

Scottish Government Windfarm Carbon Assessment Tool - Version 2.9.0

26/03/2014

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 2.9.0 - Includes multiple regions for forestry and construction (access to calculation worksheets protected for planning purposes) .
Revised by J.U.Smith to correct forestry and resotration sheets
Version 2.9.1 - Equivalent to version 2.8.0 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

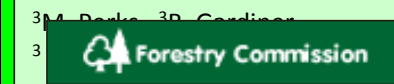
Notes on calculations are given in pale green text boxes.... [Click here to see example of Notes Box](#)

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

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?

Yes ▼

i.e. is the soil organo-mineral or organic, (i.e. a peaty gley or peat)?

3. Does windfarm construction require a significant amount of deforestation?

No ▼

i.e. is removal in excess of keyholing the turbines within the forest boundary?

You should use this tool because the soil is highly organic.

Please move to the Core input data sheet and complete 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](#)

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		Possible range of values			
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Windfarm characteristics						
Dimensions						
No. of turbines	16	Fixed	16		16	
Lifetime of windfarm (years)	25		25		25	
Performance						
Power rating of turbines (turbine capacity) (MW)	3.4		3.4		3.4	
Capacity factor	Direct input of capacity factor		Direct input of capacity factor		Direct input of capacity factor	
Enter estimated capacity factor (percentage efficiency)	32.9		30.4		35.4	
Backup						
Extra capacity required for backup (%)	5		0		5	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10		10		10	
Carbon dioxide emissions from turbine life - (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity		Calculate wrt installed capacity		Calculate wrt installed capacity	
Characteristics of peatland before windfarm development						
Type of peatland	Acid bog		Acid bog		Acid bog	
Average annual air temperature at site (°C)	7.5		3.9		11.2	
Average depth of peat at site (m)	0.65		0.50		1.00	
C Content of dry peat (% by weight)	55		49		62	
Average extent of drainage around drainage features at site (m)	7.50		5.00		10.00	
Average water table depth at site (m)	0.30		0.20		0.40	
Dry soil bulk density (g cm ⁻³)	0.25		0.20		0.45	
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	3		2		5	
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha ⁻¹ yr ⁻¹)	0.25		0.12		0.31	
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)	0		0		0	
Average rate of carbon sequestration in timber (tC ha ⁻¹ yr ⁻¹)						
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)	0.907		0.907		0.907	
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.4		0.4		0.4	
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.652		0.652		0.652	
Borrow pits						
Number of borrow pits	2		2		2	
Average length of pits (m)	200		150		250	
Average width of pits (m)	100		75		125	
Average depth of peat removed from pit (m)	0.00		0.00		0.00	
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						
Average depth of peat removed from turbine foundations (m)						
Average depth of peat removed from hard-standing (m)						
Access tracks						
Total length of access track (m)	12070		12070		12070	
Existing track length (m)	0		0		0	
Length of access track that is floating road (m)	1700		1600		1800	
Floating road width (m)	6		6		6	
Floating road depth (m)	0.00		0.00		0.00	
Length of floating road that is drained (m)	1700		1600		1800	
Average depth of drains associated with floating roads (m)	0.50		0.50		0.50	
Length of access track that is excavated road (m)	5600		5500		5700	
Excavated road width (m)	6		6		6	
Average depth of peat excavated for road (m)	0.70		0.50		0.90	
Length of access track that is rock filled road (m)	4770		4970		4570	
Rock filled road width (m)	6		6		6	
Rock filled road depth (m)	0		0		0	
Length of rock filled road that is drained (m)	4770		4970		4570	
Average depth of drains associated with rock filled roads (m)	0.50		0.50		0.50	
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)	20048		19500		20500	
Area of additional peat excavated (m ²)	30225.0		30000.0		30500.0	
Peat Landslide Hazard						
Weblink: 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)						
Water table depth in degraded bog before improvement (m)						
Water table depth in degraded bog after improvement (m)						
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)						
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)						
Improvement of felled plantation land						
Area of felled plantation to be improved (ha)						
Water table depth in felled area before improvement (m)						
Water table depth in felled area after improvement (m)						
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)						
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)						
Restoration of peat removed from borrow pits						
Area of borrow pits to be restored (ha)	2		2		2	
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.20		0.10		0.30	
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.30		0.20		0.40	
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	3.0		2.0		4.0	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	22		23		21	
Early removal of drainage from foundations and hardstanding						
Water table depth around foundations and hardstanding before restoration (m)						
Water table depth around foundations and hardstanding after restoration (m)						
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)						
Restoration of site after decommissioning						
Will the hydrology of the site be restored on decommissioning?	No		No		No	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes		Yes		No	
Will you attempt to block all artificial ditches and facilitate rewetting?	No		No		No	
Will the habitat of the site be restored on decommissioning?	No		No		No	
Will you control grazing on degraded areas?	Yes		Yes		No	
Will you manage areas to favour reintroduction of species	No		No		No	

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/wind/capacityfactors.htm.
 Capacity Factor = Electricity generated during the period [MWh] / (Installed capacity [kW] x number of hours in the period [h])
 The average capacity factor between 1996 and 2004 for Scotland was 30% (DTI, 2006, Energy Trends, March 2006). We recommend that a site-specific capacity factor site should be used (as measured during planning stage). The average capacity factor for the United Kingdom, in 2009, was 27%, and 28% for Scotland (Energy Trends, September 2010).

Note: Extra capacity required for backup. If 20% of national electricity is generated by wind energy, the extra capacity required for backup is 5% of the rated capacity of the wind plant (Dale et al 2004, Energy Policy, 32, 1949-56). We suggest this should be 5% of the actual output. If it is assumed that less than 20% of national electricity is generated by wind energy, a lower percentage should be entered (0%).
 The House of Lords Economic Affairs Committee report on The Economics of Renewable Energy (2008) (www.parliament.the-stationery-office.co.uk/pa/080708/heloc/ef/ef080702.htm#h3) 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%

Note: Emissions from turbine life. If total emissions for the windfarm are unknown, emissions will be calculated according to turbine capacity. The normal range of CO₂ emissions is 394 to 8147 t CO₂ MW (White & Kulicinski, 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. See Stoneman & Brooks (1997). A 'fen' is a type of wetland fed by surface and/or groundwater. See 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 restate the site will affect likely time for regeneration of the previous habitat. This time could also be shorter if plants regenerate during lifetime of windfarm. If so, enter number of years estimated for regeneration.

Note: Carbon fixation by bog plants. Apparent C accumulation rate in peatland is 0.12 to 0.31 tC ha⁻¹ yr⁻¹ (Turunen et al., 2001; Botch et al., 1995). The SNH guidance uses a value of 0.25 tC ha⁻¹ yr⁻¹.

Note: Area of forestry plantation to be felled. If the forestry 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 (Carmel, 1999).

Note: Coal-Fired Plant and Grid-Mix Emission Factors. Coal-fired plant EF = 0.86 t CO₂ MWh⁻¹; Grid-Mix EF = 0.43 t CO₂ MWh⁻¹. Source = Defra, 2002.

Note: Fossil Fuel-Mix Emission Factor. The 5 year average emission factor calculated using estimated CO₂ emissions for 2002 and 2003 from the National Atmospheric Emission Inventory (Baggott et al., 2007), and for 2004 to 2006 (Digest of UK Energy Statistics, 2007) is 0.607 t CO₂ MWh⁻¹.

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, 2006, Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments, Scottish Executive, Edinburgh, pp. 34-36) so that C losses due to peat landslide can be assumed to be negligible. LINK: <http://www.scotland.gov.uk/Publications/2006/12/21/1623031>

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 (Smith et al. 2007, ECOSSE: Estimating Carbon in Organic Soils - Sequestration and Emissions, Final Report, SERRAD Report, ISBN 978 0 7559 1498 2, 186pp.).

Choice of methodology for calculating emission factors Site specific (required for planning applications) [Click here](#)

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](#)
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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 bare soil is present at site need modified calculation.

Click here to move to Payback Time [Click here](#)
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Input data	Expected values		Possible range of values			
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Windfarm characteristics						
Location						
Distance to nearest biofuel plant (km)						
Dimensions						
Total wind farm area (ha)						
Performance						
Height of turbines (m)						
Average site windspeed (m s ⁻¹)						
Estimated downtime for maintenance etc (%)						
Emissions due to forestry operations						
Emissions from felling (g CO ₂ m ⁻³)						
Emissions of CO ₂ associated with transportation (g CO ₂ km ⁻¹ t ⁻¹)						
Forestry Plantation Characteristics Note - total number of turbines already specified:						
AREA 1						
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	Scots pine		Scots pine		Scots pine	
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 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!)						
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!)						
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 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 publically 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).

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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 [Click here](#)
 Click here to return to Core input data [Click here](#)

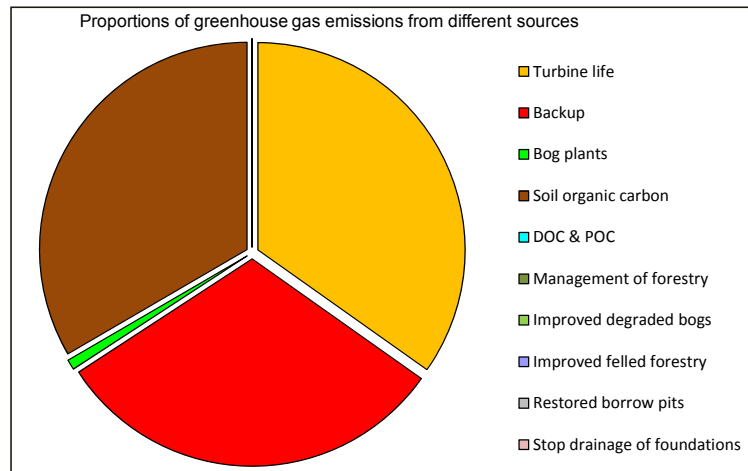
Input data	Expected values		Possible range of values		Record source of data
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	
Construction design					
Note - total number of turbines already specified: 16					
AREA 1					
Number of turbines in this area	7		7		
Turbine foundations					
Depth of hole dug when constructing foundations (m)	0.0		0.0		Peat Survey
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular		
Length at surface (m)	25		25		
Width at surface (m)	25		25		
Length at bottom (m)	25		25		
Width at bottom (m)	25		25		
Hardstanding					
Depth of hole dug when constructing hardstanding (m)	0.0		0.0		Peat Survey
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular		
Length at surface (m)	50		50		
Width at surface (m)	25		25		
Length at bottom (m)	50		50		
Width at bottom (m)	25		25		
Piling					
Is piling used?	No		No		
Volume of Concrete					
Volume of concrete used (m ³)	490		400		750
AREA 2					
Number of turbines in this area	7		7		
Turbine foundations					
Depth of hole dug when constructing foundations (m)	0.9		0.8		
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular		
Length at surface (m)	27.5		25		27.5
Width at surface (m)	27.5		25		27.5
Length at bottom (m)	25		25		25
Width at bottom (m)	25		25		25
Hardstanding					
Depth of hole dug when constructing hardstanding (m)	0.7		0.5		0.9
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular		
Length at surface (m)	50		50		50
Width at surface (m)	25		25		25
Length at bottom (m)	50		50		50
Width at bottom (m)	25		25		25
Piling					
Is piling used?	No		No		
Volume of Concrete					
Volume of concrete used (m ³)	490		400		750
AREA 3					
Number of turbines in this area	2		2		
Turbine foundations					
Depth of hole dug when constructing foundations (m)	1.9		1.7		2.2
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular		
Length at surface (m)	27.5		27.5		27.5
Width at surface (m)	27.5		27.5		27.5
Length at bottom (m)	25		25		25
Width at bottom (m)	25		25		25
Hardstanding					
Depth of hole dug when constructing hardstanding (m)	1.2		1.1		1.3
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular		
Length at surface (m)	50		50		50
Width at surface (m)	25		25		25
Length at bottom (m)	50		50		50
Width at bottom (m)	25		25		25
Piling					
Is piling used?	No		No		
Volume of Concrete					
Volume of concrete used (m ³)	490		400		750
AREA 4					
Number of turbines in this area					
Turbine foundations					
Depth of hole dug 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					
Depth of hole dug 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 (m ³)					
AREA 5					
Number of turbines in this area					
Turbine foundations					
Depth of hole dug 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					
Depth of hole dug 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 (m ³)					

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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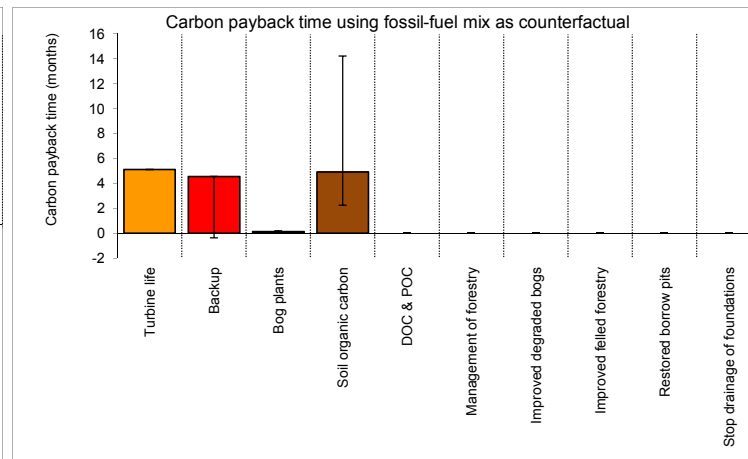
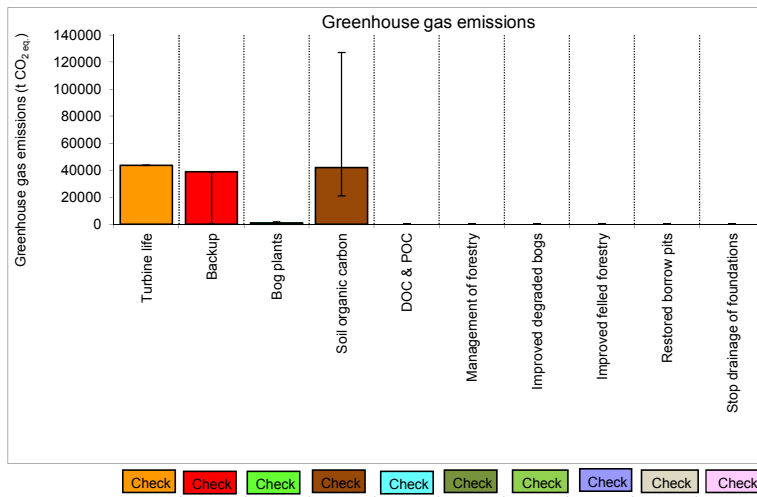
	Exp.	Min.	Max.
1. Windfarm CO₂ emission saving over...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	142289	131483	153094
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	62751	57986	67517
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	102285	94517	110052
Energy output from windfarm over lifetime (MWh)	3921957	3624117	4219797
Total CO₂ losses due to wind farm (t CO₂ eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decommissioning)	43602	43555	43737
3. Losses due to backup	38838	0	38838
4. Losses due to reduced carbon fixing potential	1002	346	1708
5. Losses from soil organic matter	41838	20961	127162
6. Losses due to DOC & POC leaching	0	0	0
7. Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	125280	64862	211446
8. Total CO₂ gains due to improvement of site (t CO₂ eq.)			
8a. Gains due to improvement of degraded bogs	0	0	0
8b. Gains due to improvement of felled forestry	0	0	0
8c. Gains due to restoration of peat from borrow pits	0	0	0
8d. Gains due to removal of drainage from foundations & hardstanding	0	0	0
Total gains	0	0	0

RESULTS			
	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO₂ eq.)	125280	64862	211446
Carbon Payback Time			
...coal-fired electricity generation (years)	0.9	0.4	1.6
...grid-mix of electricity generation (years)	2.0	1.0	3.6
...fossil fuel - mix of electricity generation (years)	1.2	0.6	2.2
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	No gains!	No gains!	No gains!
Ratio of CO₂ eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	32	18	50



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

Greenhouse gas emissions	Exp.	Min	Max
Turbine life	43602	47	135
Backup	38838	38838	0
Bog plants	1002	656	706
Soil organic carbon	41838	20877	85325
DOC & POC	0	0	0
Management of forestry	0	0	0
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



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

Greenhouse gas emissions	Exp.	Min.	Max.	Carbon payback time (months)		
				Exp.	Min.	Max.
Turbine life	43602	47	135	5	0	0
Backup	38838	38838	0	5	5	0
Bog plants	1002	656	706	0	0	0
Soil organic carbon	41838	20877	85325	5	3	9
DOC & POC	0	0	0	0	0	0
Management of forestry	0	0	0	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
	125280			15		

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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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	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	Exp	Min	Max
Power Generation Characteristics																		
No. of turbines	16	16	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Power rating of turbines (turbine capacity) (MW)	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Power of windfarm (MW)	54.4	54.4	54.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estimated downtime for maintenance etc (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Counterfactual emission factors																		
Coal-fired plant emission factor (t CO ₂ MWh ⁻¹)	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652

Calculation of capacity factor		Direct input of capacity factor		
	Exp	Min	Max	
Entered capacity factor (%)	32.92	30.42	35.42	

Parameters	Slope (a)			Intercept (b)		
	Exp	Min	Max	Exp	Min	Max
Partial power curves for different turbines						
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

Calculation of capacity factor from forestry management	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	Exp	Min	Max
Wind speed ratio calculated in 7d	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average site windspeed (m s ⁻¹)	29784	29784	29784	29784	29784	29784	29784	29784	29784	29784	29784	29784	29784	29784	29784	29784	29784	29784
Annual theoretical energy output from turbine (MW turbine ⁻¹ yr ⁻¹)																		
Power curve				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	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	Partial power curves for different turbines	Partial power curves for different turbines
(Power curve code)				1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slope (a)				0	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp
Intercept (b)				0	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp
Annual power output from an individual turbine (MW turbine ⁻¹ yr ⁻¹)																		
Calculated capacity factor (%)																		

Calculation of annual energy output from wind farm	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	Exp	Min	Max
Direct input of capacity factor	33	30	35	33	30	35	33	30	35	33	30	35	33	30	35	33	30	35
Capacity factor (%)																		
Annual energy output from windfarm (MW yr ⁻¹)	156878	144965	168792	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RESULTS	Total			Area 1			Area 2			Area 3			Area 4			Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Windfarm CO ₂ emission saving over...																		
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	142289	131483	153094	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	62751	57985.9	67516.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	102285	94517	110052	0	0	0	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 CO₂ emissions from turbine life (eg. manufacture, construction, decommissioning)? Calculate wrt installed capacity

	Exp	Min	Max
Direct input of emissions due to turbine life (t CO ₂ windfarm ⁻¹)	0	0	0
Calculation of emissions due to turbine life from energy output			
CO ₂ emissions due to turbine life (tCO ₂ turbine ⁻¹)	2709	2709	2709
No. of turbines	16	16	16
Total calculated CO ₂ emission of the wind farm due to turbine life (t CO ₂ windfarm ⁻¹)	43348	43348	43348

	Exp	Total Min	Max	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
Calculation of emissions due to cement used in construction																		
Volume of cement used (m ³)	1470	1200	2250	490	400	750	490	400	750	490	400	750	0	0	0	0	0	0
CO ₂ emission rate (t CO ₂ m ⁻³ cement)	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173
Total CO ₂ emissions due to cement used in construction	254	208	389	85	69	130	85	69	130	85	69	130	0	0	0	0	0	0

RESULTS

Losses due to turbine life (eg. manufacture, construction, decommissioning)	43602	43555	43737
Additional CO₂ payback time of windfarm due to turbine life (eg. manufacture, construction, decommissioning)			
...coal-fired electricity generation (months)	4	4	3
...grid-mix of electricity generation (months)	8	9	8
...fossil fuel - mix of electricity generation (months)	5	6	5

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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.

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Embodied carbon dioxide (ECOD) and construction materials

CONCRETE	Concrete type	ECOD, kgCO ₂ /m ³	ECOD, kgCO ₂ /m ² (nominal)
Binding, mass fill, strip footings, ramps foundations	SEN1 70 mm (CEM I only)	173	75
Trench foundations ¹	SEN1 120 mm ⁺ (CEM I only)	194	80
Reinforced Foundations ¹	RC30 70 mm ⁺⁺⁺ (CEM I only)	318	132
Ground floors ¹	RC30 70 mm ⁺⁺ (CEM I only)	315	133
Structural: in situ floors, superstructure walls, basements	RC40 70 mm ⁺⁺⁺ (CEM I only)	372	153
High strength concrete ¹	RC50 70mm ⁺⁺⁺ (CEM I only)	430	178
Dense concrete aggregate block ²	Precast block	147	75
Aerated concrete block ²	Precast block	121	240
Densic lightweight aggregate block ²	Precast block	168	120
TIMBER		ECOD, kgCO ₂ /m ³	ECOD, kgCO ₂ /m ² (nominal)
Timber, UK Sawn hardwood ⁴		369	473
Timber, UK Sawn softwood ⁴		180	440
Plywood ⁴		309	750
STEEL		ECOD, kgCO ₂ /m ³	ECOD, kgCO ₂ /m ² (nominal)
UK Produced structural steel sections ⁵		15,313	1,632

* includes 25 kg/m³ steel reinforcement
 ++ includes 30 kg/m³ steel reinforcement
 +++ includes 100 kg/m³ steel reinforcement

References:
 1. The ECOD figures for SEN 1, RC30/40 and RC40/50 were derived using industry agreed representative figures for cementitious materials, aggregates, reinforcement, admixtures and an appropriate figure for water.
 2. BRE Environmental Profiles database, Building Research Establishment (BRE), 2006
 3. Construction from the Environment Division, BRSEAM Centre, Building Research Establishment (BRE), 2000
 4. Hammond, G. & Jones, C., 2006. Inventory of Carbon & Energy (ICE) version 1.5 Beta. Department of Mechanical Engineering, University of Bath, UK
 5. Ansaldo, A and Eaton, K.J. A comparative environmental life cycle assessment of modern office buildings. Steel Construction Institute, 1999

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	16	16	16
Power rating of turbines (turbine capacity) (MW)	3.4	3.4	3.4
Power of wind farm (MW h ⁻¹)	54.4	54.4	54.4
Rated capacity (MW yr ⁻¹)	476544	476544	476544
Extra capacity required for backup (%)	5	0	5
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10
Reserve capacity (MWh yr ⁻¹)	2383	0	2383

Carbon dioxide emissions due to backup power generation			
Coal-fired plant emission factor (t CO ₂ MWh ⁻¹)	0.907	0.907	0.907
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.4	0.4	0.4
Fossil fuel- mix emission factor (t CO ₂ MWh ⁻¹)	0.652	0.652	0.652
Lifetime of windfarm (years)	25	25	25
Annual emissions due to backup from...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	2161	0	2161
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	953	0	953
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	1554	0	1554

RESULTS			
Total emissions due to backup from...			
...coal-fired electricity generation (tCO ₂)	54028	0	54028
...grid-mix of electricity generation (tCO ₂)	23827	0	23827
...fossil fuel - mix of electricity generation (tCO ₂)	38838	0	38838
Additional CO₂ payback time of windfarm due to backup			
...coal-fired electricity generation (months)	5	0	4
...grid-mix of electricity generation (months)	5	0	4
...fossil fuel - mix of electricity generation (months)	5	0	4

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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.

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.

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)	155770	138045	178545
Total area affected by drainage due to windfarm construction (m ²)	234749	153249	322306
Total area where fixation by plants is lost (m ²)	390519	291294	500851
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)	25	25	25
Time required for regeneration of bog plants after restoration (years)	3	2	5
Carbon accumulation up to time of restoration (tCO ₂ eq. ha ⁻¹)	26	12	34

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)	39	29	50
Carbon accumulation over lifetime of windfarm (tCO ₂ eq. ha ⁻¹)	26	12	34
Total loss of carbon fixation by plants at the site (t CO₂)	1002	346	1708
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	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

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			
<input type="checkbox"/> CO ₂ loss from removed peat (t CO ₂ equiv)	29105	16009	73545
<input type="checkbox"/> CO ₂ loss from drained peat (t CO ₂ equiv)	12733	4952	53617
RESULTS			
Total CO₂ loss from peat (removed + drained) (t CO₂ equiv)	41838	20961	127162
Additional CO₂ payback time of windfarm due to loss of soil CO₂			
...coal-fired electricity generation (months)	4	2	10
...grid-mix of electricity generation (months)	8	4	23
...fossil fuel - mix of electricity generation (months)	5	3	14

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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).

Volume of Peat Removed

Note: % site lost by peat removal is estimated from peat removed in borrow pits, turbine foundations, hard-standing and access tracks.

If peat is removed for any other reason, this must be added in as additional peat excavated in the core input sheet.

Peat removed from borrow pits	Exp	Total Min	Max
Number of borrow pits	2	2	2
Average length of pits (m)	200	150	250
Average width of pits (m)	100	75	125
Average depth of peat removed from pit (m)	0	0	0
Area of land lost in borrow pits (m ²)	40000	22500	62500
Volume of peat removed from borrow pits (m ³)	0	0	0

Peat removed from turbine foundations	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
Method used to calculate CO ₂ loss from foundations	Enter detailed information																	
Calculation method code	2																	
No. of turbines	16	16	16	7	7	7	7	7	7	2	2	2	0	0	0	0	0	0
Length at surface (m)				25	25	25	27.5	25	27.5	27.5	27.5	27.5	0	0	0	0	0	0
Width at surface (m)				25	25	25	27.5	25	27.5	27.5	27.5	27.5	0	0	0	0	0	0
Length at bottom (m)				25	25	25	25	25	25	25	25	25	0	0	0	0	0	0
Width at bottom (m)				25	25	25	25	25	25	25	25	25	0	0	0	0	0	0
Depth of foundations (m)				0	0	0	0.85	0.8	1	1.91	1.7	2.2	0	0	0	0	0	0
Area of land lost in hard-standing (m ²)	10647	10143.75	10646.88	4375	4375	4375	4878.125	4375	4878.125	1393.75	1393.75	1393.75	0	0	0	0	0	0
Volume of peat removed from foundation area (m ³)	6808.469	5869.375	7944.375	0	0	0	4146.406	3500	4878.125	2662.063	2369.375	3066.25	0	0	0	0	0	0

Peat removed from hard-standing	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
Method used to calculate CO ₂ loss from foundations	Enter detailed information																	
Calculation method code	2																	
No. of turbines	16	16	16	7	7	7	7	7	7	2	2	2	0	0	0	0	0	0
Length at surface (m)				50	50	50	50	50	50	50	50	50	0	0	0	0	0	0
Width at surface (m)				25	25	25	25	25	25	25	25	25	0	0	0	0	0	0
Length at bottom (m)				50	50	50	50	50	50	50	50	50	0	0	0	0	0	0
Width at bottom (m)				25	25	25	25	25	25	25	25	25	0	0	0	0	0	0
Depth of hardstanding (m)				0	0	0	0.85	0.8	1	1.91	1.7	2.2	0	0	0	0	0	0
Area of land lost in hard-standing (m ²)	20000	20000	20000	8750	8750	8750	8750	8750	8750	2500	2500	2500	0	0	0	0	0	0
Volume of peat removed from hardstanding area (m ³)	12212.5	11250	14250	0	0	0	7437.5	7000	8750	4775	4250	5500	0	0	0	0	0	0

Peat removed from access tracks	Exp	Total Min	Max
Floating roads			
Length of access track that is floating road (m)	1700	1600	1800
Floating road width (m)	6	6	6
Floating road depth (m)	0	0	0
Area of land lost in floating roads (m ²)	10200	9600	10800
Volume of peat removed for floating roads	0	0	0
Excavated roads			
Length of access track that is excavated road (m)	5600	5500	5700
Excavated road width (m)	6	6	6
Average depth of peat excavated for road (m)	0.7	0.5	0.9
Area of land lost in excavated roads (m ²)	33600	33000	34200
Volume of peat removed for excavated roads	23520	16500	30780
Rock-filled roads			
Length of access track that is rock filled road (m)	4770	4970	4570
Rock filled road width (m)	6	6	6
Rock filled road depth (m)	0	0	0
Area of land lost in excavated roads (m ²)	28620	29820	27420
Volume of peat removed for rock-filled roads	0	0	0
Total area of land lost in access tracks (m ²)	72420	72420	72420
Total volume of peat removed due to access tracks (m ³)	23520	16500	30780

Additional peat excavated - (not already accounted for above)	Exp	Total Min	Max
Volume of additional peat excavated (m ³)	20048	19500	20500
Area of additional peat excavated (m ²)	30225	30000	30500

RESULTS	Exp	Total Min	Max
Total volume of peat removed (m³) due to windfarm construction	62589	53119.4	73474.4
Total area of land lost due to windfarm construction (m²)	155770	138045	178545

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Volume of Peat Removed

Note: % site lost by peat removal is estimated from peat removed in borrow pits, turbine foundations, hard-standing and access tracks.

If peat is removed for any other reason, this must be added in to the volume of peat removed, area of land lost and % site lost at the bottom of this worksheet.

CO₂ loss from removed peats

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

	Expected	Minimum	Maximum
CO₂ loss from removed peat			
C Content of dry peat (% by weight)	55	49	62
Dry soil bulk density (g cm ⁻³)	0.25	0.20	0.45
% C contained in removed peat that is lost as CO ₂	100	100	100
Total volume of peat removed (m³) due to windfarm construction	62589	53119	73474
CO₂ loss from removed peat (t CO₂)	31558	19089	75171

Assumption: If peat is not restored, 100% of the carbon contained in the removed peat is lost as CO₂

Check

CO₂ loss from undrained peat left in situ			
Total area of land lost due to windfarm construction (ha)	16	14	18
CO ₂ loss from undrained peat left in situ (t CO ₂ ha ⁻¹)	157	223	91
CO₂ loss from undrained peat left in situ (t CO₂)	2453	3081	1626

CO₂ loss attributable to peat removal only			
CO ₂ loss from removed peat (t CO ₂)	31558	19089	75171
CO ₂ loss from undrained peat left in situ (t CO ₂)	2453	3081	1626
RESULTS			
CO₂ loss attributable to peat removal only (t CO₂)	29105	16009	73545

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CO₂ loss from removed peats

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

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

Extent of drainage around each metre of drainage ditch	Exp	Total Min	Max
Average extent of drainage around drainage features at site (m)	8	5	10

Peat affected by drainage around borrow pits	Exp	Total Min	Max
Number of borrow pits	2	2	2
Average length of pits (m)	200	150	250
Average width of pits (m)	100	75	125
Average depth of peat removed from pit (m)	0.0	0.0	0.0
Area affected by drainage per borrow pit (m ²)	4725	2350	7900
Total area affected by drainage around borrowpits (m ²)	9450	4700	15800
Total volume affected by drainage around borrowpits (m ³)	0	0	0

Peat affected by drainage around turbine foundation and hardstanding	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
No. of turbines	16	16	16	7	7	7	7	7	7	2	2	2	0	0	0	0	0	0
Average length of turbine foundations at base (m)				25	25	25	25	25	25	25	25	25	0	0	0	0	0	0
Average width of turbine foundations at base(m)				25	25	25	25	25	25	25	25	25	0	0	0	0	0	0
Average depth of peat removed from turbine foundations (m)				0.0	0.0	0.0	0.9	0.8	1.0	1.9	1.7	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Average length of hard-standing at base (m)				50	50	50	50	50	50	50	50	50	0	0	0	0	0	0
Average width of hard-standing at base (m)				25	25	25	25	25	25	25	25	25	0	0	0	0	0	0
Average depth of peat removed from hard-standing (m)				0.0	0.0	0.0	0.7	0.5	0.9	1.2	1.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Maximum depth of drains (m)				0.0	0.0	0.0	0.9	0.8	1.0	1.9	1.7	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Total length of foundation and hardstanding (m)				75	75	75	75	75	75	75	75	75	0	0	0	0	0	0
Total width of foundation and hardstanding (m)				50	50	50	50	50	50	50	50	50	0	0	0	0	0	0
Area affected by drainage of foundation and hardstanding area (m ²)	6300	4050	8700	2100	1350	2900	2100	1350	2900	2100	1350	2900	0	0	0	0	0	0
Total area affected by drainage of foundation and hardstanding area (m ²)	100800	64800	139200	14700	9450	20300	14700	9450	20300	4200	2700	5800	0	0	0	0	0	0
Total volume affected by drainage of foundation and hardstanding area (m ³)	10259	6075	16530	0	0	0	6248	3780	10150	4011	2295	6380	0	0	0	0	0	0

Peat affected by drainage of access tracks	Exp	Total Min	Max
Floating roads			
Length of floating road that is drained (m)	1700	1600	1800
Floating road width (m)	6.0	6.0	6.0
Average depth of drains associated with floating roads (m)	0.50	0.50	0.50
Area affected by drainage of floating roads (m ²)	35700	25600	46800
Volume affected by drainage of floating roads (m ³)	8925	6400	11700
Excavated Road			
Length of access track that is excavated road (m)	5600	5500	5700
Excavated road width (m)	6	6	6
Average depth of peat excavated for road (m)	0.7	0.5	0.9
Area affected by drainage of excavated roads (m ²)	84000	55000	114000
Volume affected by drainage of excavated roads (m ³)	29400	13750	51300
Rock-filled roads			
Length of rock filled road that is drained (m)	4770	4970	4570
Rock filled road width (m)	6	6	6
Average depth of drains associated with rock filled roads (m)	0.5	0.5	0.5
Area affected by drainage of rock-filled roads (m ²)	1	1	1
Volume affected by drainage of rock-filled roads (m ³)	0	0	0
Total area affected by drainage of access track (m ²)	119701	80601	160801
Total volume affected by drainage of access track (m ³)	38325	20150	63000

Peat affected by drainage of cable trenches	Exp	Total Min	Max
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)	0.0	0.0	0.0
Total area affected by drainage of cable trenches (m ²)	0	0	0
Total volume affected by drainage of cable trenches (m ³)	0.00	0.00	0.00

Drainage around additional peat excavated	Exp	Total Min	Max
Volume of additional peat excavated (m ³)	20048.0	19500.0	20500.0
Area of additional peat excavated (m ²)	30225.0	30000.0	30500.0
Average depth of excavated peat (m)	1	1	1
Radius of area excavated (m)	98	98	99
Radius of excavated and drained area (m)	106	103	109
Total area affected by drainage (m ²)	4799	3149	6505
Total volume affected by drainage (m ³)	3183.09	2012.99	4445.13

Assumption: Area excavated is assumed to be a circle

RESULTS	Exp	Total Min	Max
Total area affected by drainage due to windfarm (m ²)	234749	153249	322306
Total volume affected by drainage due to windfarm (m ³)	51766.71	28238.11	83975.26

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

CO₂ loss due to drainage

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

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	Expected	Minimum	Maximum
Drained Land			
Total area affected by drainage due to wind farm construction (ha)	23	15	32
Will the habitat of the site be restored on decommissioning?	No	No	No

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

Check Total volume affected by drainage due to wind farm (m ³)	51767	28238	83975
C Content of dry peat (% by weight)	55	49	62
Dry soil bulk density (g cm ⁻³)	0.25	0.20	0.45
Total GHG emissions from Drained Land (t CO₂ equiv.)	26101	10148	85914
Total GHG Emissions from Undrained Land (t CO₂ equiv.)	13369	5196	32297

Assumption: Losses of GHG from drained and undrained land have the same proportion throughout the emission period.

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

1. Losses if Land is Drained

Flooded period (days year ⁻¹)	0	0	0
Lifetime of windfarm (years)	25	25	25
Time required for regeneration of bog plants after restoration (years)	3	2	5
Methane Emissions from Drained Land			
Check Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.002	0.006	-0.003
Conversion factor: CH ₄ -C to CO ₂ equivalents	30.67	30.67	30.67
CH ₄ emissions from drained land (t CO ₂ equiv.)	43	82	-84
Carbon Dioxide Emissions from Drained Land			
Check Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	8.16
CO ₂ emissions from drained land (t CO ₂)	7175	6597	7893
Total GHG emissions from Drained Land (t CO₂ equiv.)	7219	6679	7809

Assumption: The drained soil is not flooded at any time of the year.

Note: Conversion = (23 x 16/12) = 30.67 CO₂ equiv. (CH₄-C)⁻¹

2. Losses if Land is Undrained

Flooded period (days year ⁻¹)	178	178	178
Lifetime of windfarm (years)	25	25	25
Time required for regeneration of bog plants after restoration (years)	3	2	5
Methane Emissions from Undrained Land			
Check Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	0.01	0.02
Conversion factor: CH ₄ -C to CO ₂ equivalents	30.67	30.67	30.67
CH ₄ emissions from undrained land (t CO ₂ equiv.)	21	40	282
Carbon Dioxide Emissions from Undrained Land			
Check Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	5.36
CO ₂ emissions from undrained land (t CO ₂)	3676	3380	2654
Total GHG Emissions from Undrained Land (t CO₂ equiv.)	3697	3420	2936

Note: Conversion = (23 x 16/12) = 30.67 CO₂ equiv. (CH₄-C)⁻¹

3. CO₂ Losses due to Drainage

Total GHG emissions from drained land (t CO ₂ equiv.)	26101	10148	85914
Total GHG emissions from undrained land (t CO ₂ equiv.)	13369	5196	32297
RESULTS			
Total GHG emissions due to drainage (t CO₂ equiv.)	12733	4952	53617

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CO₂ loss due to drainage

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

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).

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Selected Methodology = Site specific (required for planning applications)
Type of peatland = Acid Bog

Calculations following IPCC default methodology	Expected	Minimum	Maximum
Emission characteristics of acid bogs (IPCC, 1997)			
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)	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

Calculations following ECOSSE based methodology			
Drained Land			
Total area affected by drainage due to wind farm construction (ha)	23	15	32
Total volume affected by drainage due to wind farm construction (m ³)	51767	28238	83975

Soil Characteristics that Determine Emission Rates			
Average annual air temperature at the site (°C)	7.5	11.2	3.9
Average water table depth at site (m)	0.30	0.40	0.20
Average water table depth of drained land (m)	0.30	0.40	0.26

Annual Emission Rates following site specific methodology			
Acid bogs			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	8.16
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	5.36
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.002	0.006	-0.003
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	0.01	0.02

Fens			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	31.94	47.57	23.64
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	31.94	47.57	14.29
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.026	0.009	0.038
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.03	0.01	0.07

Selected emission characteristics following site specific methodology			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	8.16
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	5.36
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.002	0.006	-0.003
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	0.01	0.02

RESULTS

Selected Emission Rates			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	8.16
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	5.36
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.002	0.006	-0.003
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	0.01	0.02

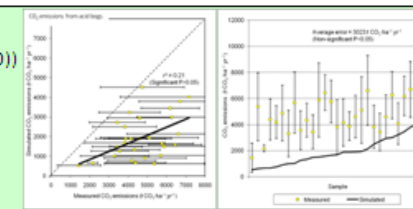
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Assumption: The period of flooding is taken to be 178 days yr⁻¹ for acid bogs and 169 days yr⁻¹ based on the monthly mean temperature and the lengths of inundation (IPCC, 1997, Revised 1996 IPCC guidelines for national greenhouse gas inventories, Vol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

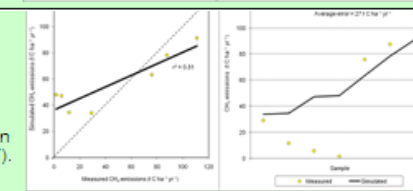
Assumption: The CH₄ emission rate provided for acid bogs is 11 (1-38) mg CH₄-C m⁻² day⁻¹ x 365 days; and for fens is 60 (21-162) mg CH₄-C m⁻² day⁻¹ x 365 days (Aselmann & Crutzen, 1989, J.Atmos.Chem. 8, 307-358)

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).

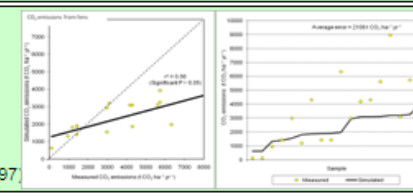
Note: Carbon dioxide emissions from acid bogs. Equation derived by regression analysis against 60 measurements (Nayak et al, 2009). The equation derived was $R_{CO_2} = (3.667/1000) \times ((6700 \times \exp(-0.26 \times \exp(-0.0515 \times ((W \times 100) - 50)))) + ((72.54 \times T) - 800))$ where 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 (r²=0.53 P>0.05). Evaluation against 29 independent experiments shows a significant association (r²=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).



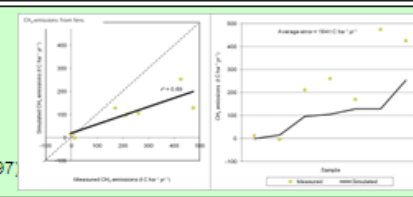
measurements (Nayak et al, 2009). The equation derived was $R_{CH_4} = (1/1000) \times (500 \times \exp(-0.1234 \times (W \times 100))) + ((3.529 \times T) - 36.67)$ where R_{CH_4} is the annual rate of CH₄ emissions (t CH₄-C (ha)⁻¹ yr⁻¹), T = average annual air temperature (°C) and W is the water table depth (m). The equation shows a significant correlation with measurements (r²=0.54, P>0.05). Evaluation against 7 independent experiments shows a significant association (r²=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 (r²=0.42, P>0.05). Evaluation against 18 independent experiments shows a significant association (r²=0.56; 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 (r²=0.41, P>0.05). Evaluation against 7 independent experiments shows a significant association (r²=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).



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).

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)	0	0	0
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
% total soil C losses, lost as POC	8	4	10
% POC loss emitted as CO ₂ over the long term	100	100	100
Total gaseous loss of C (t C)	0	0	0
Total C loss as DOC (t C)	0	0	0
Total C loss as POC (t C)	0	0	0

Note: Only restored drained land included because if land is not restored, the C lost has already been counted as carbon dioxide

Assumption: DOC loss ranges between 7 - 40% of the total gaseous loss if calculated from the reported (minimum and maximum) values in Worrall 2009 and is 26% of the total gaseous loss if calculated from the mean of reported maximum and minimum value in Worrall 2009. These DOC values are flux based on soil water concentration (i.e. 12.5 - 85.9 MgC/KM²/yr) and not on flux at catchment outlet (i.e. 10.3 - 21.8 MgC/KM²/yr)
Worrall, F. et al., 2009. The multi-annual carbon budget of a peat-covered catchment. *Science of The*

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

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/KM²/yr) (Worrall et al, 2009).

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

RESULTS			
Total CO₂ loss due to DOC leaching (t CO₂)	0	0	0
Total CO₂ loss due to POC leaching (t CO₂)	0	0	0
Total CO₂ loss due to DOC & POC leaching (t CO₂)	0	0	0
Additional CO₂ 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)	0	0	0
Carbon sequestered (tC ha ⁻¹ yr ⁻¹)	0	0	0
Lifetime of windfarm (years)	25	25	25
Carbon sequestered over the lifetime of the windfarm (t C ha ⁻¹)	0	0	0
RESULTS			
Total carbon loss due to felling of forestry (t CO₂)	0	0	0
Additional CO₂ payback time of windfarm due to management of forestry			
...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 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.

CO₂ loss from forests - calculation using detailed management information

Forest carbon calculator (Perks et al, 2009)

	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	Exp	Min	Max
Loss of carbon sequestration due to felling of forestry for the wind farm																		
Number of turbines	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area felled around each turbine (ha)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of forestry plantation to be felled for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area replanted around each turbine (ha)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of forestry plantation to be replanted (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area deforested for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon sequestered per hectare for lifetime of the wind farm (t C ha ⁻¹)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total potential carbon sequestration loss due to felling of forestry for the wind farm (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cleared Forest Floor Emissions																		
Soil type				Peaty Gley	Peaty Gley	Peaty Gley	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat
Life time of wind farm (years)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Area deforested for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon released per hectare unforrested (t C ha ⁻¹ yr ⁻¹)				3.98	3.98	3.98	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total emissions due to cleared land (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emissions from harvesting operations																		
Soil type				Peaty Gley	Peaty Gley	Peaty Gley	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat
Emissions from harvesting operations (g CO ₂ m ⁻³)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Age of forest to be felled (years)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of forestry plantation to be felled for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volume of wood felled (m ³ ha ⁻¹)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emissions due to harvesting operations (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Savings from use of felled forestry as biofuel																		
Is timber used as biofuel?				No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Area of forestry plantation to be felled for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon in felled forestry (t C ha ⁻¹) (Carbon : Biomass) ratio of felled forestry				282	282	282	282	282	282	282	282	282	282	282	282	282	282	282
Biomass weight of felled forestry (t)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Value of felled forestry as a biomass fuel (MWh t ⁻¹)				0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Total biomass power value (MWh)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652
Savings in CO ₂ emissions associated with using felled forestry as a biofuel (t CO ₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance to nearest biomass power plant (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emissions of CO ₂ associated with transportation by each km distance (t CO ₂ km ⁻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	0.00	0.00	0.00	0.00	0.00	0.00
Total emissions of CO ₂ associated with transportation (t CO ₂ eq)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil fuel equivalent saving (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Savings from use of replanted forestry as a biofuel																		
Area of replanted forestry (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soil type				Peaty Gley	Peaty Gley	Peaty Gley	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat
Number of years replanted forestry grown on site (years)				25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Carbon in replanted forestry when felled (t C ha ⁻¹) (Carbon : Biomass) ratio of felled forestry				149	149	149	149	149	149	149	149	149	149	149	149	149	149	149
Biomass weight of felled forestry (t)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Value of replanted forestry as a biomass fuel (MWh t ⁻¹)				0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Total biomass power value (MWh)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652	0.652
Savings in CO ₂ emissions associated with using replanted forestry as a biofuel (t CO ₂)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance to nearest biomass power plant (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emissions of CO ₂ associated with transportation (t CO ₂ km ⁻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	0.00	0.00	0.00	0.00	0.00	0.00
Carbon equivalent of transportation (t CO ₂ eq)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil fuel equivalent saving (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RESULTS																		
Total Carbon loss associated with forest management (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Additional CO₂ payback time of windfarm due to management of forestry																		
...coal-fired electricity generation (months)	0	0	0	0	0	0	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	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	0	0	0	0	0	0

CO₂ loss from forests - calculation using detailed management information

Forest carbon calculator (Perks et al, 2009)

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

Under Trees: Lookup
Table

Peaty Gley (t C ha⁻¹ yr⁻¹)	Deep Peat (t C ha⁻¹ yr⁻¹)
3.98	5.00

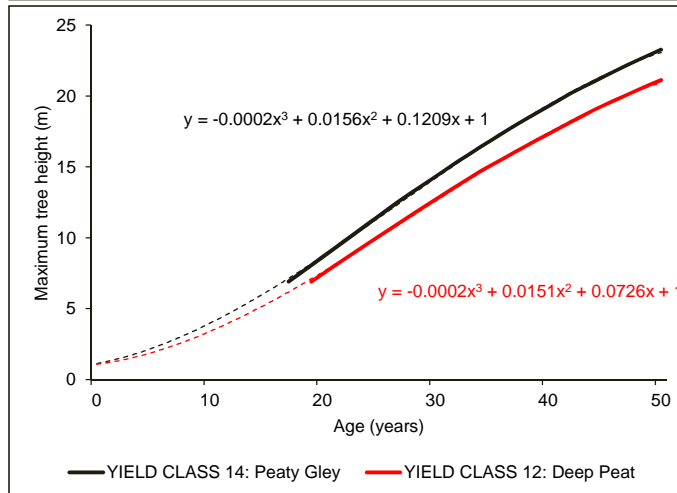
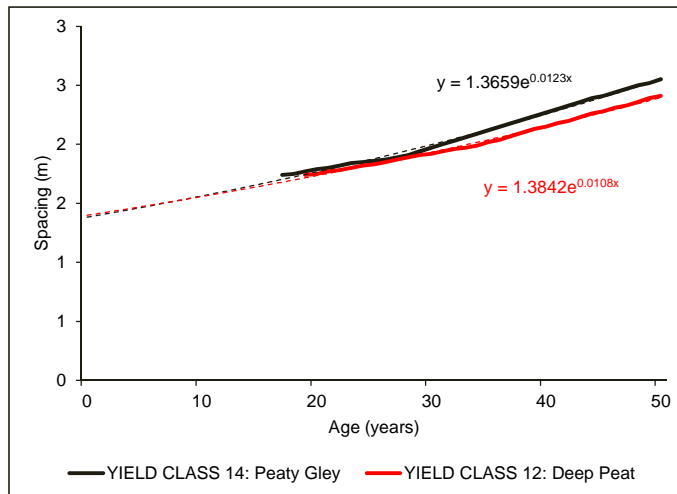
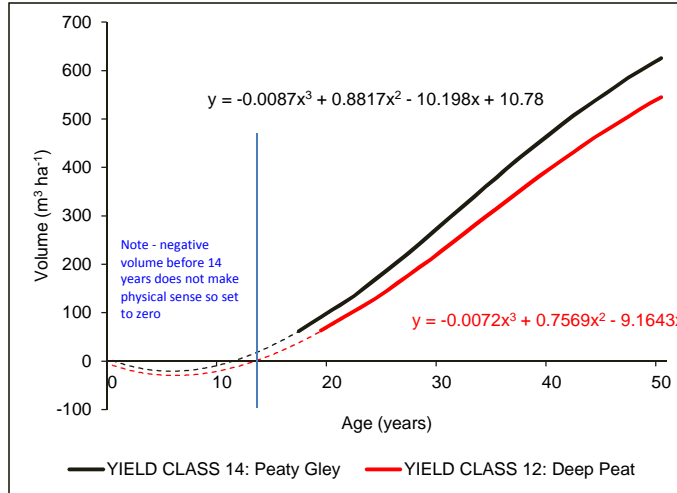
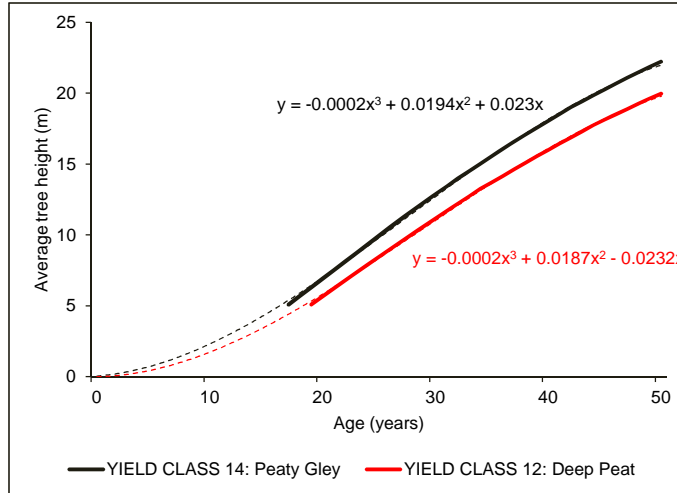
Average stand data

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

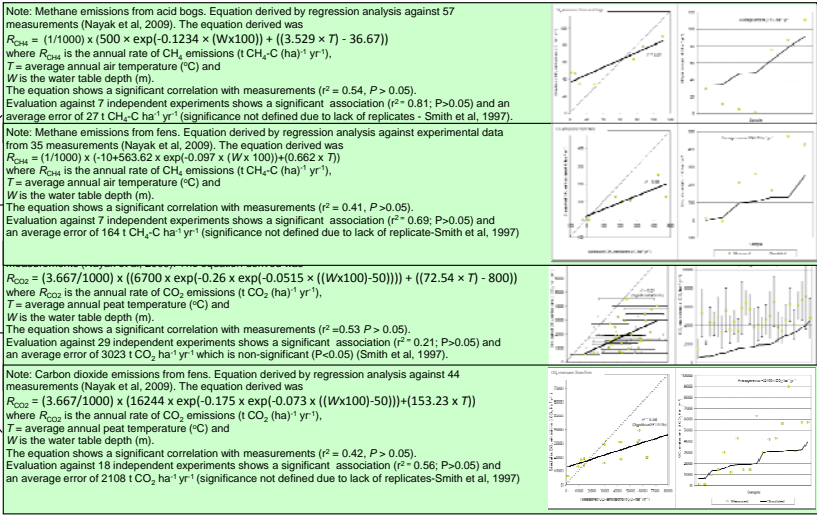
Yield class	Initial Spacing (m)	Age (years)	Average tree height (m)	Volume m ³ ha ⁻¹	Spacing (m)	Maximum tree height (m)
12	1.7	0	0.00	0.0	1.38	1.00
12	1.7	1	0.00	0.0	1.40	1.09
12	1.7	2	0.03	0.0	1.41	1.20
12	1.7	3	0.09	0.0	1.43	1.35
12	1.7	4	0.19	0.0	1.45	1.52
12	1.7	5	0.33	0.0	1.46	1.72
12	1.7	6	0.49	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

2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799	2800
2810	2811	2812	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895	2896	2897	2898	2899	2900																																																	

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 = Site specific (required for planning applications)
 Type of peatland = Acid Bog

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 guaranteed (years)	0	0	22	25	0	0	21	25	0	0	23	25
Area to be improved (ha)	0	0	0	0	0	0	0	0	0	0	0	0
Average air temperature at site (°C)	7.5	7.5	7.5	7.5	3.9	3.9	3.9	3.9	11.2	11.2	11.2	11.2
Depth of peat drained (m)	0.65	0.65	0.00	0.65	0.50	0.50	0.00	0.50	1.00	1.00	0.00	1.00
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)	178	178	178	178	178	178	178	178	178	178	178	178
Time required for hydrology and habitat to return to its previous state on restoration (years)	0	0	3	0	0	0	2	0	0	0	4	0
Improved period (years)	0	0	19	25	0	0	19	25	0	0	19	25
Methane emissions from improved land												
Site specific methane emission from improved soil on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.490	0.490	0.490	0.490	0.477	0.477	0.477	0.477	0.503	0.503	0.503	0.503
Site specific methane emission from improved soil on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.559	0.559	0.559	0.559	0.556	0.556	0.556	0.556	0.561	0.561	0.561	0.561
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)	0.490	0.490	0.490	0.490	0.477	0.477	0.477	0.477	0.503	0.503	0.503	0.503
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)	-0.13	-0.13	-0.13	-0.13	-1.09	-1.09	-1.09	-1.09	0.85	0.85	0.85	0.85
Site specific CO ₂ emissions from improved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	4.27	4.27	4.27	4.27	2.25	2.25	2.25	2.25	6.35	6.35	6.35	6.35
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)	-0.13	-0.13	-0.13	-0.13	-1.09	-1.09	-1.09	-1.09	0.85	0.85	0.85	0.85
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	0	3	0	0	0	2	0	0	0	4	0
Improved period (years)	0	0	19	25	0	0	19	25	0	0	19	25
Methane emissions from unimproved land												
Site specific methane emission from unimproved soil on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.490	0.490	0.490	0.490	0.477	0.477	0.477	0.477	0.503	0.503	0.503	0.503
Site specific methane emission from unimproved soil on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.559	0.559	0.559	0.559	0.556	0.556	0.556	0.556	0.561	0.561	0.561	0.561
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)	0.490	0.490	0.490	0.490	0.477	0.477	0.477	0.477	0.503	0.503	0.503	0.503
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)	-0.13	-0.13	-0.13	-0.13	-1.09	-1.09	-1.09	-1.09	0.85	0.85	0.85	0.85
Site specific CO ₂ emissions from unimproved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	4.27	4.27	4.27	4.27	2.25	2.25	2.25	2.25	6.35	6.35	6.35	6.35
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)	-0.13	-0.13	-0.13	-0.13	-1.09	-1.09	-1.09	-1.09	0.85	0.85	0.85	0.85
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



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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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).

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Frequently Asked Questions

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GENERAL

Syin Yi Phoon (Senior Hydrologist, EnviroCentre Ltd)

Comment: I could see the benefit of protected feature on all the sheets, but it this means we cannot even copy the equations for testing sensitivity of a parameter without changing the entire sheet. The protection should be removed as it reduces the usefulness of the tool.

Response: Protection of sheets removed

Syin Yi Phoon (Senior Hydrologist, EnviroCentre Ltd)

Comment: We miss the carbon payback table that used to be at the bottom of every carbon gain/loss component. Our clients like to see how quickly they can payback C emitted due to individual components. This is useful in planning and should be replaced.

Response: This feature has been replaced

CORE INPUT DATA

Cameron McIver (Cameron Ecology Ltd)

Question: The note on "extra capacity required for backup (%)" suggests there is a choice of % capacity or % output – I'm not clear how you know which you have chosen.

Response: The note is misleading. The number that should be entered is the percentage of the actual output of the windfarm (MWh yr⁻¹) that is required for backup. Text has been added to the note to clarify this.

Stephen Lockett (AECOM)

Question:

Average extent of drainage around drainage features at site (m)

We have reviewed the guidance but are still unsure of what this variable means. We have used a standard input of 100m but the sheet appears to be extremely sensitive to this variable and we have limited confidence on the value chosen. The note in the cell refers to obtaining data on the ground water level but I am unsure how this relates to extent of drainage around drainage features.

Response: Average extent of drainage around each drainage feature can be measured following the method by Stewart and Lance (1991). In order to determine the extent of drainage, the undrained water table depth, and the 95% confidence interval of the measurements are needed.

Possible approach:

1. Install a series of dipwells or boreholes both upslope and downslope from the drainage feature.
2. In the first instance, assume that all dipwells are from undrained areas of the site. This incorrect assumption is used to initialise the iterative process that calculated the water table depth of the undrained soil.
3. For a particular sampling occasion, calculate the mean water table depth and 95% confidence interval from all the available data.
4. Assume all dipwells with water table depths deeper than the calculated mean water table depth plus the 95% confidence interval are within the area that is drained by a ditch and so exclude these from the calculation.
5. Calculate a new mean water table depth and 95% confidence interval using only data from undrained area.
6. Repeat the process until the calculation of the mean water table depth and 95% confidence interval has stabilised, and no further data points need to be excluded. This gives the water table depth of the undrained soil.
7. The distance from the drain to the first dipwell where the water table depth of the undrained soil occurred (to within the 95% confidence interval) can then be assumed to be the total extent of the drainage impact.

Question: Our drainage strategy is to mimic the existing drainage patterns as closely as possible by intercepting surface run-off and discharging at regular intervals downstream of the tracks back onto natural ground. As such, is there an argument this value could be effectively zero?

Response: No – removing water increases the drainage of the site, and this needs to be accounted for. However, if you are following existing drainage patterns, it will be easier to determine the extent of drainage because the drains are already established.

Question: For our example site there is a significant difference in pay back when using site specific and IPCC default values (ranging from 3 to 15 years). Would you be able to provide a brief description of what is being ignored when selecting IPCC default?

Response: The IPCC default takes no account of the previous condition of the site. It provides the result for a typical acid bog or fen across Europe. Therefore, if you are working with an unusually pristine peat or a badly drained peat, you would expect the result to be very different to the average.

Tanya Ogilvy (SEPA)

Question:

Response:

5c. Volume of peat drained

Stephen Lockett (AECOM)

Question: Our new drainage will be surface swales above the ground water table so should not have any effect on the ground water table.

Response: If the surface swales will just convey storm water that would not otherwise have percolated into the soil, these swales will have no impact on the water table of the soil profile, but will only impact the water that would have runoff the surface, causing erosion. However, if the swales also reduce the amount of water entering the soil profile, then they could have an impact on the wetness of the soil. This should really be accounted for in the calculation. However, there is nothing to describe this in the carbon calculator, so you would be justified in neglecting this effect but need to indicate this in the notes.

5e. Emission rates from soils

Stephen Lockett (AECOM)

Question: Rate of carbon dioxide emission

We would expect the rate of emission in undrained soil to be worse than the rate in drained soil. This is only the case when the ground water level is very shallow. Does the output define 'drained soil' as soil which is being drained by our engineering activities and 'undrained soil' as excavated soil which was dry to start with?

Response:

I think the confusion comes about due to the definition of terms.

The "drained soil" refers to the soil after it has been drained for the windfarm development. The "undrained soil" refers to the soil before it was drained for the development. This doesn't refer to the status of the site before the development. Agreed, where a "drained site" refers to a site that has already been drained for a number of years, much of the labile carbon would already have been lost, and so losses due to the windfarm construction would be much less than the losses from an "undrained site" where the peat was still in pristine condition.

Worksheet 5e calculates the rate of emissions of CO₂ and CH₄ for the soil

1. when drained (ie dry soil);
2. when undrained (ie wet soil).

In a drained (dry) soil, we expect high rates of CO₂ emissions and low rates of CH₄ emissions.

In an undrained (wet) soil, we expect high rates of CH₄ emissions and low rates of CO₂ emissions.

These rates are then used in sheet 5d to calculate the net GHG emissions (in CO₂ equivalents) attributable to the windfarm development. This is taken as the difference between the losses following drainage for the development and the losses that were occurring before the soil was drained for the development. Because the net emissions are usually higher in the drained (dry) soil than in the undrained (wet) soil, the net emissions due to draining the site usually come out as positive. If we were to compare a "drained site" and an "undrained site" in sheet 5d, the net CO₂ emissions calculated for the drained site would be much less than for the undrained site because a smaller volume of soil is being further drained by the development.

CHANGES IN VERSION 2.1.0			
Worksheet	Cells	Change	Thanks to...
Core input data	C31, E31, F31	Redundant input for soil pH removed	Ffion Causer, Natural Power
Forestry input data		Different areas of forestry included	N/A
Construction input data		Different areas of construction included	
1. Windfarm CO2 emission savings		Different areas of forestry included	
2. CO2 loss due to turbine life		Different areas of construction included	
5a. Volume of peat removed		Different areas of construction included	
7ii. Forestry CO2 loss - detail		Different areas of forestry included	
7a. C sequest. in trees (3PG)		Different areas of forestry included	
7d. Wind speed ratios		Different areas of forestry included	

CHANGES IN VERSION 2.2.0			
Worksheet	Cells	Change	Thanks to...
Construction input data	C28, C29,...	"Volume cement..." changed to "Volume concrete..."	Marianne Brownlee, Arcus Renewable Energy Consulting
1. Windfarm CO2 emission saving	F49	=IF(F19=1,365*24*F11*F10*G21/100,SUM(L49,L49,O49,R49,U49)) changed to =IF(D19=1,365*24*F11*F10*G21/100,SUM(L49,L49,O49,R49,U49))	Cameron McIver, Cameron Ecology Ltd

CHANGES IN VERSION 2.3.0			
Worksheet	Cells	Change	Thanks to...
5a. Volume of peat removed	F23	=IF('Core input data'!C48=1,'Core input data'!C51,'Construction input data'!D17) changed to =IF('Core input data'!C48=1,'Core input data'!C49,'Construction input data'!D17)	Stuart McGowan, Golder Associates
5a. Volume of peat removed	G23,H23	Similar to above	
5a. Volume of peat removed	F24	=IF('Core input data'!C48=1,'Core input data'!C52,'Construction input data'!D18) changed to =IF('Core input data'!C48=1,'Core input data'!C50,'Construction input data'!D18)	
5a. Volume of peat removed	G24,H24	Similar to above	

CHANGES IN VERSION 2.4.0			
Worksheet	Cells	Change	Thanks to...
5c. Volume of peat drained	F33	=(C9+F31+C9)*(C9+F32+C9)-(F31*F32) changed to =IF(F23>0,(C9+F31+C9)*(C9+F32+C9)-(F31*F32),0)	Stuart McGowan, Golder Associates
5c. Volume of peat drained	G33-T33	Similar to above	

CHANGES IN VERSION 2.5.0			
Worksheet	Cells	Change	Thanks to...
7ii. Forestry CO2 loss - detail	F55	=F50*F53/F54 changed to =IF(F50>0,F50*F53/F54,0)	Jenny Sneddon, AMEC
7ii. Forestry CO2 loss - detail	G55-T55	Similar to above	
7ii. Forestry CO2 loss - detail	F46	=IF(F35="Yes",F44*F45,0) changed to =IF(F35="Yes",IF(F39>0,F44*F45,0),0)	
7ii. Forestry CO2 loss - detail	G46-T46	Similar to above	
7ii. Forestry CO2 loss - detail	F63	=F57*Core input data'!E41-F62 changed to =IF(F55>0,(F57*Core input data'!C41)-F62,0)	
7ii. Forestry CO2 loss - detail	G63-T63	Similar to above	
7ii. Forestry CO2 loss - detail	G38	=Forestry input data'!F39 changed to =Forestry input data'!H39	
7ii. Forestry CO2 loss - detail	J38,M38,P38,S38	Similar to above	
7ii. Forestry CO2 loss - detail	H38	=Forestry input data'!H39 changed to =Forestry input data'!F39	
7ii. Forestry CO2 loss - detail	K38,N38,Q38,T38	Similar to above	
7ii. Forestry CO2 loss - detail	D66	=D17+D24+D32-D47-D63 changed to =D17+D24+D32-E47-E63	
7ii. Forestry CO2 loss - detail	G66, J66, M66, P66, S66	Similar to above	
7ii. Forestry CO2 loss - detail	E66	=E17+E24+E32-E47-E63 changed to =E17+E24+E32-D47-D63	
7ii. Forestry CO2 loss - detail	H66, K66, N66, Q66, T66	Similar to above	
5c. Volume of peat drained	C54	=Core input data'!C68 changed to =Core input data'!C70	SEPA
5c. Volume of peat drained	D54, E54	Similar to above	
5c. Volume of peat drained	D48	=Core input data'!C65 changed to =Core input data'!E65	
5c. Volume of peat drained	E48	Similar to above	
5c. Volume of peat drained	G33	=IF(G23>0,(C9+G31+C9)*(C9+G32+C9)-(G31*G32),0) changed to =IF(G23>0,(C9+G31+G32)*(C9+G32+C9)-(G31*G32),0)	
5c. Volume of peat drained	J33,M33,P33,S33	Similar to above	
5c. Volume of peat drained	H33	=IF(H23>0,(C9+H31+C9)*(C9+H32+C9)-(H31*H32),0) changed to =IF(H23>0,(C9+H31+H32)*(C9+H32+C9)-(H31*H32),0)	
5c. Volume of peat drained	J33,M33,P33,S33	Similar to above	

CHANGES IN VERSION 2.6.0			
Worksheet	Cells	Change	Thanks to...
Payback Time and CO2 emissions	D33	=D31/D9 changed to =D31/E9	Sarah Lister, Natural Power
Payback Time and CO2 emissions	D34,D35	Similar to above	
Payback Time and CO2 emissions	E33	=E31/E9 changed to =E31/D9	
Payback Time and CO2 emissions	E34, E35	Similar to above	
Payback Time and CO2 emissions	D31	=D19+D25 changed to =D19+E25	
Payback Time and CO2 emissions	E31	=E19+E25 changed to =E19+D25	
6. CO2 loss by DOC & POC loss	C11	Contents deleted	Ffion Causer, Natural Power
6. CO2 loss by DOC & POC loss	D11, E11	Similar to above	
6. CO2 loss by DOC & POC loss	C26	=(C9+C12+C13+C14+C15+(C10+C17+C18+C19+C20)/C21)/3.66 changed to =((C9+C12+C13+C14+C15)/3.66)+((C10+C17+C18+C19+C20)/C21)*(12/16)	
6. CO2 loss by DOC & POC loss	D26,E26	Similar to above	
Do I need to use this tool		Wording changed to clarify that the tool SHOULD be used with highly organic soils, but COULD also be used with sites undergoing drainage or deforestation	SEPA
Core input data	C12	Set to 25 and fixed to comply with planning applications for Section 36 (planning period = 25 years)	
Core input data	Row 25	Average depth of peat at site not used - therefore removed	
1. Windfarm CO2 emission saving	D48	Set to AVERAGE(G48,J48,M48,P48,S48) to ensure a value is provided	
1. Windfarm CO2 emission saving	E37	24*365*D11 changed to 24*365*E11	Sarah Lister, Natural Power
1. Windfarm CO2 emission saving	F37-U37	Similar to above	
5e. Emission rates from soils	C34	=C28/(C27*10000) changed to =MAX(C28/(C27*10000),C33)	Ffion Causer, Natural Power
5e. Emission rates from soils	D34, E34	Similar to above	

CHANGES IN VERSION 2.7.0			
Worksheet	Cells	Change	Thanks to...
8. CO2 gain - site improvement	C63	=-12*C61/1. Windfarm CO2 emission saving'!\$D54 changed to =-12*C60/1. Windfarm CO2 emission saving'!\$D54	Sarah Lister, Natural Power
	D63-N63	Similar to above	
	C64	=-12*C62/1. Windfarm CO2 emission saving'!\$D54 changed to =-12*C60/1. Windfarm CO2 emission saving'!\$D54	
	D64-N64	Similar to above	
Core input data	C74	Volume of additional peat excavated added to make the calculation more generalised	Rob McCall, Countryside Council for Wales
	E74, G74	Similar to above	
	C75	Area of additional peat excavated added to make the calculation more generalised	
	E75, G75	Similar to above	
5a. Volume of peat removed	Row 64 - 67	Extra lines added to show the additional peat excavated in this sheet	
	C70	=C14+C27+C39+C62 changed to =C14+C27+C39+C62+C65	
	D70, E70	Similar to above	
	C71	=C13+F26+F38+C61 changed to =C13+F26+F38+C61+C66	
Core input data	B72	"Depth of cable trenches" change to "Average depth of peat cut for cable trenches (m)" to avoid overestimation of peat affected by cable trenches in shallow peats	
Core input data	Row 91	New input: Water table depth in borrow pit before restoration	Sarah Lister, Natural Power
	Row 95	New input: Water table depth around foundations and hardstanding before restoration	
	Row 15	Deleted	
8. CO2 gain - site improvement	C15 (previously C16)	=Core input data'!C45 changed to =Core input data'!C91	
	I15, M15	Similar to above	
	D15 (previously D16)	=Core input data'!C50 changed to =Core input data'!C95	
	J15, N15	Similar to above	
5d. CO2 loss from drained peat	C43	=C8*(C35+C36)*((C42*C34))/365 changed to =C8*(C35+C36)*((C42*(365-C34))/365)	University of Aberdeen
	D43, E43	Similar to above	
2. CO2 loss due to turbine life	C9	=Core input data'!C21*C12*Core input data'!C14*1. Windfarm CO2 emission saving'!D48/100 changed to =Core input data'!C21*C12*Core input data'!C14	Adrian Barnes, WSP Environment & Energy
	D9,E9	Similar to above	

CHANGES IN VERSION 2.7.2

Worksheet	Cells	Change	Comment	Thanks to...
8. CO2 gain - site improvement	C13	=Core input data!C80 changed to =IF('Core input data!C81>'Core input data!C82,'Core input data!C80,0)		Ffion Causer, Natural Power
	G13, K13 D13	Similar to above =Core input data!C85 changed to =IF('Core input data!C86>'Core input data!C87,'Core input data!C85,0)		
	H13,L13 E13	Similar to above =Core input data!C90 changed to =IF('Core input data!C91>'Core input data!C92,'Core input data!C90,0)		
	I13, M13 F13	Similar to above =5c. Volume of peat drained!C34/10000 changed to =IF('Core input data!C95>'Core input data!C96,'5c. Volume of peat drained!C34/10000,0)		
	J13, N13	Similar to above		

CHANGES IN VERSION 2.8.0

Worksheet	Cells	Change	Comment	Thanks to...
5c. Volume of peat drained	Rows 67 - 76	Inserted rows to include additional excavated peat in volume of peat drained	Include additional excavated peat in volume of peat drained	Susana Sebastian, SEPA
	C67-C68; D67-D68; E67-E68	Title lines		
	C69	=Core input data!C74		
	D69,E69	Similar to above		
	C70	=Core input data!C75		
	D70,E70	Similar to above		
	C71	=IF(C70>0,C69/C70,0)		
	D71,E71	Similar to above		
	C72	=SQRT(C70/PI())		
	D72,E72	Similar to above		
	C73	=C72+C9		
	D73,E73	Similar to above		
	C74	=PI()*C73*C73-C70		
	D74,E74	Similar to above		
	C75	=C74*C71		
	D75,E75	Similar to above		
	C79	=C18+C34+C57+C64 changed to =C18+C34+C57+C64+C74		
	D79,E79	Similar to above		
	C80	=C19+C35+C58+C65 changed to =C19+C35+C58+C65+C75		
	D80,E80	Similar to above		
7ii. Forestry CO2 loss - detail	F62	=F60*F61 changed to =F60*F61*F55	Calculation of emissions associated to the transport of wood to biomass plant should account for number of trips to plant	Susana Sebastian, SEPA
Forestry input data	G62-T62	Similar to above		
Core input data	C23	Units changed from g CO2 km ⁻¹ to g CO2 km ⁻¹ t ⁻¹		
8. CO2 gain - site improvement	Row 25	Insert input for average depth of peat at site	Limit improvements following restoration to the depth of the peat	Susana Sebastian, SEPA
	Row 15	Insert average depth of peat at site		
	C15	=Core input data!C25		
	D15-N15 (excl. E15, I15 & M15)	Similar to above		
	E15	=Core input data!C46		
	I15,M15	Similar to above		
	C16	Core input data!C82 changed to =IF('Core input data!C82<C15,'Core input data!C82,C15)		
	D16-N16	Similar to above		
	C17	=Core input data!C83 changed to =IF('Core input data!C83<C15,'Core input data!C83,C15)		
	D17-N17	Similar to above		
	C21	C12-C20 changed to =IF(C12-C20>0,C12-C20,0)		
	D21-N21	Similar to above		
Core input data	Rows 85, 94, 97	Insert period of time when the improvement can be guaranteed to work (years)	Improvements in C sequestration should continue for as long as the improvement can be guaranteed.	Rob McCall, NRW
8. CO2 gain - site improvement	C12	=Core input data!C12 changed to =Core input data!C85		
	D12-N12 (excl. E12, I12 & M12)	Similar to above		
Payback Time and CO2 emissions	Row 37	Insert ratio of soil carbon loss to gain by restoration	Include calculation of ratio of soil losses to gains	Rob McCall, NRW
	C37	=IF(C26<0,-(C17+C18)/C26,0)		
	D637,E37	Similar to above		
Payback Time and CO2 emissions	Row 38	Insert ratio of C emissions to power generation	Include calculation of C emissions to power generation	Susana Sebastian, SEPA
	C38	=((C20+C26)*1000000)/(C12*1000)		
	D637,E37	Similar to above		
5. Loss of soil CO2	D11	=D8+D9 changed to =MIN(D8+D9,E8+E9)	Correct use of minimum and maximum wrt water table depth at very low depths	Peter Batten
	E11	=E8+E9 changed to =MAX(D8+D9,E8+E9)		
5e. Emission rates from soils	D31	=Core input data!E24 changed to =Core input data!G24		
	E31	=Core input data!G24 changed to =Core input data!E24		
	D33	=Core input data!E28 changed to =Core input data!G28		
	E33	=Core input data!G28 changed to =Core input data!E28		
8. CO2 gain - site improvement	G17	=IF('Core input data!E83<G15,'Core input data!E83,G15) changed to =IF('Core input data!G83<G15,'Core input data!G83,G15)	Correct use of minimum and maximum depth of water table after restoration	Jo Smith, University of Aberdeen
	H17-J17 K17	Similar to above =IF('Core input data!G83<K15,'Core input data!G83,K15) changed to =IF('Core input data!E83<K15,'Core input data!E83,K15)		
	L17-N17	Similar to above		
8. CO2 gain - site improvement	G12	=Core input data!E85 changed to =Core input data!G85	Correct use of min/max period when restoration can be restored	Jo Smith, University of Aberdeen
	H12-J12 K12	Similar to above =Core input data!G85 changed to =Core input data!E85		
	L12-N12	Similar to above		
8. CO2 gain - site improvement	C34	=IF('Core input data!\$C\$112=2,'8. CO2 gain - site improvement!C30,'8. CO2 gain - site improvement!C32) changed to =IF('Core input data!\$C\$112=2,IF('Core input data!\$C\$23=1,C30,C31),IF('Core input data!\$C\$23=1,C32,C31))	Correct selection of emission factor when soil type is fen	Elizabeth Keen, Peter Brett Associates LLP
	D34-N34 C53	Similar to above =IF('Core input data!\$C\$112=2,'8. CO2 gain - site improvement!C49,'8. CO2 gain - site improvement!C51) changed to =IF('Core input data!\$C\$112=2,IF('Core input data!\$C\$23=1,C49,C50),IF('Core input data!\$C\$23=1,C51,C52))		
	D53-N53	Similar to above		

CHANGES IN VERSION 2.9.0

Worksheet	Cells	Change	Comment	Thanks to...
Core input data	B94	"Water table depth in borrow pit before restoration (m)" changed to "Depth of water table in borrow pit before restoration with respect to the restored surface (m)"	Confusing wording as water table depth may always be entered as zero.	Clare Wharmby - Carbon Forecast
	B95	"Water table depth in borrow pit after restoration (m)" changed to "Depth of water table in borrow pit after restoration with respect to the restored surface (m)"		
8. CO2 gain - site improvement	C47	=((23*16/12)*C\$13*C\$40*C46*(C\$19/365) changed to =(23*16/12)*C\$13*C\$40*C46*(C\$38/365)	Error in formula using the improved flooded period instead of the unflooded period	Elizabeth Keen - Peter Brett Associates
	D47-N47	Similar to above		
7c. Average stand data	Rows 13-29	Stand data extended from 17 year to 0 years	If forest stand is less than 17 years old, the calculations fail	Brenda Park - AMEC
	Rows 168-86	Similar to above		
7ii. Forestry CO2 loss - detail	F31	=IF(F29>0,IF(F27="Deep Peat",VLOOKUP(F29,7c. Average stand data!\$D\$87:\$G\$118,3)),VLOOKUP(F29,7c. Average stand data!\$D\$30:\$G\$63,3)),0) changed to =IF(F29>0,IF(F27="Deep Peat",VLOOKUP(F29,7c. Average stand data!\$D\$68:\$G\$118,3)),VLOOKUP(F29,7c. Average stand data!\$D\$12:\$G\$63,3)),0)		
	G31-T31	Similar to above		
7ii. Forestry CO2 loss - detail	G35	=IF('Forestry input data!\$F\$33=1,"Yes", "No") changed to =IF('Forestry input data!\$D\$33=1,"Yes", "No")	Use of felled wood as biofuel not correctly read in min and max calculations	Jo Smith - University of Aberdeen
	H35,J35,K35,M35,N35,P35,Q35 S35,T35	Similar to above		
7ii. Forestry CO2 loss - detail	F16	=7a. C sequest. in trees (3PG)!\$F\$24 changed to =IF(F12>0,7a. C sequest. in trees (3PG)!\$F\$24,0)	Avoid #NA	Claire Frost - AECOM
	G16-T16	Similar to above		
Forestry input data	Note: Emissions from felling and timber removal.	"the emissions are 6657 g CO ₂ m ^{-3m} " changed to "the emissions are 6675 g CO ₂ m ^{-3m} "		Jonathon Davison - Mott MacDonald
Forestry input data	Note: Emissions associated with transportation	"3933000 g CO ₂ km ⁻¹ (range 3850000 - 4015000 g CO ₂ km ⁻¹ - average = 39.33 g CO ₂ km ⁻¹ t ⁻¹)" changed to "39.33 g CO ₂ km ⁻¹ t ⁻¹ (range 38.5 - 40.15 g CO ₂ km ⁻¹ t ⁻¹ - average = 39.33 g CO ₂ km ⁻¹ t ⁻¹)"		Jonathon Davison - Mott MacDonald
Payback Time and CO2 emissions	C37	=IF(C26<0,-(C17+C18)/C26,"No gains!")	Ensure no restoration is highlighted as no gains rather than appearing	Sarah Lister, Natural Power
	D637,E37	Similar to above		
Payback Time and CO2 emissions	C38	=((12/44)*(C20+C26)*1000000)/(C12*1000)	Express ratio as CO2 rather than C emissions to power generation	Sarah Lister, Natural Power
	D637,E37	Similar to above		