DO NOT USE EXAMPLE VALUES AS DEFAULTS!** ENTER YOUR OWN VALUES THAT ARE SPECIFIC TO YOUR PARTICULAR SITE.

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

Click here to move to Payback Time [Click here](#)

Click here to return to Instructions [Click here](#)

Input data	Expected values	Record source of data	Possible range of values			Record source of data
	Enter expected value here		Enter minimum value here	Enter maximum value here		
Windfarm characteristics						
Dimensions						
No. of turbines	6	Fixed	6	6		
Lifetime of windfarm (years)	35		35	35		
Performance						
Power rating of turbines (turbine capacity) (MW)	4.26		4.5	4.8		
Capacity factor	Direct input of capacity fac ▼		Direct input of capacity fac ▼	Direct input of capacity fac ▼		
Enter estimated capacity factor (percentage efficiency)	29.2		29.2	29.2		
Backup						
Extra capacity required for backup (%)	5		5	5		
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10		10	10		
Carbon dioxide emissions from turbine life - (eq. manufacture, construction, decommissioning)	Direct input of total emis ▼		Direct input of total emis ▼	Direct input of total emis ▼		
Total CO2 emission from turbine life (tCO2 MW-1) (if known use direct input of emissions from turbine life)	3876		394	8147		
Characteristics of peatland before windfarm development						
Type of peatland	Fen ▼		Fen ▼	Fen ▼		
Average annual air temperature at site (°C)	10		4.3	14.3		
Average depth of peat at site (m)	0.00		0.00	0.00		
C Content of dry peat (%) by weight	0		0	0		
Average extent of drainage around drainage features at site (m)	1.00		1.00	1.00		
Average water table depth at site (m)	20.00		15.00	25.00		
Dry soil bulk density (g cm ⁻³)	0.00		0.00	0.00		
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	10		5	15		
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha ⁻¹ yr ⁻¹)	0.25		0.12	0.34		
Forestry Plantation Characteristics						
Method used to calculate CO ₂ loss from forest felling	Enter simple data ▼		Enter simple data ▼	Enter simple data ▼		
Area of forestry plantation to be felled (ha)	7.3		7.2	11.56		
Average rate of carbon sequestration in timber (tC ha ⁻¹ yr ⁻¹)	3.60		3.50	3.70		
Counterfactual emission factors						
To update counterfactual emission factors from the web Click here (not yet operational)						
Coal-fired plant emission factor (t CO ₂ MWh ⁻¹)	0.093		0.093	0.093		
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.229		0.229	0.229		
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.642		0.642	0.642		
Borrow pits						
Number of borrow pits	0		0	0		
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		
Foundations and hard-standing area associated with each turbine						
Method used to calculate CO ₂ loss from foundations and hard-standing	Enter detailed information ▼		Enter detailed information ▼	Enter detailed information ▼		
Please enter construction data in sheet: Construction input data	25.5		25.5	25.5		
Average depth of peat removed from turbine foundations (m)	0.00		0.00	0.00		
Average depth of peat removed from hard-standing (m)	0.00		0.00	0.00		
Access tracks						
Total length of access track (m)	4400		4400	4400		
Existing track length (m)	0		0	0		
Length of access track that is floating road (m)	0		0	0		
Floating road width (m)	0		0	0		
Floating road depth (m)	0		0	0		
Length of floating road that is drained (m)	0		0	0		
Average depth of drains associated with floating roads (m)	0		0	0		
Length of access track that is excavated road (m)	0		0	0		
Excavated road width (m)	0		0	0		
Average depth of peat excavated for road (m)	0		0	0		
Length of access track that is rock filled road (m)	4400		4400	4400		
Rock filled road width (m)	5.5		5.5	5.5		
Rock filled road depth (m)	1.20		1.20	1.20		
Length of rock filled road that is drained (m)	0		0	0		
Average depth of drains associated with rock filled roads (m)	0.00		0.00	0.00		
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)	0		0	0		
Average depth of peat cut for cable trenches (m)	0.00		0.00	0.00		
Additional peat excavated (not already accounted for above)						
Volume of additional peat excavated (m ³)	0		0	0		
Area of additional peat excavated (m ²)	0.0		0.0	0.0		
Peat Landslide Hazard						
Web link: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments						
Improvement of C sequestration at site by blocking drains, restoration of habitat etc						
Improvement of degraded bog						
Area of degraded bog to be improved (ha)	0		0	0		
Water table depth in degraded bog before improvement (m)	0.00		0.00	0.00		
Water table depth in degraded bog after improvement (m)	0.00		0.00	0.00		
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	0		0	0		
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	0		0	0		
Improvement of felled plantation land						
Area of felled plantation to be improved (ha)	3		3	3		
Water table depth in felled area before improvement (m)	0.00		0.00	0.00		
Water table depth in felled area after improvement (m)	0.00		0.00	0.00		
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	15		15	15		
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	15		15	15		
Restoration of peat removed from borrow pits						
Area of borrow pits to be restored (ha)	0		0	0		
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.00		0.00	0.00		
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.00		0.00	0.00		
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	0		0	0		
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	0		0	0		
Early removal of drainage from foundations and hardstanding						
Water table depth around foundations and hardstanding before restoration (m)	20.00		15.00	25.00		
Water table depth around foundations and hardstanding after restoration (m)	20.00		15.00	25.00		
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	35		35	35		
Restoration of site after decommissioning						
Will the hydrology of the site be restored on decommissioning?	Yes		Yes	Yes		
Will you attempt to block any gullies that have formed due to the windfarm?	Not appli ▼		Not appli ▼	Not appli ▼		
Will you attempt to block all artificial ditches and facilitate revegetation?	Not appli ▼		Not appli ▼	Not appli ▼		
Will the habitat of the site be restored on decommissioning?	Yes		Yes	Yes		
Will you control grazing on degraded areas?	Not appli ▼		Not appli ▼	Not appli ▼		
Will you manage areas to favour reintroduction of species	Not appli ▼		Not appli ▼	Not appli ▼		
Choice of methodology for calculating emission factors						
Choice of methodology for calculating emission factors	IPCC default					
Core input data						
ENTER INPUT DATA HERE! VALUES SHOULD ONLY BE CHANGED ON THIS SHEET. DO NOT USE EXAMPLE VALUES AS DEFAULTS! ENTER YOUR OWN VALUES THAT ARE SPECIFIC TO YOUR PARTICULAR SITE.						
Note: The input parameters include some variables that can be specified by default values, but others that must be site specific. Variables that can be taken from defaults are marked with purple tags on left hand side.						

Note: Capacity factor. The capacity factor of any power plant is the proportion of energy produced during a given period with respect to the energy that would have been produced had the wind farm been running continually and at maximum output (DECC (2004); see also [www.bwea.com/ref/capacityfactors.html](#)).

Capacity Factor = Electricity generated during the period [kWh] / installed capacity [kW] x number of hours in the period [h]

We recommend that a site-specific capacity factor ~~etc~~ should be used, as measured during planning stage), and should represent the average emission factor ~~etc~~ over the lifetime of the windfarm, accounting for decline in efficiency with age (Hughes, 2012). The 5 year average capacity factor (or 'load factor') for UK onshore wind between 2010 and 2014, based on average beginning and end of year capacity, was 29.2% (DUKES, 2015).

Note: Extra capacity required for backup. If 20% of national electricity is generated by wind energy, the extra capacity required for backup is 5% of the rated capacity of the wind plant (Dale et al 2004). We suggest this should be 5% of the actual output. If it is assumed that less than 20% of national electricity is generated by wind energy, a lower percentage should be entered (0%). The House of Lords Economic Affairs Committee report on 'The Economics of Renewable Energy' (Parliamentary Business, 2008) notes that to cover peak demand a 20% margin of extra capacity has been sufficient to keep the risk of a power cut due to insufficient generation at a very low level. The estimate provided by BERR was a range of 10% to 20% of installed capacity of wind energy. E.ON is reported as proposing that the capacity credit of wind power should be 8%, and The Renewable Energy Foundation proposed the use of the square root of the wind capacity (in GW) as conventional capacity (e.g. 36 GW of wind plant to match 6 GW of conventional plant).

Note: Extra emissions due to reduced thermal efficiency of the reserve power generation = 10% (Dale et al 2004).

Note: Emissions from turbine life. If total emissions for the windfarm are unknown, emissions should be calculated according to turbine capacity. The normal range of CO₂ emissions is 394 to 8147 t CO₂ MW (White & Kulcinski, 2000; White, 2007).

Note: Type of peatland. An 'acid bog' is fed primarily by rainwater and often inhabited by sphagnum moss, thus making it acidic (Stoneman & Brooks, 1997). A 'fen' is a type of wetland fed by surface and/or groundwater (McBride et al., 2011).

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

Note: Carbon fixation by bog plants

Apparent C accumulation rate in peatland is 0.12 to 0.31 t C ha⁻¹ yr⁻¹ (Turunen et al., 2001; Botch et al., 1995). The SNH guidance uses a value of 0.25 t C ha⁻¹ yr⁻¹.

Note: Area of forestry plantation to be felled. If the forestry was planned to be removed, with no further rotations planted, before the windfarm development, the area to be felled should be entered as zero.

Note: Plantation carbon sequestration. This is dependent on the yield class of the forestry. The SNH technical guidance assumed yield class of 16 m³ ha⁻¹ yr⁻¹, compared to the value of 14 m³ ha⁻¹ yr⁻¹ provided by the Forestry Commission. Carbon sequestered for yield class 16 m³ ha⁻¹ yr⁻¹ = 3.6 tC ha⁻¹ yr⁻¹ (Cannell, 1999).

Note: Coal-Fired Plant and Grid Mix Emission Factors. Coal-fired plant emission factor (EF) from electricity supplied in 2014 = 0.093 t CO₂ MWh⁻¹ Grid-Mix EF for 2014 = 0.394 t CO₂ MWh⁻¹. Source = DUKES, 2015b.

Note: Fossil Fuel-Mix Emission Factor. The emission factor from electricity supplied in 2014 from all fossil fuels = 0.642 t CO₂ MWh⁻¹. Source = DUKES, 2015b.

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

Note: Floating road depth. Accounts for sinking of floating road. Should be entered as the average depth of the road expected over the lifetime of the windfarm. If no sinking is expected, enter as zero.

Note: Length of floating road that is drained. Refers to any drains running along the length of the road.

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

Note: Depth of peat cut for cable trenches. In shallow peats, the cable trenches may be cut below the peat. To avoid overestimating the depth of peat affected by the cable trenches, only enter the depth of the peat that is cut.

Note: Peat Landslide Hazard. It is assumed that measures have been taken to limit damage (Scottish Executive, 2008; Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments, Scottish Executive, Edinburgh, pp. 34-35) so that C losses due to peat landslide can be assumed to be negligible. Link: [http://www.scotland.gov.uk/Publications/2008/12/21162303/1](#).

Note: Period of time when improvement can be guaranteed. This guarantee should be absolute. Therefore, if you enter a value beyond the lifetime of the windfarm you should provide strong supporting evidence that this improvement can be guaranteed for the full period given. This includes the time requirement for the improvement to become effective. For example if time required for hydrology and habitat to return to its previous state is 10 years and the restoration can be guaranteed over the lifetime of the windfarm (25 years), the period of time when the improvement can be guaranteed should be entered as 25 years, and the improvement will be effective for (25-10) = 15 years.

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Note: Period of time when improvement can be guaranteed. This is assumed to be the lifetime of the windfarm as restoration after windfarm decommissioning is already accounted for in restoration of the site

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

Note: Choice of methodology for calculating emission factors. The IPCC default methodology is the internationally accepted standard (IPCC, 1997). However, it is stated in IPCC (1997) that these are rough estimates, and "these rates and production periods can be used if countries do not have more appropriate estimates". Therefore, we have developed more site specific estimates for use here based on work from the Scottish Government funded ECOSSE project (Sinha et al. 2007; ECOSSE: Estimating Carbon in Organic Soils - Sequestration and Emissions, Final Report, SEERAD Report, ISBN 978 0 7559 1498 2, 166pp.).

Click here to move to Payback Time [Click here](#)

Click here to return to Instructions [Click here](#)

Forestry input data

ENTER DETAILS OF FORESTRY MANAGEMENT HERE!

Note: Data only needed if select to calculate capacity factor from forestry data (cell C15 in Core input data sheet), or to include detailed forestry management (cell C35 in Core input data sheet)

(1) for estimating compensatory planting woodland carbon
<http://tinyurl.com/woodlandcarboncode>

(2) for UK policy
<http://tinyurl.com/FCPolicy>

(3) FC Scotland Control of Woodland Removal (including Compensatory Planting)
<http://tinyurl.com/FCScotlandCompPlant>

No POC losses for bare soil included yet. If extensive areas of base soil is present at site need modified calculation.

Click here to move to Payback Time
Click here to return to Instructions

Click here
Click here

Input data	Expected values	Record source of data	Possible range of values			Record source of data
	Enter expected value here		Enter minimum value here	Enter maximum value here		
Windfarm characteristics						
Location						
Distance to nearest biofuel plant (km)	200		200		200	
Dimensions						
Total wind farm area (ha)	45.37		45.37		45.37	
Performance						
Height of turbines (m)	158		156		160	
Average site windspeed (m s ⁻¹)	7		6		8	
Estimated downtime for maintenance etc (%)	5		3		4	
Emissions due to forestry operations						
Emissions from felling (g CO ₂ m ⁻³)	8010000		7342500		8677500	
Emissions of CO ₂ associated with transportation (g CO ₂ km ⁻¹ t ⁻¹)	39		39		40	
Forestry Plantation Characteristics						
Note - total number of turbines already specified:						
AREA 1						
Number of turbines in this area	6		6		6	
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)	User-defined		User-defined		User-defined	
Major soil sub-group	Peaty gley		Peaty gley		Peaty gley	
Species	Sitka spruce		Sitka spruce		Sitka spruce	
Felled Forest Biomass used as biofuel?	No		No		No	
Felling regime						
Age of forestry when felled for windfarm (yr)	20		20		20	
Area felled around each turbine (ha)	1.69		1.69		1.69	
Width of forest around felled area (m)	200		200		200	
Value of felled forestry as a biomass fuel (MWh t ⁻¹)	500.00000		500.00000		500.00000	
(Carbon : Biomass) ratio of felled forestry	0.5		0.5		0.5	
Replanting regime						
Years after felling when replanting occurs	35		35		35	
Age of seedlings on planting (yr)	1		1		1	
Area replanted around each turbine (ha)	1.69		1.69		1.69	
AREA 2						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)	User-defined		User-defined		User-defined	
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t ⁻¹)						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 3						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)	User-defined		User-defined		User-defined	
Major soil sub-group	Peaty gley		Peaty gley		Peaty gley	
Species	Sitka spruce		Sitka spruce		Sitka spruce	
Felled Forest Biomass used as biofuel?	No		No		No	
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t ⁻¹)						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 4						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t ⁻¹)						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 5						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t ⁻¹)						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						

Note: Estimated downtime. Estimated downtime for maintenance etc. Few reports on downtime of wind turbines are publicly available. However, one review by Garrad Hassan (2011) suggests that the minimum downtime reported was 2% for the annual moving average for between 8 to 9 years of operation of new turbines, for a sample of 240 turbines. For a summary of findings see Garrad Hassan (2011).

Note: Emissions from felling and timber removal. Based on emissions factors from UK taken from Morison et al (2011), if clearfelling assumed to be performed by harvester and timber is assumed extracted with forwarder, the emissions are 6675 g CO₂ m⁻³.

Note: Emissions associated with transportation. Assuming transportation by trucks running on diesel and 20% of journey taken on forest roads, emissions factor obtained from Morison et al (2011) is 39.33 g CO₂ km⁻¹ t⁻¹ (range 38.5 – 40.15 g CO₂ km⁻¹ t⁻¹ - average = 39.33 g CO₂ km⁻¹ t⁻¹)

Note: Power curve. Based on Vestas 2.0MW Optispeed turbine with roughness class C2, modelled over wind speed of 5-10 m s⁻¹. To define a the power curve for a different turbine type, plot annual power output, P (MWh) against annual windspeed, W (m s⁻¹) and fit a linear regression to obtain slope, a, and intercept, b:
 $P = aW + b$

Note: Soil sub-group. Used in determination of forestry characteristic. Peaty gley = Peaty Soils (5-50cm) e.g. peaty gley, peaty podsol. Deep peat = Deep Peat (>50cm) e.g. basin and blanket bogs

Note: Species. So far only Scots pine and Sitka spruce included.

Note: Value of felled forestry. Values available in Mason et al., 2009.

Note: Carbon : Biomass ratio of felled forestry. Wood biomass can be converted to dry weight using wood density based values from Lavers (1983) with a subsequent assumption that C:dry matter ratio is 50% (Matthews 1993). For simplicity an integrated factor, the 'wood density to biomass factor' taken from Mason et al (2009) can be used.
Value = 0.5

Forestry input data

ENTER DETAILS OF FORESTRY MANAGEMENT HERE!

Note: Data only needed if select to calculate capacity factor from forestry data (cell C15 in Core input data sheet), or to include detailed forestry management (cell C35 in Core input data sheet)

Click here to move to Payback Time
Click here to return to Instructions

Click here
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Construction input data

ENTER DETAILS OF CONSTRUCTION HERE!

Note: This data only used in the calculation if the selection "Enter detailed information" is made in cell C50 of the Core input data sheet.

Click here to move to
Payback Time
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Core input data

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Input data	Expected values	Record source of data	Possible range of values		Record source of data
	Enter expected value here		Enter minimum value here	Enter maximum value here	
Construction design					
Note - total number of turbines already specified:					
AREA 1	6		6		6
Number of turbines in this area	6		6		6
Turbine foundations					
Average depth of peat removed when constructing foundations (m)	0.0				
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular		Rectangular
Length at surface (m)	13		13		13
Width at surface (m)	10		10		10
Length at bottom (m)	13		13		13
Width at bottom (m)	10		10		10
Hardstanding					
Average depth of peat removed when constructing hardstanding (m)	0.0		0.0		0.0
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular		Rectangular
Length at surface (m)	42		42		42
Width at surface (m)	25		25		25
Length at bottom (m)	42		42		42
Width at bottom (m)	25		25		25
Piling					
Is piling used?	Yes		Yes		Yes
Volume of Concrete					
Volume of concrete used (m³)	6215		6215		6215
AREA 2					
Number of turbines in this area					
Turbine foundations					
Average depth of peat removed when constructing foundations (m)					
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular		Rectangular
Length at surface (m)					
Width at surface (m)					
Length at bottom (m)					
Width at bottom (m)					
Hardstanding					
Average depth of peat removed when constructing hardstanding (m)					
Approximate geometric shape of whole dug when constructing hardstanding					
Length at surface (m)					
Width at surface (m)					
Length at bottom (m)					
Width at bottom (m)					
Piling					
Is piling used?					
Volume of Concrete					
Volume of concrete used (m³)					
AREA 3					
Number of turbines in this area					
Turbine foundations					
Average depth of peat removed when constructing foundations (m)					
Approximate geometric shape of whole dug when constructing foundations					
Length at surface (m)					
Width at surface (m)					
Length at bottom (m)					
Width at bottom (m)					
Hardstanding					
Average depth of peat removed when constructing hardstanding (m)					
Approximate geometric shape of whole dug when constructing hardstanding					
Length at surface (m)					
Width at surface (m)					
Length at bottom (m)					
Width at bottom (m)					
Piling					
Is piling used?					
Volume of Concrete					
Volume of concrete used (m³)					
AREA 4					
Number of turbines in this area					
Turbine foundations					
Average depth of peat removed when constructing foundations (m)					
Approximate geometric shape of whole dug when constructing foundations					
Length at surface (m)					
Width at surface (m)					
Length at bottom (m)					
Width at bottom (m)					
Hardstanding					
Average depth of peat removed when constructing hardstanding (m)					
Approximate geometric shape of whole dug when constructing hardstanding					
Length at surface (m)					
Width at surface (m)					
Length at bottom (m)					
Width at bottom (m)					
Piling					
Is piling used?					
Volume of Concrete					
Volume of concrete used (m³)					
AREA 5					
Number of turbines in this area					
Turbine foundations					
Average depth of peat removed when constructing foundations (m)					
Approximate geometric shape of whole dug when constructing foundations					
Length at surface (m)					
Width at surface (m)					
Length at bottom (m)					
Width at bottom (m)					
Hardstanding					
Average depth of peat removed when constructing hardstanding (m)					
Approximate geometric shape of whole dug when constructing hardstanding					
Length at surface (m)					
Width at surface (m)					
Length at bottom (m)					
Width at bottom (m)					
Piling					
Is piling used?					
Volume of Concrete					
Volume of concrete used (m³)					

Results

PAYBACK TIME AND CO₂ EMISSIONS

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

Click here to return to Input data

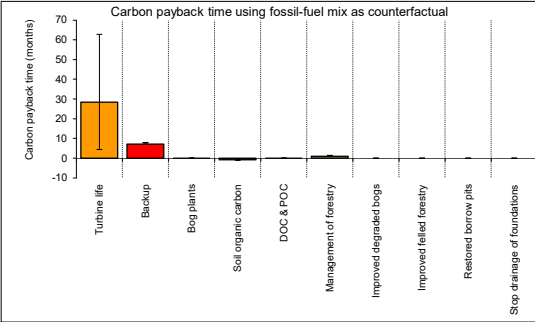
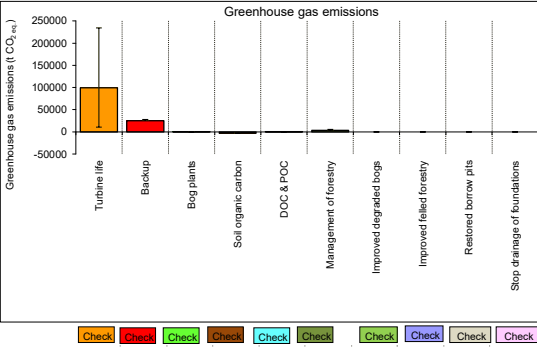
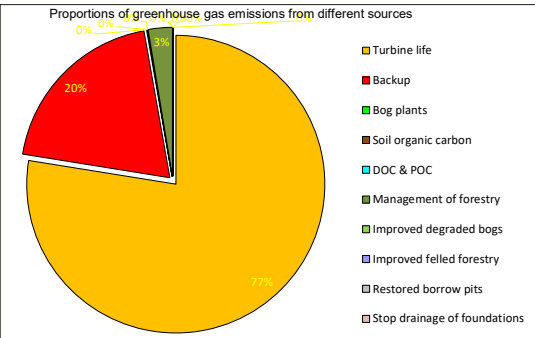
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	Exp.	Min.	Max.
1. Windfarm CO ₂ emission saving over...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	6080	6423	6851
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	14972	15816	16870
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	41974	44339	47295
Energy output from windfarm over lifetime (MWh)	2288315	2417234	2578383
Total CO ₂ losses due to wind farm (t CO ₂ eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decommissioning)	99071	10638	234634
3. Losses due to backup	25156	26573	28345
4. Losses due to reduced carbon fixing potential	130	56	180
5. Losses from soil organic matter	-2956	-3299	-2627
6. Losses due to DOC & POC leaching	28	8	45
7. Losses due to felling forestry	3373	3234	5490
Total losses of carbon dioxide	124802	37210	266065
8. Total CO ₂ gains due to improvement of site (t CO ₂ 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 CO ₂ eq.)	124802	37210	266065
Carbon Payback Time			
...coal-fired electricity generation (years)	20.5	5.4	41.4
...grid-mix of electricity generation (years)	8.3	2.2	16.8
...fossil fuel - mix of electricity generation (years)	3.0	0.8	6.0
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	No gains!	No gains!	No gains!
Ratio of CO ₂ eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	55	14	110



Check Check Check Check Check Check Check Check Check Check

Results

PAYBACK TIME AND CO₂ EMISSIONS

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

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Data used in barchart of carbon payback time using fossil-fuel mix as counterfactual

Greenhouse gas emissions	Exp.	Min	Max
Turbine life	99071	88433	135563
Backup	25156	0	3189
Bog plants	130	75	49
Soil organic carbon	0	343	328
DOC & POC	28	20	17
Management of forestry	3373	139	2117
Improved degraded bogs	0	0	0
Improved felled forestry	0	0	0
Restored borrow pits	0	0	0
Stop drainage of foundations	0	0	0

89008 141264

Data used in barchart of carbon payback time using fossil-fuel mix as counterfactual

Greenhouse gas emissions			Carbon payback time (months)			
	Exp.	Min.	Max.	Exp.	Min.	Max.
Turbine life	99071	88433	135563	28	24	34
Backup	25156	-1417	3189	7	0	1
Bog plants	130	75	49	0	0	0
Soil organic carbon	-2956	343	328	-1	0	0
DOC & POC	28	20	17	0	0	0
Management of forestry	3373	139	2117	0	0	0
Improved degraded bogs	0	0	0	0	0	0
Improved felled forestry	0	0	0	0	0	0
Restored borrow pits	0	0	0	0	0	0
Stop drainage of foundations	0	0	0	0	0	0
	124802			36		

Windfarm CO₂ emission saving

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

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Values taken from input sheet				Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Power Generation Characteristics																		
No. of turbines	6	6	6	6	6	6	0	0	0	0	0	0	0	0	0	0	0	0
Power rating of turbines (turbine capacity) (MW)	4.26	4.5	4.8	4.26	4.5	4.8	4.26	4.5	4.8	4.26	4.5	4.8	4.26	4.5	4.8	4.26	4.5	4.8
Power of windfarm (MW)	25.56	27	28.8	25.56	27	28.8	0	0	0	0	0	0	0	0	0	0	0	0
Estimated downtime for maintenance etc (%)	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4
Counterfactual emission factors																		
Coal-fired plant emission factor (t CO ₂ MWh ⁻¹)	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642	0.642
Calculation of capacity factor																		
1 Direct input of capacity factor				Exp			Min			Max								
Entered capacity factor (%)				29.2			29.2			29.2								
Parameters				Slope (a)			Intercept (b)											
Partial power curves for different turbines				Exp	Min	Max	Exp	Min	Max									
User-defined				0.0	0.0	0.0	0.0	0.0	0.0									
Vestas 2.0 MW Optispeed C2				1392.5	1392.5	1392.5	-4291.9	-4291.9	-4291.9									

Values taken from input sheet				Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Calculation of capacity factor from forestry management																		
Wind speed ratio calculated in 7d	7	6	8	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!
Average site windspeed (m s ⁻¹)	7	6	8	7	6	8	7	6	8	7	6	8	7	6	8	7	6	8
Annual theoretical energy output from turbine (MW turbine ⁻¹ yr ⁻¹)	37318	39420	42048	37317.6	39420	42048	37318	39420	42048	37318	39420	42048	37318	39420	42048	37318	39420	42048
Power curve (Power curve code)				User-defined	User-defined	User-defined	User-defined	User-defined	User-defined	User-defined	User-defined	User-defined	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines
				1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0	Exp	Min	Max	Exp	Min	Max
				0	0	0	0	0	0	0	0	0	Exp	Min	Max	Exp	Min	Max
Slope (a)				0	0	0	0	0	0	0	0	0	Exp	Min	Max	Exp	Min	Max
Intercept (b)				0	0	0	0	0	0	0	0	0	Exp	Min	Max	Exp	Min	Max
Annual power output from an individual turbine (MW turbine ⁻¹ yr ⁻¹)				#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#####	#####	#####	#####	#####	#####
Calculated capacity factor (%)				#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#####	#####	#####	#####	#####	#####
Calculation of annual energy output from wind farm																		
Total				Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
Direct input of capacity factor	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Capacity factor(%)																		
Annual energy output from windfarm (MW yr ⁻¹)	65380	69064	73668	65380	69064	73668	0	0	0	0	0	0	0	0	0	0	0	0
RESULTS																		
Windfarm CO₂ emission saving over...				Area 1			Area 2			Area 3			Area 4			Area 5		
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	6080	6422.9	6851.1	6080	6423	6851	0	0	0	0	0	0	0	0	0	0	0	0
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	14972	15816	16870	14972	15816	16870	0	0	0	0	0	0	0	0	0	0	0	0
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	41974	44339	47295	41974	44339	47295	0	0	0	0	0	0	0	0	0	0	0	0

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Windfarm CO₂ emission saving

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

Emissions due to turbine life

Note: 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.

Method used to estimate CO ₂ emissions from turbine life (eg. manufacture, construction,	Direct input of total emissions
---	---------------------------------

	Exp	Min	Max
Direct input of emissions due to turbine life (t CO ₂ windfarm ⁻¹)	99071	10638	234634
Calculation of emissions due to turbine life from energy output			
CO ₂ emissions due to turbine life (tCO ₂ turbine ⁻¹)	3513	3737	4017
No. of turbines	6	6	6
Total calculated CO ₂ emission of the wind farm due to turbine life (t CO ₂ windfarm ⁻¹)	21077	22422	24104

	Total			Construction Area 1			Construction Area 2			Construction Area 3			Construction Area 4			Construction Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Calculation of emissions due to cement used in construction																		
Volume of cement used (m ³)	6215	6215	6215	6215	6215	6215	0	0	0	0	0	0	0	0	0	0	0	0
CO ₂ emission rate (t CO ₂ m ⁻³ cement)	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316
Total CO ₂ emissions due to cement used in construction	1964	1964	1964	1964	1964	1964	0	0	0	0	0	0	0	0	0	0	0	0

RESULTS			
Losses due to turbine life (eg.	99071	10638	234634
Additional CO ₂ payback time of windfarm due to turbine life (eg. manufacture, construction, decommissioning)			
...coal-fired electricity generation (months)	196	20	411
...grid-mix of electricity generation (months)	79	8	167
...fossil fuel - mix of electricity generation (months)	28	3	60

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Emissions due to turbine life

Note: 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.

http://www.concretecentre.com/PDF/SCF_Table%207%20Embodied%20CO2_April%202013.pdf



Embodied carbon dioxide (CO₂e) of concretes used in buildings

CONCRETE APPLICATION	Concrete designation	CO ₂ e (kgCO ₂ e/m ³) ¹			CO ₂ e (kgCO ₂ e/tonne) ¹		
		CEM I concrete	30% fly ash concrete	50% ggbs concrete	CEM I concrete	30% fly ash concrete	50% ggbs concrete
Blinding, mass fill, strip footings, mass foundations, trench foundations ²	GEN1	177	128	101	77	55	44
Reinforced Foundations ²	RC25/30**	316	263	197	133	111	83
Ground floors ²	RC28/35	316	261	186	134	110	79
Structural: in situ floors, superstructure, walls, basements ²	RC32/40**	369	313	231	154	131	96
High strength concrete ²	RC40/50**	432	351	269	178	146	111
		CO ₂ e (kgCO ₂ e/m ³)			CO ₂ e (kgCO ₂ e/tonne)		
Unreinforced Precast flooring ³		-			165		
Reinforced precast flooring ³		-			171		
Average Generic Concrete Block ⁴		-			84		

*

includes 30kg/m³ steel reinforcement

**

includes 100kg/m³ steel reinforcement

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Emissions due to backup power generation

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

	Expected	Minimum	Maximum
Reserve capacity required for backup			
No. of turbines	6	6	6
Power rating of turbines (turbine capacity) (MW)	4.26	4.5	4.8
Power of wind farm (MW h ⁻¹)	25.56	27	28.8
Rated capacity (MW yr ⁻¹)	223905.6	236520	252288
Extra capacity required for backup (%)	5	5	5
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10
Reserve capacity (MWh yr ⁻¹)	1120	1183	1261

Carbon dioxide emissions due to backup power generation			
Coal-fired plant emission factor (t CO ₂ MWh ⁻¹)	0.093	0.093	0.093
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.229	0.229	0.229
Fossil fuel- mix emission factor (t CO ₂ MWh ⁻¹)	0.642	0.642	0.642
Lifetime of windfarm (years)	35	35	35
Annual emissions due to backup from...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	104	110	117
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	256	271	289
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	719	759	810

RESULTS			
Total emissions due to backup from...			
...coal-fired electricity generation (tCO ₂)	3644	3849	4106
...grid-mix of electricity generation (tCO ₂)	8973	9479	10110
...fossil fuel - mix of electricity generation (tCO ₂)	25156	26573	28345
Additional CO ₂ payback time of windfarm due to backup			
...coal-fired electricity generation (months)	7	7	7
...grid-mix of electricity generation (months)	7	7	7
...fossil fuel - mix of electricity generation (months)	7	7	7

Note: 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.

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Emissions due to backup power generation

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

Emissions due to loss of bog plants

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

	Expected	Minimum	Maximum
Area where carbon accumulation by bog plants is lost			
Total area of land lost due to windfarm construction (m ²)	30500	30500	30500
Total area affected by drainage due to windfarm construction (m ²)	1104	1104	1104
Total area where fixation by plants is lost (m ²)	31604	31604	31604
Total loss of carbon accumulation			
Carbon accumulation in undrained peats (tC ha ⁻¹ yr ⁻¹)	0.25	0.12	0.31
Lifetime of windfarm (years)	35	35	35
Time required for regeneration of bog plants after restoration (years)	10	5	15
Carbon accumulation up to time of restoration (tCO ₂ eq. ha ⁻¹)	41	18	57

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

RESULTS			
Total loss of carbon accumulation by bog plants			
Total area where fixation by plants is lost (ha)	3	3	3
Carbon accumulation over lifetime of windfarm (tCO ₂ eq. ha ⁻¹)	41	18	57
Total loss of carbon fixation by plants at the site (t CO ₂)	130	56	180
Additional CO ₂ 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	0
...fossil fuel - mix of electricity generation (months)	0	0	0

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Emissions due to loss of bog plants

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

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

		Expected result	Minimum result	Maximum result
CO₂ loss due to windfarm construction				
Check	CO ₂ loss from removed peat (t CO ₂ equiv)	-3021	-2685	-3357
Check	CO ₂ loss from drained peat (t CO ₂ equiv)	66	58	58
RESULTS				
Total CO ₂ loss from peat (removed + drained) (t CO ₂ equiv)		-2956	-3299	-2627
Additional CO₂ payback time of windfarm due to loss of soil CO₂				
...coal-fired electricity generation (months)		-6	-6	-5
...grid-mix of electricity generation (months)		-2	-3	-2
...fossil fuel - mix of electricity generation (months)		-1	-1	-1

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

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Emission rates from soils

Note: 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).

Click here to move to 5d. [Click here](#)
Click here to move to Payback Time [Click here](#)

Selected Methodology = IPCC default
Type of peatland = Fen

Calculations following IPCC default methodology

Emission characteristics of acid bogs (IPCC, 1997)

	Expected	Minimum	Maximum
Flooded period (days year ⁻¹)	178	178	178
Annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.04015	0.04015	0.04015
Annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2

Emission characteristics of fens (IPCC, 1997)

Flooded period (days year ⁻¹)	169	169	169
Annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
Annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2

Selected emission characteristics (IPCC, 1997)

Flooded period (days year ⁻¹)	169	169	169
Annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
Annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2

Calculations following ECOSSE based methodology

Drained Land

Total area affected by drainage due to wind farm construction (ha)	0	0	0
Total volume affected by drainage due to wind farm construction (m ³)	0	0	0

Soil Characteristics that Determine Emission Rates

Average annual air temperature at the site (°C)	10	4.3	14.3
Average water table depth at site (m)	20.00	25.00	15.00
Average water table depth of drained land (m)	20.00	25.00	15.00

Annual Emission Rates following site specific methodology

Acid bogs			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	24.30	22.78	25.44
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	24.30	22.78	25.44
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	-0.001	-0.021	0.014
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	-0.02	0.01
Fens			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	65.19	61.98	67.60
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	65.19	61.98	67.60
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	-0.003	-0.007	-0.001
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	-0.01	0.00

Selected emission characteristics following site specific methodology

Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	65.19	61.98	67.60
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	65.19	61.98	67.60
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	-0.003	-0.007	-0.001
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	-0.01	0.00

RESULTS

Selected Emission Rates

Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.22	0.22	0.22

Click here to move to 5d. CO₂ loss from drained peat [Click here](#)

Click here to move to Payback Time [Click here](#)

Emission rates from soils

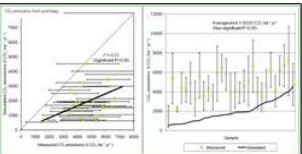
Note: Note, CO₂ losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been thoroughly tested against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

Assumption: The period of flooding is taken to be 178 days yr⁻¹ for acid bogs and 169 days yr⁻¹ based on the monthly mean temperature and the lengths of inundation (IPCC, 1997, Revised 1996 IPCC guidelines for national greenhouse gas inventories, Vol 3, table 5-13)

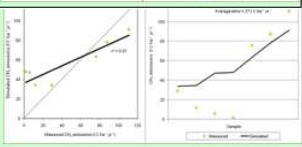
Assumption: The CH₄ emission rate provided for acid bogs is 11 (1-38) mg CH₄-C m⁻² day⁻¹ x 365 days, and for fens is 60 (21-162) mg CH₄-C m⁻² day⁻¹ x 365 days (Asemlann & Crutzen, 1989, J. Atmos. Chem. 8, 307-358)

Assumption: CO₂ emissions on drainage of organic soils for upland crops (e.g., grain, vegetables) are 3.667x9.6 (7.9-11.3) t CO₂ ha⁻¹ yr⁻¹ in temperate climates (Armentano and Menges, 1986, J. Ecol. 74, 755-774).

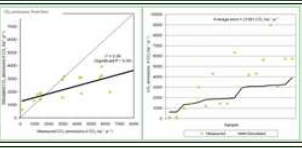
Note: Carbon dioxide emissions from acid bogs. Equation derived by regression analysis against 60 measurements (Nayak et al, 2009). The equation derived was $R_{CO_2} = (3.667/1000) \times ((5700 \times \exp(-0.26 \times \exp(-0.0515 \times ((W \times 100) - 50)))) + ((72.54 \times T) - 800))$ where R_{CO_2} is the annual rate of CO₂ emissions (t CO₂ (ha)⁻¹ yr⁻¹), T = average annual peat temperature (°C) and W is the water table depth (m). The equation shows a significant correlation with measurements ($r^2 = 0.53$, $P > 0.05$). Evaluation against 29 independent experiments shows a significant association ($r^2 = 0.21$; $P > 0.05$) and an average error of 3023 t CO₂ ha⁻¹ yr⁻¹ which is non-significant ($P < 0.05$) (Smith et al, 1997).



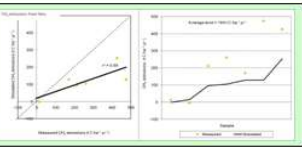
measurements (Nayak et al, 2009). The equation derived was $R_{CH_4} = (1/1000) \times (500 \times \exp(-0.1234 \times (W \times 100))) + ((3.529 \times T) - 36.67)$ where R_{CH_4} is the annual rate of CH₄ emissions (t CH₄-C (ha)⁻¹ yr⁻¹), T = average annual air temperature (°C) and W is the water table depth (m). The equation shows a significant correlation with measurements ($r^2 = 0.54$, $P > 0.05$). Evaluation against 7 independent experiments shows a significant association ($r^2 = 0.81$; $P > 0.05$) and an average error of 27 t CH₄-C ha⁻¹ yr⁻¹ (significance not defined due to lack of replicates - Smith et al, 1997).



Note: Carbon dioxide emissions from fens. Equation derived by regression analysis against 44 measurements (Nayak et al, 2009). The equation derived was $R_{CO_2} = (3.667/1000) \times (16244 \times \exp(-0.175 \times \exp(-0.073 \times ((W \times 100) - 50)))) + (153.23 \times T)$ where R_{CO_2} is the annual rate of CO₂ emissions (t CO₂ (ha)⁻¹ yr⁻¹), T = average annual peat temperature (°C) and W is the water table depth (m). The equation shows a significant correlation with measurements ($r^2 = 0.42$, $P > 0.05$). Evaluation against 18 independent experiments shows a significant association ($r^2 = 0.66$; $P > 0.05$) and an average error of 2108 t CO₂ ha⁻¹ yr⁻¹ (significance not defined due to lack of replicates - Smith et al, 1997).



Note: Methane emissions from fens. Equation derived by regression analysis against experimental data from 35 measurements (Nayak et al, 2009). The equation derived was $R_{CH_4} = (1/1000) \times (-10 + 563.62 \times \exp(-0.097 \times (W \times 100))) + (0.662 \times T)$ where R_{CH_4} is the annual rate of CH₄ emissions (t CH₄-C (ha)⁻¹ yr⁻¹), T = average annual air temperature (°C) and W is the water table depth (m). The equation shows a significant correlation with measurements ($r^2 = 0.41$, $P > 0.05$). Evaluation against 7 independent experiments shows a significant association ($r^2 = 0.69$; $P > 0.05$) and an average error of 164 t CH₄-C ha⁻¹ yr⁻¹ (significance not defined due to lack of replicate - Smith et al, 1997).



Emissions due to loss of DOC and POC

Note: 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)

	Expected	Minimum	Maximum	
Total C loss				
Gross CO ₂ loss from restored drained land (t CO ₂)	81	72	90	Note: Only restored drained land included because if land is not restored, the C lost has already been counted as carbon dioxide
Gross CH ₄ loss from restored drained land (t CO ₂ equiv.)	0	0	0	
Gross CO ₂ loss from improved land (t CO ₂)				
Degraded Bog	0	0	0	
Felled Forestry	0	0	0	
Borrow Pits	0	0	0	
Foundations & Hardstanding	0	0	0	
Gross CH ₄ loss from improved land (t CO ₂ equiv.)				
Degraded Bog	0	0	0	
Felled Forestry	0	0	0	
Borrow Pits	0	0	0	
Foundations & Hardstanding	0	0	0	
Conversion factor: CH ₄ -C to CO ₂ equivalents	30.6667	30.6667	30.6667	
% total soil C losses, lost as DOC	26	7	40	
% DOC loss emitted as CO ₂ over the long term	100	100	100	Assumption: In the long term, 100% of leached DOC is assumed to be lost as CO ₂
% total soil C losses, lost as POC	8	4	10	
% POC loss emitted as CO ₂ over the long term	100	100	100	Assumption: POC loss ranges between 4-10% of the total gaseous loss if calculated from the reported values and is 8% of the total gaseous loss if calculated from the mean of reported maximum and minimum value in Worrall 2009. POC range is (7 - 22.4 MgC/KM ² /yr) (Worrall et al, 2009).
Total gaseous loss of C (t C)	22	20	25	
Total C loss as DOC (t C)	6	1	10	
Total C loss as POC (t C)	2	1	2	
RESULTS				
Total CO ₂ loss due to DOC leaching (t CO ₂)	21	5	36	
Total CO ₂ loss due to POC leaching (t CO ₂)	6	3	9	
Total CO ₂ loss due to DOC & POC leaching (t CO ₂)	28	8	45	
Additional CO ₂ payback time of windfarm due to DOC & POC				
...coal-fired electricity generation (months)	0	0	0	
...grid-mix of electricity generation (months)	0	0	0	
...fossil fuel - mix of electricity generation (months)	0	0	0	

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Emissions due to loss of DOC and POC

Note: 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)

Emissions due to forest felling - calculation using simple management data

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

	Expected	Minimum	Maximum
Emissions due to forestry felling			
Area of forestry plantation to be felled (ha)	7.3	7.2	11.56
Carbon sequestered (tC 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)	3373	3234	5490
Additional CO ₂ payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	7	6	10
...grid-mix of electricity generation (months)	3	2	4
...fossil fuel - mix of electricity generation (months)	1	1	1

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Emissions due to forest felling - calculation using simple management data

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

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Financial Statement - Income Statement											
Period: 01/01/2025 to 31/12/2025											
Currency: USD											
Unit: Millions											
Accounting Method: Accrual											
Reported by: Finance Department											
Audited by: External Auditor											
Approved by: CFO											
Date: 15/09/2025											
Version: 1.0											
Page: 1 of 1											
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Carbon sequestration in trees

Inspired version of the 3P model (Xenakis et al. 2006). This version, despite requires data on an explicit environmental modifier to calculate the impact of climate change on growth (the third P) (representing the total effect of environmental modifier) requires a value of annual incoming solar radiation, a modifier for the age-related decline in productivity, a light extinction coefficient and specific leaf area. The model calculates gross primary productivity (GPP) and net primary production (NPP) through a standard route. It allocates NPP to roots, wood and foliage. A soil model calculates the size of old and young carbon pools, respiration losses from these pools and from the net ecosystem exchange.

The model does not need temperature-related data. The impact of the environment at the site is included by adjusting the environmental modifier, based on site yield class and temperature. Light is converted to energy (GPP) using quantum yield efficiency (QYIE) to assess, making it easier to develop the model for many species even for a grouping such as "conifers" or "deciduous".

Calibration for Sitka Spruce gives $QYIE = 0.08$ (mole/m²/s) $LE = 2.21$ (m²/mol), and $SP_{OPE} = 0.05$ (mole/m²/s) $LE = 1.37$ (m²/mol).

RESULTS	Production	Net Primary Production	Total		Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
			Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max		
		Net loss in forest primary production over lifetime of wind farm (t C ha ⁻¹)	349	349	349	240	240	240	IN/A	IN/A	IN/A	457	457	457	IN/A	IN/A	IN/A	IN/A	IN/A
		Total forest net primary production at felling for wind farm (t C ha ⁻¹)	71	71	71	136	136	136	IN/A	IN/A	IN/A	7	7	7	IN/A	IN/A	IN/A	IN/A	IN/A
		Net primary production of replanted forest assuming same species replanted and managed over lifespan of windfarm (t C ha ⁻¹)	457	457	457	#REF!	#REF!	#REF!	IN/A	IN/A	IN/A	457	457	457	IN/A	IN/A	IN/A	IN/A	IN/A

[illegible]

Carbon sequestration in soil under trees

Note. More data needed. This should be the respiration from newly felled and disturbed soil, so as to include respiration from fresh plant inputs, from background soil organic matter decomposition, and from the disturbance of soil resulting in the release of additional C from soil aggregates. Different types of management disturbance should be considered. This information is not yet available, but will become available following experiments to be done by Mike Perks during 2009-2012. As an interim measure, C sequestration in soil under trees is used, so including background respiration from soil organic matter decomposition and respiration from fresh plant input.

Carbon Sequestration in Soil

<u>Under Trees:</u> <u>Lookup</u>	
<u>Table</u>	
Peaty Gley (t C ha ⁻¹ yr ⁻¹)	Deep Peat (t C ha ⁻¹ yr ⁻¹)
3.98	5.00

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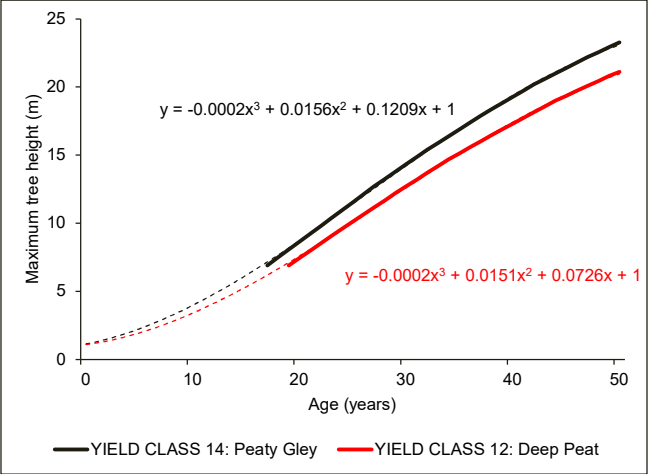
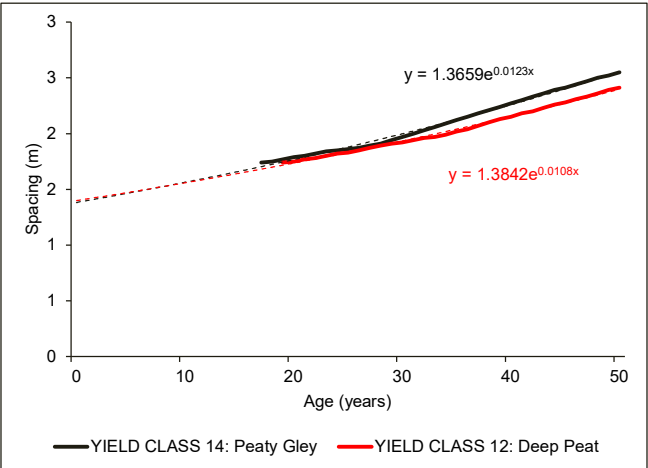
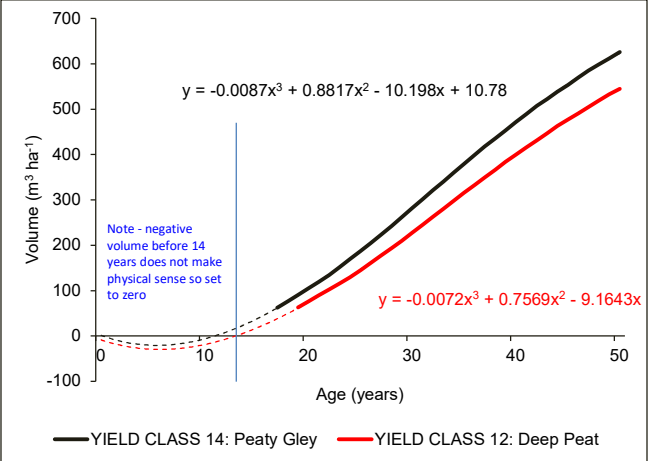
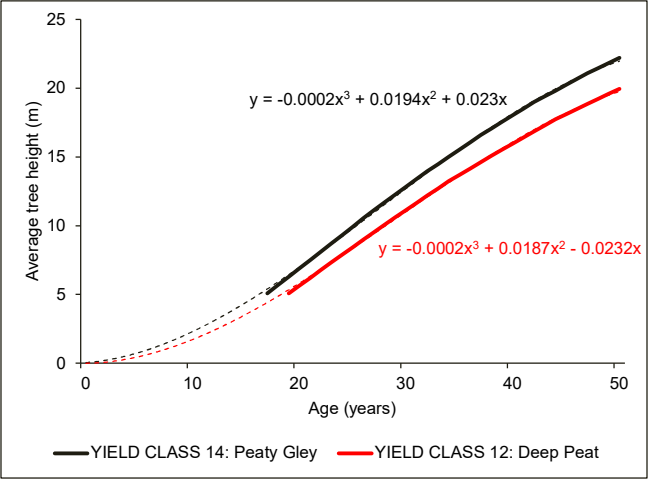
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Average stand data	
Data obtained from Forestry Commission growth and yield tables (Edwards & Christie, 1981)	

STAND_ID ForestGALES
SPECIES Sitka Spruce

YIELD CLASS 14: Peaty Gley

Yield class	Initial Spacing (m)	Age (years)	Average tree height (m)	Volume m ³ ha ⁻¹	Spacing (m)	Maximum tree height (m)
14	1.7	0	0.00	0.0	1.37	1.00
14	1.7	1	0.04	0.0	1.38	1.14
14	1.7	2	0.12	0.0	1.40	1.30
14	1.7	3	0.24	0.0	1.42	1.50
14	1.7	4	0.39	0.0	1.43	1.72
14	1.7	5	0.58	0.0	1.45	1.97
14	1.7	6	0.79	0.0	1.47	2.24
14	1.7	7	1.04	0.0	1.49	2.54
14	1.7	8	1.32	0.0	1.51	2.86
14	1.7	9	1.63	0.0	1.53	3.21
14	1.7	10	1.97	0.0	1.54	3.57
14	1.7	11	2.33	0.0	1.56	3.95
14	1.7	12	2.72	0.0	1.58	4.35
14	1.7	13	3.14	0.0	1.60	4.77
14	1.7	14	3.58	6.2	1.62	5.20
14	1.7	15	4.04	16.1	1.64	5.65
14	1.7	16	4.52	26.9	1.66	6.11
14	1.7	17	5.08	62	1.74	6.9
14	1.7	18	5.68	76.4	1.75	7.48
14	1.7	19	6.29	90.8	1.77	8.06
14	1.7	20	6.90	105.2	1.79	8.64
14	1.7	21	7.51	119.6	1.8	9.22
14	1.7	22	8.11	134	1.82	9.8
14	1.7	23	8.72	151.8	1.84	10.38
14	1.7	24	9.33	169.6	1.85	10.96
14	1.7	25	9.93	187.4	1.86	11.54
14	1.7	26	10.54	205.2	1.87	12.12
14	1.7	27	11.15	223	1.89	12.7
14	1.7	28	11.71	242.6	1.91	13.24
14	1.7	29	12.28	262.2	1.94	13.78
14	1.7	30	12.84	281.8	1.97	14.32
14	1.7	31	13.41	301.4	2	14.86
14	1.7	32	13.97	321	2.03	15.4
14	1.7	33	14.50	340.4	2.06	15.9
14	1.7	34	15.02	359.8	2.09	16.4
14	1.7	35	15.54	379.2	2.12	16.9
14	1.7	36	16.07	398.6	2.15	17.4
14	1.7	37	16.59	418	2.18	17.9
14	1.7	38	17.07	435.8	2.21	18.36
14	1.7	39	17.55	453.6	2.24	18.82
14	1.7	40	18.04	471.4	2.27	19.28
14	1.7	41	18.52	489.2	2.3	19.74
14	1.7	42	19.00	507	2.33	20.2
14	1.7	43	19.42	522.6	2.36	20.6
14	1.7	44	19.84	538.2	2.39	21
14	1.7	45	20.25	553.8	2.41	21.4
14	1.7	46	20.67	569.4	2.44	21.8
14	1.7	47	21.09	585	2.47	22.2
14	1.7	48	21.47	598.6	2.5	22.56
14	1.7	49	21.85	612.2	2.52	22.92
14	1.7	50	22.22	625.8	2.55	23.28



YIELD CLASS 12: Deep Peat

Yield class	Initial Spacing (m)	Age (years)	Average tree height (m)	Volume m ³ ha ⁻¹	Spacing (m)	Maximum tree height (m)
12	1.7	0	0.00	0.0	1.38	1.00
12	1.7	1	0.00	0.0	1.40	1.09
12	1.7	2	0.03	0.0	1.41	1.20
12	1.7	3	0.09	0.0	1.43	1.35
12	1.7	4	0.19	0.0	1.45	1.52
12	1.7	5	0.33	0.0	1.46	1.72
12	1.7	6	0.49	0.0	1.48	1.94
12	1.7	7	0.69	0.0	1.49	2.18
12	1.7	8	0.91	0.0	1.51	2.44
12	1.7	9	1.16	0.0	1.53	2.73
12	1.7	10	1.44	0.0	1.54	3.04
12	1.7	11	1.74	0.0	1.56	3.36
12	1.7	12	2.07	0.0	1.58	3.70
12	1.7	13	2.42	0.0	1.59	4.06
12	1.7	14	2.79	0.3	1.61	4.43
12	1.7	15	3.18	8.5	1.63	4.81
12	1.7	16	3.60	17.6	1.65	5.21
12	1.7	17	4.03	27.6	1.66	5.62
12	1.7	18	4.47	38.3	1.68	6.03
12	1.7	19	5.08	63	1.74	6.9
12	1.7	20	5.64	76.2	1.75	7.44
12	1.7	21	6.21	89.4	1.77	7.98
12	1.7	22	6.77	102.6	1.78	8.52
12	1.7	23	7.34	115.8	1.8	9.06
12	1.7	24	7.90	129	1.82	9.6
12	1.7	25	8.45	145.2	1.83	10.12
12	1.7	26	8.99	161.4	1.85	10.64
12	1.7	27	9.54	177.6	1.87	11.16
12	1.7	28	10.08	193.8	1.89	11.68
12	1.7	29	10.62	210	1.91	12.2
12	1.7	30	11.15	227.6	1.92	12.7
12	1.7	31	11.67	245.2	1.94	13.2
12	1.7	32	12.19	262.8	1.96	13.7
12	1.7	33	12.72	280.4	1.97	14.2
12	1.7	34	13.24	298	1.99	14.7
12	1.7	35	13.70	315.2	2.02	15.14
12	1.7	36	14.16	332.4	2.04	15.58
12	1.7	37	14.62	349.6	2.07	16.02
12	1.7	38	15.08	366.8	2.1	16.46
12	1.7	39	15.54	384	2.13	16.9
12	1.7	40	15.98	399.8	2.15	17.32
12	1.7	41	16.42	415.6	2.18	17.74
12	1.7	42	16.86	431.4	2.2	18.16
12	1.7	43	17.30	447.2	2.23	18.58
12	1.7	44	17.74	463	2.26	19
12	1.7	45	18.12	477	2.28	19.36
12	1.7	46	18.50	491	2.31	19.72
12	1.7	47	18.87	505	2.33	20.08
12	1.7	48	19.25	519	2.36	20.44
12	1.7	49	19.63	533	2.39	20.8
12	1.7	50	19.96	544.8	2.41	21.12

Gains due to site improvement

Note: 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).

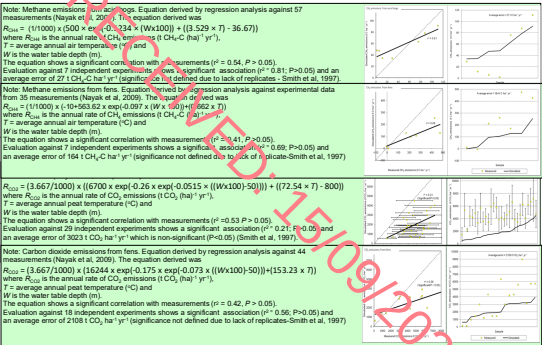
Selected Methodology = IPCC default
Type of peatland = Fen

Reduction in GHG emissions due to improvement of site	Expected result				Minimum result				Maximum result			
	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Hardstanding	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Hardstanding	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Hardstanding
1. Description of site												
Period of time when effectiveness of the improvement can be quantified (years)	0	15	0	35	0	15	0	35	0	15	0	35
Area to be improved (ha)	0	0	0	0	0	0	0	0	0	0	0	0
Average air temperature at site (°C)	10	10	10	10	4.3	4.3	4.3	4.3	14.3	14.3	14.3	14.3
Depth of peat drained (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Depth of peat above water table before improvement (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Depth of peat above water table after improvement (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Losses with improvement												
Flooded period (days year ⁻¹)	169	169	169	169	169	169	169	169	169	169	169	169
Time required for hydrology and habitat to return to its previous state on restoration (years)	0	15	0	35	0	15	0	35	0	15	0	35
Improved period (years)	0	0	0	0	0	0	0	0	0	0	0	0
Methane emissions from improved land												
Site specific methane emission from improved soil on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.499	0.499	0.499	0.499	0.479	0.479	0.479	0.479	0.514	0.514	0.514	0.514
Site specific methane emission from improved soil on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.560	0.560	0.560	0.560	0.556	0.556	0.556	0.556	0.563	0.563	0.563	0.563
IPCC annual rate of methane emission on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
IPCC annual rate of methane emission on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219
Selected annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Carbon dioxide emissions from improved land												
Site specific CO ₂ emission from improved soil on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	0.53	0.53	0.53	0.53	-0.99	-0.99	-0.99	-0.99	1.67	1.67	1.67	1.67
Site specific CO ₂ emissions from improved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	5.68	5.68	5.68	5.68	2.47	2.47	2.47	2.47	8.09	8.09	8.09	8.09
IPCC annual rate of carbon dioxide emission on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IPCC annual rate of carbon dioxide emission on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Selected annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂ emissions from improved land (t CO ₂)	0	0	0	0	0	0	0	0	0	0	0	0
Total GHG emissions from improved land (t CO₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
3. Losses without improvement												
Flooded period (days year ⁻¹)	0	0	0	0	0	0	0	0	0	0	0	0
Time required for hydrology and habitat to return to its previous state on restoration (years)	0	15	0	35	0	15	0	35	0	15	0	35
Improved period (years)	0	0	0	0	0	0	0	0	0	0	0	0
Methane emissions from unimproved land												
Site specific methane emission from unimproved soil on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.499	0.499	0.499	0.499	0.479	0.479	0.479	0.479	0.514	0.514	0.514	0.514
Site specific methane emission from unimproved soil on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.560	0.560	0.560	0.560	0.556	0.556	0.556	0.556	0.563	0.563	0.563	0.563
IPCC annual rate of methane emission on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IPCC annual rate of methane emission on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Selected annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CH ₄ emissions from unimproved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Carbon dioxide emissions from unimproved land												
Site specific CO ₂ emission from unimproved soil on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	0.53	0.53	0.53	0.53	-0.99	-0.99	-0.99	-0.99	1.67	1.67	1.67	1.67
Site specific CO ₂ emissions from unimproved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	5.68	5.68	5.68	5.68	2.47	2.47	2.47	2.47	8.09	8.09	8.09	8.09
IPCC annual rate of carbon dioxide emission on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20
IPCC annual rate of carbon dioxide emission on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20
Selected annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20
CO ₂ emissions from unimproved land (t CO ₂)	0	0	0	0	0	0	0	0	0	0	0	0
Total GHG emissions from unimproved land (t CO₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
RESULTS												
4. Reduction in GHG emissions due to improvement of site												
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Reduction in GHG emissions due to improvement (t CO₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Additional CO₂ payback time of windfarm due to site improvement												
... coal-fired electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0
... grid-mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0
... fossil fuel - mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0

Click here to move to Payback Tm [Click here](#)

Gains due to site improvement

Note: 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).



Note: Methane emissions from acid bogs. As above

Note: Methane emissions from fens. As above

Note: CO₂ emissions from acid bogs. As above

Note: CO₂ emissions from fens. As above

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