July 2026

Environmental Impact Assessment Report

Lairdmannoch Energy Park

Technical Appendix 13-1: Carbon Calculator (Additional Information)

Lairdmannoch Energy Park Limited

your project our expertise

Scottish Government Windfarm Carbon Assessment Tool - Version 2.15.0

05/12/2025

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 2.15.0 - Adding counterfactual emission factors
Version 2.15.1 - Equivalent to version 2.15.0 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 CO_2 emission saving
2. CO_2 loss due to turbine life
3. CO_2 loss due to backup
4. Loss of CO_2 Fixing Pot.
5. Loss of soil CO_2
    - 5a. Volume of peat removed
    - 5b. CO_2 loss from removed peat
    - 5c. Volume of peat drained
    - 5d. CO_2 loss from drained peat
    - 5e. Emission rates
6. CO_2 loss by DOC & POC loss
- 7i. Forestry CO_2 loss - simple
- 7ii. Forestry CO_2 loss - detailed
    - 7a. C sequest. in trees (3PG)
    - 7b. C seq. in soil under trees
    - 7c. Average stand data
    - 7d. Windspeed ratios
8. CO_2 gain - site improvement

In addition, there are spreadsheets containing references and requesting feedback.

- References
- Frequently asked questions

Notes on calculations are given in pale green text boxes.... Click here to see example of Notes Box
Protocols for measurements are given in pale yellow comment boxes..... Click here to see example of Protocol Box
Assumptions are given in pale blue text boxes.... Click here to see example of Assumptions Box

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Note on official version number

Version X.Y.Z

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

Officially released versions will always have Z=0

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

The latest version can be obtained from Scottish Government Energy Consents Unit
Email: Econsents_admin@gov.scot

For further information see:
Carbon calculator for wind farms on

Do I need to use this tool?

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

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? Yes
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: Enter expected value here	Record source of data	Possible range of values: Enter minimum value here	Record source of data	Possible range of values: Enter maximum value here	Record source of data
Windfarm characteristics						
Dimensions						
No. of turbines	8		8		8	
Lifetime of windfarm (years)	40		40		40	
Performance						
Power rating of turbines (turbine capacity) (MW)	6.625		6.625		6.625	
Capacity factor	Direct input of capacity fac		Direct input of capacity fac		Direct input of capacity fac	
Enter estimated capacity factor (percentage efficiency)	26.2		23.6		28.8	
Backup						
Extra capacity required for backup (%)	5		5		5	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10		10		10	
Carbon dioxide emissions from turbine life - (eg. manufacture, construction, decommissioning)	Calculate wrt installed cap		Calculate wrt installed cap		Calculate wrt installed cap	
Characteristics of peatland before windfarm development						
Type of peatland	Acid b		Acid b		Acid b	
Average annual air temperature at site (^{o}C)	9.2		6.5		11.89	
Average depth of peat at site (m)	0.46		0.46		0.46	
C Content of dry peat (% by weight)	55.5		49		62	
Average extent of drainage around drainage features at site (m)	10.00		5.00		50.00	
Average water table depth at site (m)	0.30		0.10		0.50	
Dry soil bulk density (g cm^{-3})	0.13		0.07		0.29	
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	10		5		15	
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25		0.12		0.31	
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)	0.77		0.77		0.77	
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	3.60		3.60		3.60	
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})	0.919		0.919		0.919	
Grid-mix emission factor (t CO_2 MWh^{-1})	0.177		0.177		0.177	
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.448		0.448		0.448	
Borrow pits						
Number of borrow pits	1		1		1	
Average length of pits (m)	359.43		359.43		359.43	
Average width of pits (m)	100		100		100	
Average depth of peat removed from pit (m)	0.27		0.27		0.27	
Foundations and hard-standing area associated with each turbine						
Method used to calculate CO_2 loss from foundations and hard-standing	Rectangular with vertical v		Rectangular with vertical v		Rectangular with vertical v	
Average length of turbine foundations (m)	530.875		530.875		530.875	

Note: Capacity factor. The capacity factor of any power plant is the proportion of energy produced during a given period with respect to the energy that would have been produced had the wind farm been running continually and at maximum output (DECC (2004); see also www.bwea.com/ref/capacityfactors.html).
Capacity Factor = Electricity generated during the period [kWh]/ (Installed capacity [kW] x number of hours in the period [h])
We recommend that a site-specific capacity factor ~~site~~ should be used (as measured during planning stage), and should represent the average emission factor expected over the lifetime of the windfarm, accounting for decline in efficiency with age (Hughes, 2012). The 5 year average capacity factor (or "load factor") for UK onshore wind between 2010 and 2014, based on average beginning and end of year capacity, was 29.2% (DUKES, 2015).

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

Note: Extra emissions due to reduced thermal efficiency of the reserve power generation ≈ 10%

Note: Emissions from turbine life. If total emissions for the windfarm are unknown, emissions should be calculated according to turbine capacity. The normal range of CO_2 emissions is 394 to 8147 t CO_2 MW (White & Kulcinski, 2000; White, 2007).

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

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

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

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

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

Note: Coal-fired plant emission factor (EF) from electricity supplied in 2024 = 0.919 t CO_2 MWh^{-1}; Digest of UK Energy Statistics (DUKES): electricity - GOV.UK (updated 31 July 2025) Grid Mix EF for 2025 = 0.17700 t CO_2 MWh^{-1}. Greenhouse gas reporting: conversion factors 2025 - GOV.UK

Note: Fossil Fuel-Mix Emission Factor. The emission factor from electricity supplied in 2024 from all non renewable fuels = 0.448 t CO_2 MWh^{-1} Digest of UK Energy Statistics (DUKES): electricity -

Average width of turbine foundations (m)	1		1		1	
Average depth of peat removed from turbine foundations (m)	0.00		0.00		0.00	
Average length of hard-standing (m)	1519.625		1519.625		1519.625	
Average width of hard-standing (m)	1		1		1	
Average depth of peat removed from hard-standing (m)	0.11		0.10		0.13	
Access tracks						
Total length of access track (m)	12,734.73		12734.73		12734.73	
Existing track length (m)	6100		6100		6100	
Length of access track that is floating road (m)	490		490		490	
Floating road width (m)	5.5		5.5		5.5	
Floating road depth (m)	0.00		0.00		0.00	
Length of floating road that is drained (m)	0		0		0	
Average depth of drains associated with floating roads (m)	0.00		0.00		0.00	
Length of access track that is excavated road (m)	12150		12150		12150	
Excavated road width (m)	5.5		5.5		5.5	
Average depth of peat excavated for road (m)	0.13		0.13		0.13	
Length of access track that is rock filled road (m)	0		0		0	
Rock filled road width (m)	5		5		5	
Rock filled road depth (m)	0		0		0	
Length of rock filled road that is drained (m)	0		0		0	
Average depth of drains associated with rock filled roads (m)	0.00		0.00		0.00	
Cable Trenches						
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0		0		0	
Average depth of peat cut for cable trenches (m)	0.00		0.00		0.00	
Additional peat excavated (not already accounted for above)						
Volume of additional peat excavated (m^3)	6102		6102		6102	
Area of additional peat excavated (m^2)	28488.0		28488.0		28488.0	
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)	88		88		88	
Water table depth in degraded bog before improvement (m)	0.30		0.10		0.50	
Water table depth in degraded bog after improvement (m)	0.10		0.05		0.30	
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	15		5		30	
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	30		30		30	
Improvement of felled plantation land						
Area of felled plantation to be improved (ha)	0		0		0	
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		1.85		1.85	
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.00		0.00		0.00	
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.00		0.00		0.00	
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	30		30		30	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	30		30		30	
Early removal of drainage from foundations and hardstanding						
Water table depth around foundations and hardstanding before restoration (m)	0.30		0.10		0.50	

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

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. 34-35) so that C losses due to peat landslide can be assumed to be negligible. Link: http://www.scotland.gov.uk/Publications/2006/12/21162303/1.

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.

Note: Period of time when improvement can be guaranteed. This gurantee 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

Water table depth around foundations and hardstanding after restoration (m)	0.10		0.50		0.30	
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	5		5		5	
Restoration of site after decomissioning						
Will the hydrology of the site be restored on decommissioning?	Yes		Yes		Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes		Yes		Yes	
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes		Yes		Yes	
Will the habitat of the site be restored on decommissioning?	Yes		Yes		Yes	
Will you control grazing on degraded areas?	Yes		Yes		Yes	
Will you manage areas to favour reintroduction of species	Yes		Yes		Yes	

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%.

Choice of methodology for calculating emission factors	Site specific (required for planning applications)

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. SEERAD Report. ISBN 978 0 7559 1498 2. 166pp.).

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

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

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

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

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

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

Click here to move to Payback Time — Click here

Click here to return to Instructions — Click here

Input data	Expected values: Enter expected value here	Record source of data	Possible range of values: Enter minimum value here	Record source of data	Possible range of values: 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						

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 CO_2 m^{-3}

Note: Emissions associated with transportation. Assuming trasportation 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 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})

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.

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)

Forestry input data
ENTER DETAILS OF FORESTRY MANAGEMENT HERE!
Note: Data only needed if select to calculate capacity factor from forestry data (cell C15 in Core input data sheet), or to include detailed forestry management (cell C35 in Core input data sheet)

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

Construction input data

ENTER DETAILS OFCONSTRUCTION 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: Enter expected value here	Record source of data	Possible range of values: Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Construction design						
Note - total number of turbines already specified:	0		0		0	
AREA 1						
Number of turbines in this area - Error! Total in areas < total on site!						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Diameter at surface (m)						
Diameter at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Diameter at surface (m)						
Diameter at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m^3)						
AREA 2						
Number of turbines in this area - Error! Total in areas < total on site!						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Diameter at surface (m)						
Diameter at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Diameter at surface (m)						
Diameter at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m^3)						

AREA 3			
Number of turbines in this area - Error! Total in areas < total on site!			
Turbine foundations			
Average depth of peat removed when constructing foundations (m)			
Approximate geometric shape of whole dug when constructing foundations			
Diameter at surface (m)			
Diameter at bottom (m)			
Hardstanding			
Average depth of peat removed when constructing hardstanding (m)			
Approximate geometric shape of whole dug when constructing hardstanding			
Diameter at surface (m)			
Diameter at bottom (m)			
Piling			
Is piling used?			
Volume of Concrete			
Volume of concrete used (m^3)			

AREA 4			
Number of turbines in this area - Error! Total in areas < total on site!			
Turbine foundations			
Average depth of peat removed when constructing foundations (m)			
Approximate geometric shape of whole dug when constructing foundations			
Diameter at surface (m)			
Diameter at bottom (m)			
Hardstanding			
Average depth of peat removed when constructing hardstanding (m)			
Approximate geometric shape of whole dug when constructing hardstanding			
Diameter at surface (m)			
Diameter at bottom (m)			
Piling			
Is piling used?			
Volume of Concrete			
Volume of concrete used (m^3)			

AREA 5			
Number of turbines in this area - Error! Total in areas < total on site!			
Turbine foundations			
Average depth of peat removed when constructing foundations (m)			
Approximate geometric shape of whole dug when constructing foundations			
Diameter at surface (m)			
Diameter at bottom (m)			
Hardstanding			

Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Diameter at surface (m)						
Diameter at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m^3)						

Results

PAYBACK TIME AND CO_2 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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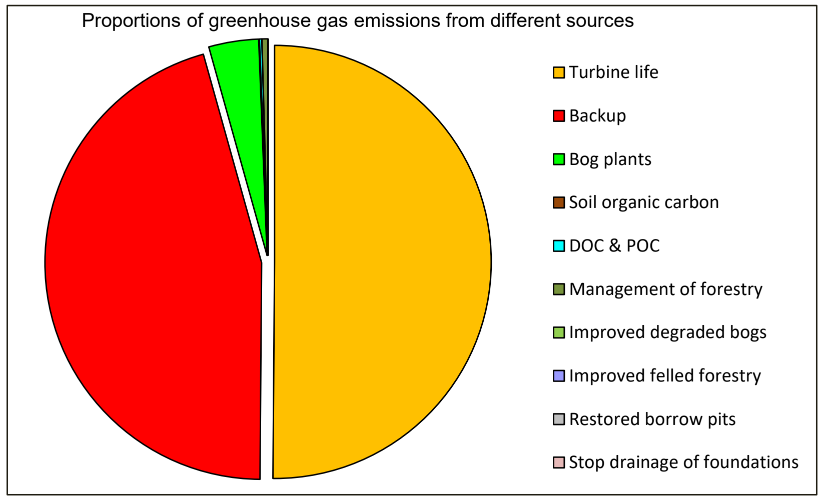
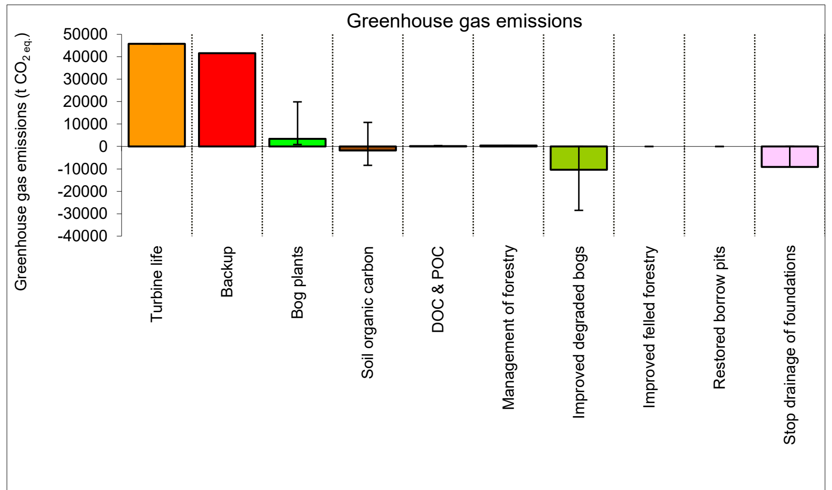
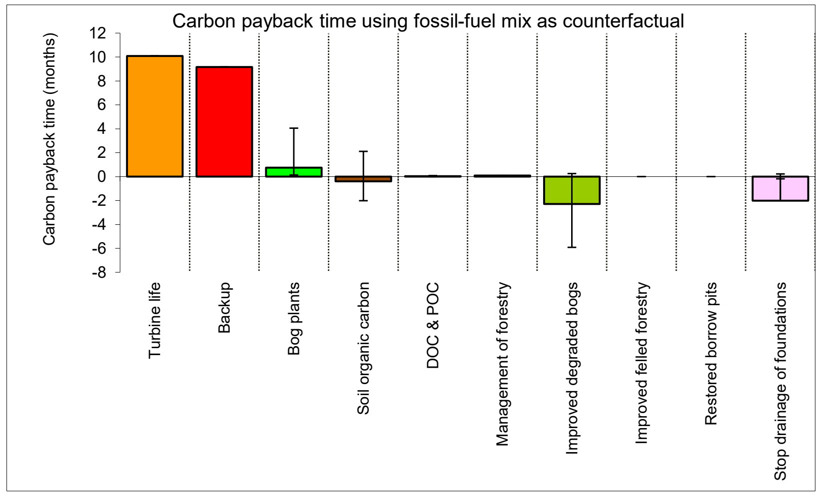
	Exp.	Min.	Max.
1. Windfarm CO_2 emission saving over…			
…coal-fired electricity generation ($tCO_2\ yr^{-1}$)	111788	100610	122967
…grid-mix of electricity generation ($tCO_2\ yr^{-1}$)	21531	19377	23684
…fossil fuel - mix of electricity generation ($tCO_2\ yr^{-1}$)	54495	49046	59945
Energy output from windfarm over lifetime (MWh)	4865654	4379089	5352220
Total CO_2 losses due to wind farm (t CO_2 eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	45780	45780	45780
3. Losses due to backup	41599	41599	41599
4. Losses due to reduced carbon fixing potential	3396	880	19889
5. Losses from soil organic matter	-1793	-8412	10725
6. Losses due to DOC & POC leaching	160	0	405
7. Losses due to felling forestry	407	407	407
Total losses of carbon dioxide	89549	80255	118805
8. Total CO_2 gains due to improvement of site (t CO_2 eq.)			
8a. Change in emissions due to improvement of degraded bogs	-10390	0	-28493
8b. Change in emissions due to improvement of felled forestry	0	0	0
8c. Change in emissions due to restoration of peat from borrow pits	0	0	0
8d. Change in emissions due to removal of drainage from foundations & hardstanding	-9135	0	0
Total change in emissions due to improvements	-19525	0	-28493

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t $CO_{2\ eq.}$)	**70024**	**51761**	**118805**
Carbon Payback Time			
…coal-fired electricity generation (years)	0.6	0.4	1.2
…grid-mix of electricity generation (years)	3.3	2.2	6.1
…fossil fuel - mix of electricity generation (years)	**1.3**	**0.9**	**2.4**
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	**-0.1**	**No gains!**	**0.4**
Ratio of CO_2 eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	**14**	**10**	**27**







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

Greenhouse gas emissions

	Exp.	Min	Max
Turbine life	45780	0	0
Backup	41599	0	0
Bog plants	3396	2515	16493
Soil organic carbon	0	6619	12517
DOC & POC	160	160	245
Management of forestry	407	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	9135

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

Greenhouse gas emissions				Carbon payback time (months)		
	Exp.	Min.	Max.	Exp.	Min.	Max.
Turbine life	45780	0	0	10	0	0
Backup	41599	0	0	9	0	0
Bog plants	3396	2515	16493	1	1	3
Soil organic carbon	-1793	6619	12517	0	2	3
DOC & POC	160	160	245	0	0	0
Management of forestry	407	0	0	0	0	0
Improved degraded bogs	-10390	-10390	-18103	-2	-3	-4
Improved felled forestry	0	0	0	0	0	0
Restored borrow pits	0	0	0	0	0	0
Stop drainage of foundations	-9135	-9135	9135	-2	-2	2
	70024			15		

Check Check Check Check Check Check Check Check Check Check

Results

PAYBACK TIME AND CO_2 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 CO_2 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 Exp	Total Min	Total Max	Forestry Area 1 Exp	Forestry Area 1 Min	Forestry Area 1 Max	Forestry Area 2 Exp	Forestry Area 2 Min	Forestry Area 2 Max	Forestry Area 3 Exp	Forestry Area 3 Min	Forestry Area 3 Max	Forestry Area 4 Exp	Forestry Area 4 Min	Forestry Area 4 Max	Forestry Area 5 Exp	Forestry Area 5 Min	Forestry Area 5 Max
Power Generation Characteristics																		
No. of turbines	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Power rating of turbines (turbine capacity) (MW)	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625	6.625
Power of windfarm (MW)	53	53	53	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})	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919	0.919
Grid-mix emission factor (t CO_2 MWh^{-1})	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448

Calculation of capacity factor	1	Direct input of capacity factor		
		Exp	Min	Max
Entered capacity factor (%)		26.2	23.58	28.82

Parameters	Slope (a)			Intercept (b)		
Partial power curves for different turbines	Exp	Min	Max	Exp	Min	Max
User-defined	0.0	0.0	0.0	0.0	0.0	0.0
Vestas 2.0 MW Optispeed C2	1392.5	1392.5	1392.5	-4291.9	-4291.9	-4291.9

Calculation of capacity factor from forestry management	Total Exp	Total Min	Total Max	Forestry Area 1 Exp	Forestry Area 1 Min	Forestry Area 1 Max	Forestry Area 2 Exp	Forestry Area 2 Min	Forestry Area 2 Max	Forestry Area 3 Exp	Forestry Area 3 Min	Forestry Area 3 Max	Forestry Area 4 Exp	Forestry Area 4 Min	Forestry Area 4 Max	Forestry Area 5 Exp	Forestry Area 5 Min	Forestry Area 5 Max
Wind speed ratio calculated in 7d				#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Average site windspeed (m s^{-1})	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual theoretical energy output from turbine (MW $turbine^{-1}$ yr^{-1})	58035	58035	58035	58035	58035	58035	58035	58035	58035	58035	58035	58035	58035	58035	58035	58035	58035	58035
Power curve				User-defined	User-defined	User-defined	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	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	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Slope (a)				0	0	0	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Intercept (b)				0	0	0	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
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		
Direct input of capacity factor																		
Capacity factor(%)	26	24	29	26	24	29	26	24	29	26	24	29	26	24	29	26	24	29
Annual energy output from windfarm (MW yr^{-1})	**121641**	**109477**	**133805**	**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		
Windfarm CO_2 emission saving over…																		
…coal-fired electricity generation (tCO_2 yr^{-1})	111788	100610	122967	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
…grid-mix of electricity generation (tCO_2 yr^{-1})	21531	19377.5	23683.6	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})	54495	49045.8	59944.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Windfarm CO_2 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, decomissioning) is calculated by comparing the emissions due to turbine life with carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or grid-mix.

Method used to estimate CO_2 emissions from turbine life (eg. manufacture, construction,	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})	5723	5723	5723
No. of turbines	8	8	8
Total calculated CO_2 emission of the wind farm due to turbine life (t CO_2 windfarm^{-1})	45780	45780	45780

	Total			Construction Area 1			Construction Area 2			Construction Area 3			Construction Area 4			Construction Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Calculation of emissions due to cement used in construction																		
Volume of cement used (m^3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CO_2 emission rate (t CO_2 m^{-3} cement)	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316
Total CO_2 emissions due to cement used	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RESULTS			
Losses due to turbine life (eg.	45780	45780	45780
Additional CO_2 payback time of windfarm due to turbine life (eg. manufacture, contruction, decomissioning)			
…coal-fired electricity generation (months)	5	5	4
…grid-mix of electricity generation (months)	26	28	23
…fossil fuel - mix of electricity generation (months)	10	11	9

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Emissions due to turbine life

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

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

mpa The Concrete Centre

Embodied carbon dioxide (CO_2e) of concretes used in buildings

CONCRETE APPLICATION	Concrete designation	CO_2e (kgCO_2e/m^3)[1]			CO_2e (kgCO_2e/tonne)[1]		
		CEM I concrete	30% fly ash concrete	50% ggbs concrete	CEM I concrete	30% fly ash concrete	50% ggbs concrete
Blinding, mass fill, strip footings, mass foundations, trench foundations [2]	GEN1	177	128	101	77	55	44
Reinforced Foundations [2]	RC25/30**	316	263	197	133	111	83
Ground floors [2]	RC28/35 *	316	261	186	134	110	79
Structural: in situ floors, superstructure, walls, basements [2]	RC32/40 **	369	313	231	154	131	96
High strength concrete [2]	RC40/50 **	432	351	269	178	146	111
		CO_2e (kgCO_2e/m^3)			CO_2e (kgCO_2e/tonne)		
Unreinforced Precast flooring[3]		-			165		
Reinforced precast flooring[3]		-			171		
Average Generic Concrete Block[4]		-			84		

* *includes 30kg/m^3 steel reinforcement*

** *includes 100kg/m^3 steel reinforcement*

Emissions due to backup power generation

Note: CO_2 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	8	8	8
Power rating of turbines (turbine capacity) (MW)	6.625	6.625	6.625
Power of wind farm (MW h^{-1})	53	53	53
Rated capacity (MW yr^{-1})	464280	464280	464280
Extra capacity required for backup (%)	5	5	5
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10
Reserve capacity (MWh yr^{-1})	2321	2321	2321
Carbon dioxide emissions due to backup power generation			
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.919	0.919	0.919
Grid-mix emission factor (t CO_2 MWh^{-1})	0.177	0.177	0.177
Fossil fuel- mix emission factor (t CO_2 MWh^{-1})	0.448	0.448	0.448
Lifetime of windfarm (years)	40	40	40
Annual emissions due to backup from…			
…coal-fired electricity generation (tCO_2 yr^{-1})	2133	2133	2133
…grid-mix of electricity generation (tCO_2 yr^{-1})	411	411	411
…fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	1040	1040	1040
RESULTS			
Total emissions due to backup from…			
…coal-fired electricity generation (tCO_2)	85335	85335	85335
…grid-mix of electricity generation (tCO_2)	16436	16436	16436
…fossil fuel - mix of electricity generation (tCO_2)	**41599**	**41599**	**41599**
Additional CO_2 payback time of windfarm due to backup			
…coal-fired electricity generation (months)	9	10	8
…grid-mix of electricity generation (months)	9	10	8
…fossil fuel - mix of electricity generation (months)	9	10	8

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

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Emissions due to backup power generation

Note: CO_2 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.

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)	150355	150355	150355
Total area affected by drainage due to windfarm construction (m^{-2})	590486	294264	3030713
Total area where fixation by plants is lost (m^2)	740841	444619	3181068
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)	40	40	40
Time required for regeneration of bog plants after restoration (years)	10	5	15
Carbon accumulation up to time of restoration (tCO_2 eq. ha^{-1})	46	20	63
RESULTS			
Total loss of carbon accumulation by bog plants			
Total area where fixation by plants is lost (ha)	74	44	318
Carbon accumulation over lifetime of windfarm (tCO_2 eq. ha^{-1})	46	20	63
Total loss of carbon fixation by plants at the site (t CO_2)	**3396**	**880**	**19889**
Additional CO_2 payback time of windfarm due to loss of CO2 fixing potential			
…coal-fired electricity generation (months)	0	0	2
…grid-mix of electricity generation (months)	2	1	10
…fossil fuel - mix of electricity generation (months)	1	0	4

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.

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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), CO_2 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
	CO_2 loss due to windfarm construction			
Check	CO_2 loss from removed peat (t CO_2 equiv)	-1793	-8412	10725
Check	CO_2 loss from drained peat (t CO_2 equiv)	0	0	0
	RESULTS			
	Total CO_2 loss from peat (removed + drained) (t CO_2 equiv)	**-1793**	**-8412**	**10725**
	Additional CO_2 payback time of windfarm due to loss of soil CO2			
	…coal-fired electricity generation (months)	0	-1	1
	…grid-mix of electricity generation (months)	-1	-5	5
	…fossil fuel - mix of electricity generation (months)	0	-2	2

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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), CO_2 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	Total		
	Exp	Min	Max
Number of borrow pits	1	1	1
Average length of pits (m)	359.43	359.43	359.43
Average width of pits (m)	100	100	100
Average depth of peat removed from pit (m)	0.27	0.27	0.27
Area of land lost in borrow pits (m^2)	35943	35943	35943
Volume of peat removed from borrow pits (m^3)	9704.61	9704.61	9704.61

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	Rectangular with vertical walls																	
Calculation method code		1																
No. of turbines	8	8	8	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0
Diameter at surface (m)				531 1	531 1	531 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Diameter at bottom (m)				531 1	531 1	531 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Depth of foundations (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
"Area" of land lost in hard-standing (m^2)	4247	4247	4247	4247	4247	4247	0	0	0	0	0	0	0	0	0	0	0	0
Volume of peat removed from foundation area (m^3)	8.9187	8.9187	8.9187	8.9187	8.9187	8.9187	0	0	0	0	0	0	0	0	0	0	0	0

Peat removed from hard-standing																		
Method used to calculate CO_2 loss from foundations	Rectangular with vertical walls																	
Calculation method code		1																
No. of turbines	8	8	8	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0
Diameter at surface (m)				1520 1	1519.63 1	1519.63 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Diameter at bottom (m)				1520 1	1519.63 1	1519.63 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Depth of hardstanding (m)				0	0.1	0.13	0	0	0	0	0	0	0	0	0	0	0	0
Area of land lost in hard-standing (m^2)	12157	12157	12157	12157	12157	12157	0	0	0	0	0	0	0	0	0	0	0	0
Volume of peat removed from hardstandingarea (m^3)	1337.27	1215.7	1580.41	1337.27	1215.7	1580.41	0	0	0	0	0	0	0	0	0	0	0	0

Peat removed from access tracks	Total		
	Exp	Min	Max
Floating roads			
Length of access track that is floating road (m)	490	490	490
Floating road width (m)	5.5	5.5	5.5

Floating road depth (m)	0	0	0
Area of land lost in floating roads (m^2)	2695	2695	2695
Volume of peat removed for floating roads	0	0	0
Excavated roads			
Length of access track that is excavated road (m)	12150	12150	12150
Excavated road width (m)	5.5	5.5	5.5
Average depth of peat excavated for road (m)	0.13	0.13	0.13
Area of land lost in excavated roads (m^2)	66825	66825	66825
Volume of peat removed for excavated roads	8687.25	8687.25	8687.25
Rock-filled roads			
Length of access track that is rock filled road (m)	0	0	0
Rock filled road width (m)	5	5	5
Rock filled road depth (m)	0	0	0
Area of land lost in excavated roads (m^2)	0	0	0
Volume of peat removed for rock-filled roads	0	0	0
Total area of land lost in access tracks (m^2)	69520	69520	69520
Total volume of peat removed due to access tracks (m^3)	8687.25	8687.25	8687.25

Additional peat excavated - (not already accounted for above)			
Volume of additional peat excavated (m^3)	6102	6102	6102
Area of additional peat excavated (m^2)	28488	28488	28488

RESULTS		**Total**	
	Exp	**Min**	**Max**
Total volume of peat removed (m^3) due to windfarm construction	**25840**	**25718.5**	**26083.2**
Total area of land lost due to windfarm construction (m^2)	**150355**	**150355**	**150355**

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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.

CO_2 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
CO_2 loss from removed peat			
C Content of dry peat (% by weight)	55.5	49	62
Dry soil bulk density (g cm^{-3})	0.13	0.07	0.29
% C contained in removed peat that is lost as CO_2	100	100	100
Total volume of peat removed (m^3) due to windfarm construction	25840	25718	26083
CO_2 loss from removed peat (t CO_2)	6942	3327	17375

Check

Assumption: If peat is not restored, 100% of the carbon contained in the removed peat is lost as CO_2

	Expected	Minimum	Maximum
CO_2 loss from undrained peat left in situ			
Total area of land lost due to windfarm construction (ha)	15	15	15
CO_2 loss from undrained peat left in situ (t CO_2 ha^{-1})	581	781	442
CO_2 loss from undrained peat left in situ (t CO_2)	8734	11739	6651

	Expected	Minimum	Maximum
CO_2 loss attributable to peat removal only			
CO_2 loss from removed peat (t CO_2)	6942	3327	17375
CO_2 loss from undrained peat left in situ (t CO_2)	8734	11739	6651
RESULTS			
CO_2 loss attributable to peat removal only (t CO_2)	**-1793**	**-8412**	**10725**

Click here to move to 5. Loss of soil CO_2 Click here

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CO_2 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	Total Exp	Total Min	Total Max
Average extent of drainage around drainage features at site (m)	10	5	50

Peat affected by drainage around borrow pits	Total Exp	Total Min	Total Max
Number of borrow pits	1	1	1
Average length of pits (m)	359	359	359
Average width of pits (m)	100	100	100
Average depth of peat removed from pit (m)	0.3	0.3	0.3
Area affected by drainage per borrow pit (m^2)	9589	4694	55943
Total area affected by drainage around borrowpits (m^2)	9589	4694	55943
Total volume affected by drainage around borrowpits (m^3)	1294	634	7552

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	8	8	8	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0
Average length of turbine foundations at base (m)				531	531	531	0	0	0	0	0	0	0	0	0	0	0	0
Average width of turbine foundations at base(m)				1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Average depth of peat removed from turbine foundations (m)				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
Average length of hard-standing at base (m)				1520	1520	1520	0	0	0	0	0	0	0	0	0	0	0	0
Average width of hard-standing at base (m)				1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Average depth of peat removed from hard-standing (m)				0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum depth of drains (m)				0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total length of foundation and hardstanding (m)				2051	2051	2051	0	0	0	0	0	0	0	0	0	0	0	0
Total width of foundation and hardstanding (m)				2	2	2	0	0	0	0	0	0	0	0	0	0	0	0
Area affected by drainage of foundation and hardstanding area (m^2)	41450	20625	215250	41450	20625	215250	0	0	0	0	0	0	0	0	0	0	0	0
Total area affected by drainage of foundation and hardstanding area (m^2)	331600	165000	1722000	331600	165000	1722000	0	0	0	0	0	0	0	0	0	0	0	0
Total volume affected by drainage of foundation and hardstanding area (m^3)	18238	8250	111930	18238	8250	111930	0	0	0	0	0	0	0	0	0	0	0	0

Peat affected by drainage of access tracks	Total Exp	Total Min	Total Max
Floating roads			

Length of floating road that is drained (m)	0	0	0
Floating road width (m)	5.5	5.5	5.5
Average depth of drains associated with floating roads (m)	0.00	0.00	0.00
Area affected by drainage of floating roads (m^2)	0	0	0
Volume affected by drainage of floating roads (m^3)	0	0	0
Excavated Road			
Length of access track that is excavated road (m)	12150	12150	12150
Excavated road width (m)	6	6	6
Average depth of peat excavated for road (m)	0.1	0.1	0.1
Area affected by drainage of excavated roads (m^2)	243000	121500	1215000
Volume affected by drainage of excavated roads (m^3)	15795	7898	78975
Rock-filled roads			
Length of rock filled road that is drained (m)	0	0	0
Rock filled road width (m)	5	5	5
Average depth of drains associated with rock filled roads (m)	0.0	0.0	0.0
Area affected by drainage of rock-filled roads (m^2)	0	0	0
Volume affected by drainage of rock-filled roads (m^2)	0	0	0
Total area affected by drainage of access track (m^2)	243000	121500	1215000
Total volume affected by drainage of access track (m^3)	15795	7898	78975

Peat affected by drainage of cable trenches	**Total**		
	Exp	**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	**Total**		
	Exp	**Min**	**Max**
Volume of additional peat excavated (m^3)	6102.0	6102.0	6102.0
Area of additional peat excavated (m^2)	28488.0	28488.0	28488.0
Average depth of excavated peat (m)	0	0	0
Radius of area excavated (m)	95	95	95

Assumption: Area excavated is assumed to be a circle

Radius of excavated and drained area (m)	105	100	145
Total area affected by drainage (m^2)	6297	3070	37770
Total volume affected by drainage (m^3)	1348.87	657.61	8090.19

assumed to be a circle

RESULTS	Total		
	Exp	**Min**	**Max**
Total area affected by drainage due to windfarm (m^2)	**590486**	**294264**	**3030713**
Total volume affected by drainage due to windfarm (m^3)	**36676.33**	**17438.84**	**206547.5**

Click here to move to 5d. CO2 loss from drained peat Click here

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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.

CO_2 loss due to drainage

Note: Note, CO_2 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)	59	29	303
Will the hydrology of the site be restored on decommissioning?	Yes	Yes	Yes
Will the habitat of the site be restored on decommissioning?	Yes	Yes	Yes

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

		Expected	Minimum	Maximum
Check	Total volume affected by drainage due to wind farm (m^3)	36676	17439	206547
	C Content of dry peat (% by weight)	56	49	62
	Dry soil bulk density (g cm^{-3})	0.13	0.07	0.29
	Total GHG emissions from Drained Land (t CO_2 equiv.)	9853	2256	137591
	Total GHG Emissions from Undrained Land (t CO_2 equiv.)	9853	2256	137591

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

		Expected	Minimum	Maximum
	Flooded period (days $year^{-1}$)	0	0	0
	Lifetime of windfarm (years)	40	40	40
	Time required for regeneration of bog plants after restoration (years)	10	5	15
	Methane Emissions from Drained Land			
Check	Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.008	-0.013	0.151
	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.)	736	-515	77113
	Carbon Dioxide Emissions from Drained Land			
Check	Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	11.37	17.74	3.42
	CO_2 emissions from drained land (t CO_2)	33566	23490	56944
	Total GHG emissions from Drained Land (t CO_2 equiv.)	34302	22975	134057

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

Note:Conversion = (23 x 16/12) = 30.67 CO_2 equiv. $(CH_4\text{-}C)^{-1}$

2. Losses if Land is Undrained

		Expected	Minimum	Maximum
	Flooded period (days $year^{-1}$)	178	178	178
	Lifetime of windfarm (years)	40	40	40
	Time required for regeneration of bog plants after restoration (years)	10	5	15
	Methane Emissions from Undrained Land			
Check	Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.01	-0.01	0.15
	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.)	736	-515	77113
	Carbon Dioxide Emissions from Undrained Land			
Check	Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	11.37	17.74	3.42
	CO_2 emissions from undrained land (t CO_2)	33566	23490	56944
	Total GHG Emissions from Undrained Land (t CO_2 equiv.)	34302	22975	134057

Note:Conversion = (23 x 16/12) = 30.67 CO_2 equiv. $(CH_4\text{-}C)^{-1}$

3. CO_2 Losses due to Drainage

	Expected	Minimum	Maximum
Total GHG emissions from drained land (t CO_2 equiv.)	34302	22975	134057

Total GHG emissions from undrained land (t CO_2 equiv.)	34302	22975	134057
RESULTS **Total GHG emissions due to drainage (t CO_2 equiv.)**	**0**	**0**	**0**

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CO_2 loss due to drainage

Note: Note, CO_2 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, CO_2 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

Emission characteristics of acid bogs (IPCC, 1997)

	Expected	Minimum	Maximum
Flooded period (days $year^{-1}$)	178	178	178
Annual rate of methane emission (t CH_4-C ha^{-1} yr^{-1})	0.04015	0.04015	0.04015
Annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	35.2	35.2	35.2

Emission characteristics of fens (IPCC, 1997)

	Expected	Minimum	Maximum
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)

	Expected	Minimum	Maximum
Flooded period (days $year^{-1}$)	178	178	178
Annual rate of methane emission (t CH_4-C ha^{-1} yr^{-1})	0.04015	0.04015	0.04015
Annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	35.2	35.2	35.2

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 CH_4 emission rate provided for acid bogs is 11 (1-38) mg CH_4-C m^{-2} day^{-1} x 365 days; and for fens is 60 (21-162) mg CH_4-C m^{-2} day^{-1} x 365 days (Aselmann & Crutzen ,1989. J.Atm.Chem. 8, 307-358)

Assumption: CO_2 emissions on drainage of organic soils for upland crops (e.g., grain, vegetables) are 3.667x9.6 (7.9-11.3) t CO_2 ha^{-1} yr^{-1} in temperate climates (Armentano and Menges, 1986. J. Ecol. 74, 755-774).

Calculations following ECOSSE based methodology

Drained Land

	Expected	Minimum	Maximum
Total area affected by drainage due to wind farm construction (ha)	59	29	303
Total volume affected by drainage due to wind farm construction (m^3)	36676	17439	206547

Soil Characteristics that Determine Emission Rates

	Expected	Minimum	Maximum
Average annual air temperature at the site (^oC)	9.2	6.5	11.89
Average water table depth at site (m)	0.30	0.50	0.10
Average water table depth of drained land (m)	0.30	0.50	0.10

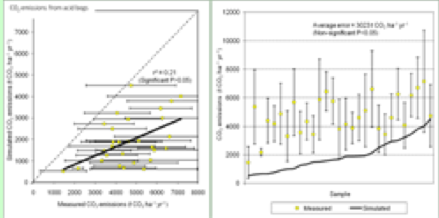
Annual Emission Rates following site specific methodology

	Expected	Minimum	Maximum
Acid bogs			
Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	11.37	17.74	3.42
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	11.37	17.74	3.42
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.008	-0.013	0.151
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.01	-0.01	0.15
Fens			
Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	32.90	53.61	8.83
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	32.90	53.61	8.83
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.027	-0.001	0.211
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.03	0.00	0.21

Note: Carbon dioxide emissions from acid bogs. Equation derived by regression analysis against 60 measurements (Nayak et al, 2009). The equation derived was

R_{CO2} = (3.667/1000) x ((6700 x exp(-0.26 x exp(-0.0515 × ((*W*x100)-50)))) + ((72.54 × *T*) - 800))

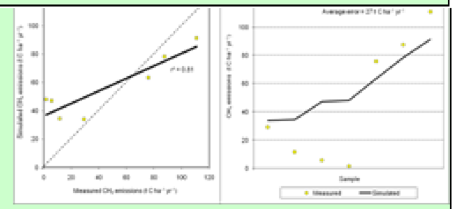
where R_{CO2} is the annual rate of CO_2 emissions (t CO_2 $(ha)^{-1}$ yr^{-1}),
T = average annual peat temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 =0.53 P > 0.05).
Evaluation against 29 independent experiments shows a significant association (r^2 = 0.21; P>0.05) and an average error of 3023 t CO_2 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_{CH4} = (1/1000) x (500 × exp(-0.1234 × (Wx100)) + ((3.529 × *T*) - 36.67))

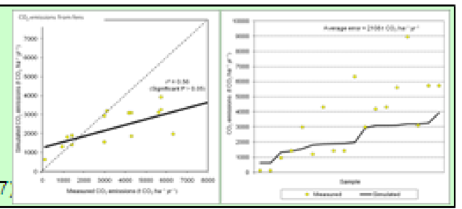
where R_{CH4} is the annual rate of CH_4 emissions (t CH_4-C $(ha)^{-1}$ yr^{-1}),
T = average annual air temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 = 0.54, P > 0.05).
Evaluation against 7 independent experiments shows a significant association (r^2 = 0.81; P>0.05) and an average error of 27 t CH_4-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_{CO2} = (3.667/1000) x (16244 x exp(-0.175 x exp(-0.073 x ((*W*x100)-50)))+(153.23 x *T*))

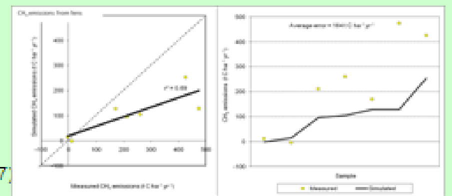
where R_{CO2} is the annual rate of CO_2 emissions (t CO_2 $(ha)^{-1}$ yr^{-1}),
T = average annual peat temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 = 0.42, P > 0.05).
Evaluation against 18 independent experiments shows a significant association (r^2 = 0.56; P>0.05) and an average error of 2108 t CO_2 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_{CH4} = (1/1000) x (-10+563.62 x exp(-0.097 x (*W* x 100))+(0.662 x *T*))

where R_{CH4} is the annual rate of CH_4 emissions (t CH_4-C $(ha)^{-1}$ yr^{-1}),
T = average annual air temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 = 0.41, P >0.05).
Evaluation against 7 independent experiments shows a significant association (r^2 = 0.69; P>0.05) and an average error of 164 t CH_4-C ha^{-1} yr^{-1} (significance not defined due to lack of replicate-Smith et al, 1997)



Selected emission characteristics following site specific methodology

	Expected	Minimum	Maximum
Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	11.37	17.74	3.42
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	11.37	17.74	3.42
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.008	-0.013	0.151
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.01	-0.01	0.15

RESULTS

Selected Emission Rates

	Expected	Minimum	Maximum
Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	11.37	17.74	3.42
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	11.37	17.74	3.42
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.008	-0.013	0.151
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.01	-0.01	0.15

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Emission rates from soils

Note: Note, CO_2 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, CO_2 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	2791	0	9050
Felled Forestry	0	0	0
Borrow Pits	0	0	0
Foundations & Hardstanding	2454	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)	128	0	221
Total C loss as DOC (t C)	33	0	89
Total C loss as POC (t C)	10	0	22

RESULTS			
Total CO_2 loss due to DOC leaching (t CO_2)	**122**	**0**	**324**
Total CO_2 loss due to POC leaching (t CO_2)	**38**	**0**	**81**
Total CO_2 loss due to DOC & POC leaching (t CO_2)	**160**	**0**	**405**
Additional CO_2 payback time of windfarm due to DOC & POC			
…coal-fired electricity generation (months)	0	0	0
…grid-mix of electricity generation (months)	0	0	0
…fossil fuel - mix of electricity generation (months)	0	0	0

Note: Only restored drained land included because if land is not

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/KM^2/yr) and not on flux at catchment outlet (i.e. 10.3 - 21.8 MgC/KM^2/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 CO_2

Assumption: POC loss ranges between 4-10% of the total gaseous loss if calculated from the reported values and is **8%** of the total gaseous loss if calculated from the mean of reported maximum and minimum value in Worrall 2009. POC range is (7 - 22.4 MgC/KM^2/yr) (Worrall et al, 2009).

Assumption: In the long term, 100% of leached POC is assumed to be lost as CO_2

Click here to move to Payback Time Click here

Emissions due to loss of DOC and POC

Note: Note, CO_2 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)	0.77	0.77	0.77
Carbon sequestered (tC ha^{-1} yr^{-1})	3.6	3.6	3.6
Lifetime of windfarm (years)	40	40	40
Carbon sequestered over the lifetime of the windfarm (t C ha^{-1})	144	144	144
RESULTS			
Total carbon loss due to felling of forestry (t CO_2)	**407**	**407**	**407**
Additional CO_2 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

Click here to move to Payback Time Click here

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.

CO_2 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 CO_2)	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)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
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 unforested (tC 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 CO_2)	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 CO_2)	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 (tC ha^{-1})				6	6	6	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
(Carbon : Biomass) ratio of felled forestry				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
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})	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448
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 CO_2)	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)				40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Carbon in replanted forestry when felled (tC ha^{-1})				275	275	275	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
(Carbon : Biomass) ratio of felled forestry				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
Biomass weight (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})	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448
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} t^{-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 CO_2)	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 CO_2)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Additional CO_2 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**

CO_2 loss from forests - calculation using detailed management information

Forest carbon calculator (Perks et al, 2009)

Carbon sequestration in trees

Simplified version of the 3PG model (Xenakis et al, 2008). This version, doesn't require climate data as no explicit environmental modifier is calculated. Instead, it uses a factor (from 0 to 1) representing the total effect of environment on growth. The simplified model requires a value of annual incoming solar radiation, a modifier for the age-related decline in productivity, a light extinction coefficient and specific leaf area.

The model calculates gross primary productivity (GPP) and then net primary production (NPP) through a standard ratio. It allocates NPP to roots, wood and foliage. A soil model calculates the size of old and young carbon pools, respiration losses from these pools and from this net ecosystem productivity (NEP).

The model does not need temp/rain/solrad data: the impact of the environment at the site is included by adjusting the environmental modifier, based on site yield class and temperature. Light use efficiency (LUE), rather than quantum use efficiency (QYE) is used, making it easier to develop the model for many species even for a grouping such as "conifers" or "deciduous".

Calibration for Sitka Spruce gives QYE = 0.08 (mol/mol) => LUE = 2.21 (kC/MJ), and for SP QYE = 0.05 (mol/mol) => LUE = 1.37 (kC/MJ)

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
Accumulated temperature (day-degrees > 5°C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)	(> 1050 deg.C)
Code number	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Major Soil Sub Group	Peaty gley			Peaty gley	Peaty gley	Peaty gley	0	0	0	0	0	0	0	0	0	0	0	0
Code number	1			1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Species	Scots pine			Scots pine	Scots pine	Scots pine	0	0	0	0	0	0	0	0	0	0	0	0
Code number	1			1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Age of forestry when felled for windfarm (yr)	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lifetime of windfarm (years)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Years after felling when replanting occurs	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Age of seedlings on planting (yr)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Years when replanted forestry will be grown on wind farm site	40			40	40	40	40	40	40	40	40	40	40	40	40	40	40	40

RESULTS Calculated Net Primary Production	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Net loss in forest primary production over lifetime of wind farm (t C ha^{-1})	**275**	**275**	**275**	**275**	**275**	**275**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Total forest net primary production at felling for wind farm (t C ha^{-1})	**6**	**6**	**6**	**6**	**6**	**6**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Net primary production of replanted forestry assuming same species replanted and managed over lifespan of windfarm (t C ha^{-1})	**275**	**275**	**275**	**275**	**275**	**275**	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

BACKGROUND CALCULATIONS

	Species	Selected Value

Parameter		Units	Scots Pine	Sitka Spruce	Area 1	Area 2	Area 3	Area 4	Area 5
3PG module									
Average annual photosynthetically active radiation	2880	MJ m^{-2} yr^{-1}			2880	2880	2880	2880	2880
Light extinction coefficient	0.5	-			0.5	0.5	0.5	0.5	0.5
Specific leaf area		m^2 kg^{-1} C	6	8	6	8	8	8	8
Leaf longevity		yrs	4	7	4	7	7	7	7
Fine root longevity	1	yrs			1	1	1	1	1
Maximum light-use efficiency		kg C $MJ^{-1}day^{-1}$	0.00152	0.00166	0.00152	0.001656	0.001656	0.001656	0.001656
Total reduction factor for misc environmental effects		-			0.3720	#N/A	#N/A	#N/A	#N/A
Ratio of NPP to GPP	0.47	-			0.47	0.47	0.47	0.47	0.47
Allocation to foliage	0.25	-			0.25	0.25	0.25	0.25	0.25
Coefficient for allocation response to nitrogen	1.00	-			1.00	1.00	1.00	1.00	1.00
Age for 50% reduction in light-use efficiency		yrs	100	120	100	120	120	120	120
Initial foliage biomass	0.005	kg C m^{-2}			0.005	0.005	0.005	0.005	0.005
Understorey module									
Understorey LAI	3.00	-			3.00	3.00	3.00	3.00	3.00

Conversion Factors	*Quantum yield efficiency (mol mol^{-1})*	*to*	*Light use efficiency (kgC MJ^{-1})*
	0.05		***0.00130***
	Light use efficiency (kgC MJ^{-1})	*to*	*Quantum yield efficiency (mol mol^{-1})*
	0.00135		***0.0489***
gDM_mol	*24*		
molPAR_MJ	*2.3*		

GPP Reduction Factor Lookup Table

Soil type		*Accumulated temperature*		
		Less than 1050 °C yr^{-1}	*1050 to 1350 °C yr^{-1}*	*More than 1050 °C yr^{-1}*
	Code	*1*	*2*	*3*
Peaty Gley	*1*	0.3178	0.3551	0.3720
Deep Peat	*2*	0.3177	0.3569	0.3679

Integration step (yrs) 1

Age (years)	Thinning regime	Forestry Area 1								Forestry Area 2										
		State variables		Light interception			Primary production			State variables		Light interception			Primary production			State variables		Lig
		Wf - Foliage biomass (kg C m^{-2})	*LAI* - Leaf area index (m^2 m^{-2})	*ϕpau* - Utilized absorbed photosynth-etically active radiation (MJ m^{-2} yr^{-1})	*ϕpa$_{US}$* - Absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	*ϕpau$_{US}$* - Utilized absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	*NPP$_{trees}$* - Net primary production of trees (kg C m^{-2} yr^{-1})	*NPP$_{tot}$* - Total net primary production (t C ha^{-1} yr^{-1})	*ΣNPP$_{tot}$* - Cumulated total net primary production (t C ha^{-1})	*Wf* - Foliage biomass (kg C m^{-2})	*LAI* - Leaf area index (m^2 m^{-2})	*ϕpau* - Utilized absorbed photosynth-etically active radiation (MJ m^{-2} yr^{-1})	*ϕpa$_{US}$* - Absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	*ϕpau$_{US}$* - Utilized absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	*NPP$_{trees}$* - Net primary production of trees (kg C m^{-2} yr^{-1})	*NPP$_{tot}$* - Total net primary production (t C ha^{-1} yr^{-1})	*ΣNPP$_{tot}$* - Cumulated total net primary production (t C ha^{-1})	*Wf* - Foliage biomass (kg C m^{-2})	*LAI* - Leaf area index (m^2 m^{-2})	*ϕpau* - Utilized absorbed photosynth-etically active radiation (MJ m^{-2} yr^{-1})
0	0.00	0.0050	0.03	15.95	2204	820	0.0	6.0	6	0.0050	0.04	#N/A	2193	#N/A	#N/A	#N/A	#N/A	0.0050	0.04	#N/A
1	0.00	0.0078	0.05	24.93	2185	813	0.0	6.0	12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
2	0.00	0.0123	0.07	38.81	2156	802	0.0	6.0	18	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
3	0.00	0.0192	0.12	60.06	2112	786	0.0	6.0	24	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
4	0.00	0.0300	0.18	92.08	2045	761	0.1	6.1	30	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
5	0.00	0.0464	0.28	139.21	1947	724	0.1	6.2	36	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
6	0.00	0.0597	0.36	175.57	1871	696	0.1	6.2	42	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
7	0.00	0.0761	0.46	218.67	1781	662	0.2	6.3	49	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
8	0.00	0.0961	0.58	268.38	1677	624	0.2	6.4	55	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
9	0.00	0.1200	0.72	323.91	1561	581	0.2	6.5	62	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
10	0.00	0.1479	0.89	383.78	1436	534	0.3	6.6	68	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
11	0.00	0.1794	1.08	445.88	1306	486	0.3	6.7	75	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
12	0.00	0.2142	1.29	507.78	1177	438	0.4	6.8	82	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
13	0.00	0.2514	1.51	567.12	1053	392	0.4	6.8	88	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

14	0.00	0.2898	1.74	621.94	938	349	0.4	6.9	95	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
15	0.00	0.3284	1.97	670.98	835	311	0.5	7.0	102	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
16	0.00	0.3662	2.20	713.65	746	277	0.5	7.1	109	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
17	0.00	0.4021	2.41	749.97	670	249	0.5	7.1	117	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
18	0.00	0.4355	2.61	780.37	606	225	0.6	7.2	124	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
19	0.00	0.4660	2.80	805.50	553	206	0.6	7.2	131	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
20	0.19	0.4050	2.43	752.18	664	247	0.5	7.1	138	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
21	0.00	0.4381	2.63	781.90	601	224	0.6	7.2	145	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
22	0.00	0.4682	2.81	806.41	549	204	0.6	7.2	153	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
23	0.00	0.4952	2.97	826.42	507	188	0.6	7.2	160	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
24	0.00	0.5190	3.11	842.65	472	175	0.6	7.3	167	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
25	0.18	0.4460	2.68	787.13	587	218	0.6	7.2	174	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
26	0.00	0.4751	2.85	809.98	538	200	0.6	7.2	181	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
27	0.00	0.5010	3.01	828.52	498	185	0.6	7.2	189	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
28	0.00	0.5237	3.14	843.45	465	173	0.6	7.3	196	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
29	0.00	0.5434	3.26	855.37	438	163	0.6	7.3	203	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
30	0.17	0.4698	2.82	803.02	547	203	0.6	7.2	210	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
31	0.00	0.4957	2.97	821.56	506	188	0.6	7.2	218	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
32	0.00	0.5185	3.11	836.38	472	176	0.6	7.2	225	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
33	0.00	0.5383	3.23	848.09	445	166	0.6	7.2	232	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
34	0.00	0.5552	3.33	857.23	423	157	0.6	7.2	239	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
35	0.14	0.4909	2.95	813.40	513	191	0.6	7.2	247	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
36	0.00	0.5135	3.08	827.77	479	178	0.6	7.2	254	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
37	0.00	0.5329	3.20	838.98	452	168	0.6	7.2	261	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
38	0.00	0.5495	3.30	847.55	430	160	0.6	7.2	268	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
39	0.00	0.5635	3.38	853.94	413	153	0.6	7.2	275	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
40	0.05	0.5467	3.28	841.89	434	161	0.6	7.2	282	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
41	0.00	0.5604	3.36	847.85	417	155	0.6	7.2	290	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
42	0.00	0.5717	3.43	851.97	403	150	0.6	7.2	297	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
43	0.00	0.5809	3.49	854.53	392	146	0.6	7.1	304	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
44	0.00	0.5883	3.53	855.78	383	142	0.6	7.1	311	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
45	0.05	0.5624	3.37	838.66	414	154	0.6	7.1	318	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
46	0.00	0.5716	3.43	840.78	403	150	0.6	7.1	325	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
47	0.00	0.5789	3.47	841.52	394	147	0.6	7.1	332	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
48	0.00	0.5844	3.51	841.06	388	144	0.6	7.0	339	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
49	0.00	0.5886	3.53	839.58	383	142	0.6	7.0	346	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
50	0.00	0.5914	3.55	837.20	380	141	0.6	7.0	353	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
51	0.00	0.0050	0.03	15.95	2204	820	0.0	6.0	6	#N/A	0.04	#N/A	2193	#N/A	#N/A	#N/A	#N/A	0.0050	0.04	#N/A
52	0.00	0.0078	0.05	24.93	2185	813	0.0	6.0	12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
53	0.00	0.0123	0.07	38.81	2156	802	0.0	6.0	18	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
54	0.00	0.0192	0.12	60.06	2112	786	0.0	6.0	24	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
55	0.00	0.0300	0.18	92.08	2045	761	0.1	6.1	30	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
56	0.00	0.0464	0.28	139.21	1947	724	0.1	6.2	36	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
57	0.00	0.0597	0.36	175.57	1871	696	0.1	6.2	42	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
58	0.00	0.0761	0.46	218.67	1781	662	0.2	6.3	49	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
59	0.00	0.0961	0.58	268.38	1677	624	0.2	6.4	55	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
60	0.00	0.1200	0.72	323.91	1561	581	0.2	6.5	62	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
61	0.00	0.1479	0.89	383.78	1436	534	0.3	6.6	68	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
62	0.00	0.1794	1.08	445.88	1306	486	0.3	6.7	75	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
63	0.00	0.2142	1.29	507.78	1177	438	0.4	6.8	82	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
64	0.00	0.2514	1.51	567.12	1053	392	0.4	6.8	88	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
65	0.00	0.2898	1.74	621.94	938	349	0.4	6.9	95	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
66	0.00	0.3284	1.97	670.98	835	311	0.5	7.0	102	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
67	0.00	0.3662	2.20	713.65	746	277	0.5	7.1	109	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
68	0.00	0.4021	2.41	749.97	670	249	0.5	7.1	117	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
69	0.00	0.4355	2.61	780.37	606	225	0.6	7.2	124	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
70	0.00	0.4660	2.80	805.50	553	206	0.6	7.2	131	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
71	0.00	0.4050	2.43	752.18	664	247	0.5	7.1	138	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
72	0.00	0.4381	2.63	781.90	601	224	0.6	7.2	145	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

73	0.00	0.4682	2.81	806.41	549	204	0.6	7.2	153	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
74	0.00	0.4952	2.97	826.42	507	188	0.6	7.2	160	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
75	0.00	0.5190	3.11	842.65	472	175	0.6	7.3	167	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
76	0.00	0.4460	2.68	787.13	587	218	0.6	7.2	174	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
77	0.00	0.4751	2.85	809.98	538	200	0.6	7.2	181	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
78	0.00	0.5010	3.01	828.52	498	185	0.6	7.2	189	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
79	0.00	0.5237	3.14	843.45	465	173	0.6	7.3	196	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
80	0.00	0.5434	3.26	855.37	438	163	0.6	7.3	203	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
81	0.00	0.4698	2.82	803.02	547	203	0.6	7.2	210	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
82	0.00	0.4957	2.97	821.56	506	188	0.6	7.2	218	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
83	0.00	0.5185	3.11	836.38	472	176	0.6	7.2	225	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
84	0.00	0.5383	3.23	848.09	445	166	0.6	7.2	232	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
85	0.00	0.5552	3.33	857.23	423	157	0.6	7.2	239	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
86	0.00	0.4909	2.95	813.40	513	191	0.6	7.2	247	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
87	0.00	0.5135	3.08	827.77	479	178	0.6	7.2	254	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
88	0.00	0.5329	3.20	838.98	452	168	0.6	7.2	261	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
89	0.00	0.5495	3.30	847.55	430	160	0.6	7.2	268	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
90	0.00	0.5635	3.38	853.94	413	153	0.6	7.2	275	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
91	0.00	0.5467	3.28	841.89	434	161	0.6	7.2	282	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
92	0.00	0.5604	3.36	847.85	417	155	0.6	7.2	290	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
93	0.00	0.5717	3.43	851.97	403	150	0.6	7.2	297	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
94	0.00	0.5809	3.49	854.53	392	146	0.6	7.1	304	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
95	0.00	0.5883	3.53	855.78	383	142	0.6	7.1	311	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
96	0.00	0.5624	3.37	838.66	414	154	0.6	7.1	318	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
97	0.00	0.5716	3.43	840.78	403	150	0.6	7.1	325	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
98	0.00	0.5789	3.47	841.52	394	147	0.6	7.1	332	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
99	0.00	0.5844	3.51	841.06	388	144	0.6	7.0	339	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
100	0.00	0.5886	3.53	839.58	383	142	0.6	7.0	346	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
101	0.00	0.0050	0.03	15.95	2204	820	0.0	6.0	6	#N/A	0.04	#N/A	2193	#N/A	#N/A	#N/A	#N/A	0.0050	0.04	#N/A
102	0.00	0.0078	0.05	24.93	2185	813	0.0	6.0	12	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
103	0.00	0.0123	0.07	38.81	2156	802	0.0	6.0	18	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
104	0.00	0.0192	0.12	60.06	2112	786	0.0	6.0	24	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
105	0.00	0.0300	0.18	92.08	2045	761	0.1	6.1	30	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
106	0.00	0.0464	0.28	139.21	1947	724	0.1	6.2	36	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
107	0.00	0.0597	0.36	175.57	1871	696	0.1	6.2	42	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
108	0.00	0.0761	0.46	218.67	1781	662	0.2	6.3	49	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
109	0.00	0.0961	0.58	268.38	1677	624	0.2	6.4	55	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
110	0.00	0.1200	0.72	323.91	1561	581	0.2	6.5	62	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
111	0.00	0.1479	0.89	383.78	1436	534	0.3	6.6	68	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
112	0.00	0.1794	1.08	445.88	1306	486	0.3	6.7	75	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
113	0.00	0.2142	1.29	507.78	1177	438	0.4	6.8	82	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
114	0.00	0.2514	1.51	567.12	1053	392	0.4	6.8	88	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
115	0.00	0.2898	1.74	621.94	938	349	0.4	6.9	95	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
116	0.00	0.3284	1.97	670.98	835	311	0.5	7.0	102	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
117	0.00	0.3662	2.20	713.65	746	277	0.5	7.1	109	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
118	0.00	0.4021	2.41	749.97	670	249	0.5	7.1	117	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
119	0.00	0.4355	2.61	780.37	606	225	0.6	7.2	124	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
120	0.00	0.4660	2.80	805.50	553	206	0.6	7.2	131	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
121	0.00	0.4050	2.43	752.18	664	247	0.5	7.1	138	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
122	0.00	0.4381	2.63	781.90	601	224	0.6	7.2	145	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
123	0.00	0.4682	2.81	806.41	549	204	0.6	7.2	153	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
124	0.00	0.4952	2.97	826.42	507	188	0.6	7.2	160	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
125	0.00	0.5190	3.11	842.65	472	175	0.6	7.3	167	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
126	0.00	0.4460	2.68	787.13	587	218	0.6	7.2	174	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
127	0.00	0.4751	2.85	809.98	538	200	0.6	7.2	181	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
128	0.00	0.5010	3.01	828.52	498	185	0.6	7.2	189	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
129	0.00	0.5237	3.14	843.45	465	173	0.6	7.3	196	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
130	0.00	0.5434	3.26	855.37	438	163	0.6	7.3	203	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
131	0.00	0.4698	2.82	803.02	547	203	0.6	7.2	210	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

132	0.00	0.4957	2.97	821.56	506	188	0.6	7.2	218	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
133	0.00	0.5185	3.11	836.38	472	176	0.6	7.2	225	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
134	0.00	0.5383	3.23	848.09	445	166	0.6	7.2	232	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
135	0.00	0.5552	3.33	857.23	423	157	0.6	7.2	239	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
136	0.00	0.4909	2.95	813.40	513	191	0.6	7.2	247	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
137	0.00	0.5135	3.08	827.77	479	178	0.6	7.2	254	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
138	0.00	0.5329	3.20	838.98	452	168	0.6	7.2	261	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
139	0.00	0.5495	3.30	847.55	430	160	0.6	7.2	268	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
140	0.00	0.5635	3.38	853.94	413	153	0.6	7.2	275	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
141	0.00	0.5467	3.28	841.89	434	161	0.6	7.2	282	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
142	0.00	0.5604	3.36	847.85	417	155	0.6	7.2	290	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
143	0.00	0.5717	3.43	851.97	403	150	0.6	7.2	297	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
144	0.00	0.5809	3.49	854.53	392	146	0.6	7.1	304	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
145	0.00	0.5883	3.53	855.78	383	142	0.6	7.1	311	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
146	0.00	0.5624	3.37	838.66	414	154	0.6	7.1	318	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
147	0.00	0.5716	3.43	840.78	403	150	0.6	7.1	325	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
148	0.00	0.5789	3.47	841.52	394	147	0.6	7.1	332	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
149	0.00	0.5844	3.51	841.06	388	144	0.6	7.0	339	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Carbon sequestration in trees

Simplified version of the 3PG model (Xenakis et al, 2008). This version, doesn't require climate data as no explicit environmental modifier is calculated. Instead, it uses a factor (from 0 to 1) representing the total effect of environment on growth. The simplified model requires a value of annual incoming solar radiation, a modifier for the age-related decline in productivity, a light extinction coefficient and specific leaf area.

The model calculates gross primary productivity (GPP) and then net primary production (NPP) through a standard ratio. It allocates NPP to roots, wood and foliage. A soil model calculates the size of old and young carbon pools, respiration losses from these pools and from this net ecosystem productivity (NEP).

The model does not need temp/rain/solrad data: the impact of the environment at the site is included by adjusting the environmental modifier, based on site yield class and temperature. Light use efficiency (LUE), rather than quantum use efficiency (QYE) is used, making it easier to develop the model for many species even for a grouping such as "conifers" or "deciduous".
Calibration for Sitka Spruce gives QYE = 0.08 (mol/mol) => LUE = 2.21 (kC/MJ), and for SP QYE = 0.05 (mol/mol) => LUE = 1.37 (kC/MJ).

Forestry Area 3					Forestry Area 4								Forestry Area 5							
ht interception		Primary production			State variables		Light interception			Primary production			State variables		Light interception			Primary production		
ϕpa_{US} - Absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	ϕpau_{US} - Utilized absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	NPP_{trees} - Net primary production of trees (kg C m^{-2} yr^{-1})	NPP_{tot} - Total net primary production (t C ha^{-1} yr^{-1})	ΣNPP_{tot} - Cumulated total net primary production (t C ha^{-1})	*Wf* - Foliage biomass (kg C m^{-2})	*LAI* - Leaf area index (m^2 m^{-2})	ϕpau - Utilized absorbed photosynth-etically active radiation (MJ m^{-2} yr^{-1})	ϕpa_{US} - Absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	ϕpau_{US} - Utilized absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	NPP_{trees} - Net primary production of trees (kg C m^{-2} yr^{-1})	NPP_{tot} - Total net primary production (t C ha^{-1} yr^{-1})	ΣNPP_{tot} - Cumulated total net primary production (t C ha^{-1})	*Wf* - Foliage biomass (kg C m^{-2})	*LAI* - Leaf area index (m^2 m^{-2})	ϕpau - Utilized absorbed photosynth-etically active radiation (MJ m^{-2} yr^{-1})	ϕpa_{US} - Absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	ϕpau_{US} - Utilized absorbed photosynth-etically active radiation of the understorey (MJ m^{-2} yr^{-1})	NPP_{trees} - Net primary production of trees (kg C m^{-2} yr^{-1})	NPP_{tot} - Total net primary production (t C ha^{-1} yr^{-1})	ΣNPP_{tot} - Cumulated total net primary production (t C ha^{-1})
2193	#N/A	#N/A	#N/A	#N/A	0.0050	0.04	#N/A	2193	#N/A	#N/A	#N/A	#N/A	0.0050	0.04	#N/A	2193	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
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2193	#N/A	#N/A	#N/A	#N/A	0.0050	0.04	#N/A	2193	#N/A	#N/A	#N/A	#N/A	0.0050	0.04	#N/A	2193	#N/A	#N/A	#N/A	#N/A
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2193	#N/A	#N/A	#N/A	#N/A	0.0050	0.04	#N/A	2193	#N/A	#N/A	#N/A	#N/A	0.0050	0.04	#N/A	2193	#N/A	#N/A	#N/A	#N/A
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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

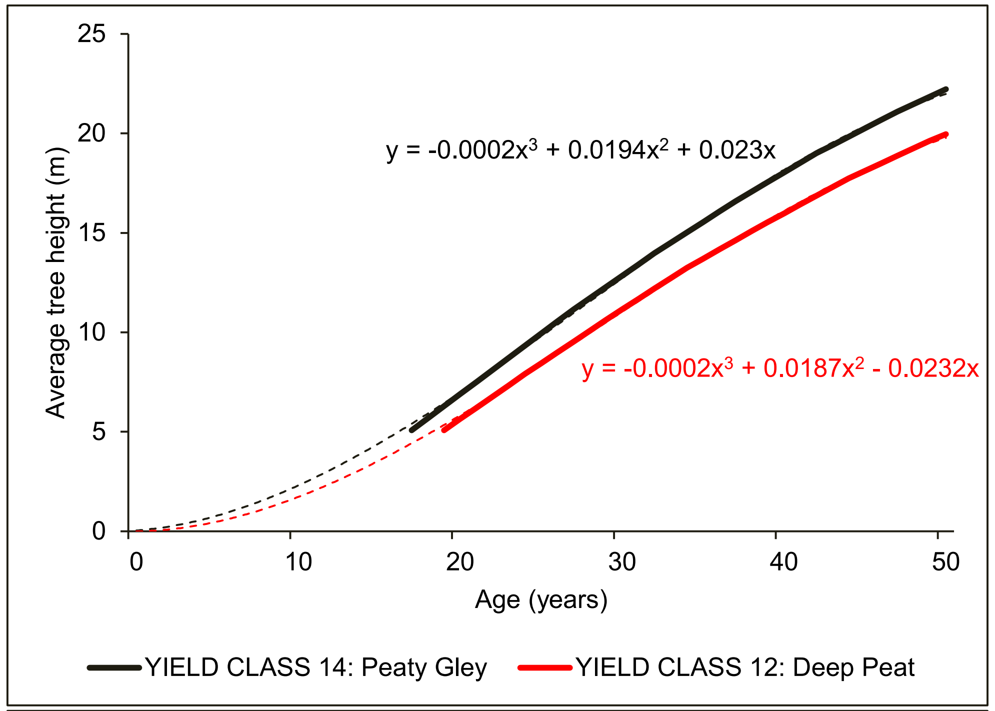
Average stand data

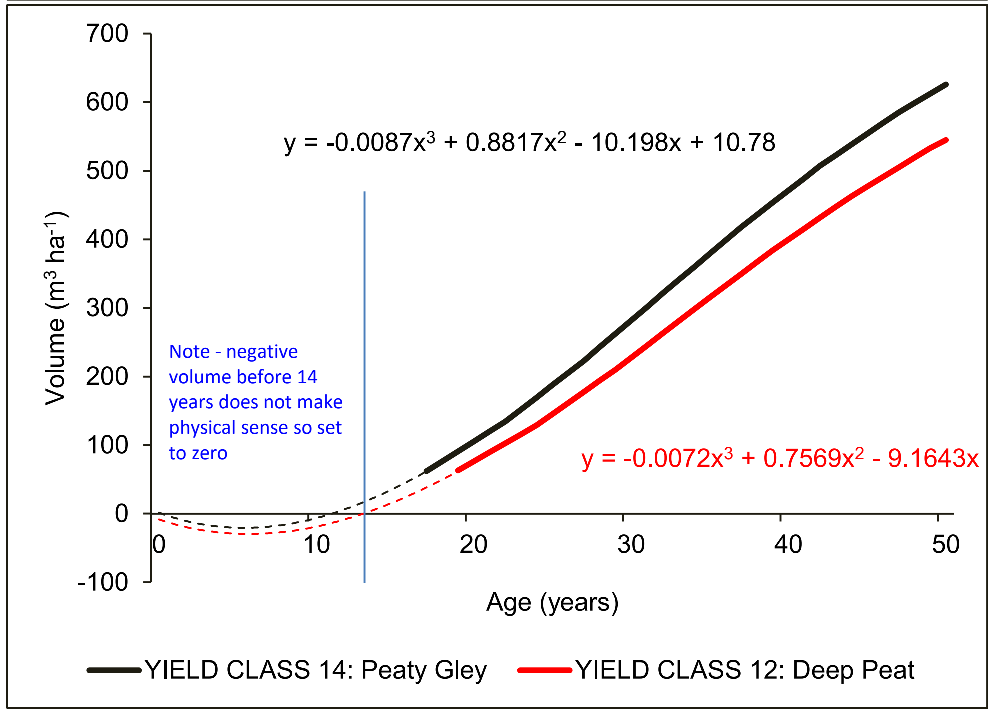
Data obtained from Forestry Commission growth and yield tables (Edwards & Christie, 1981)

STANDAID **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





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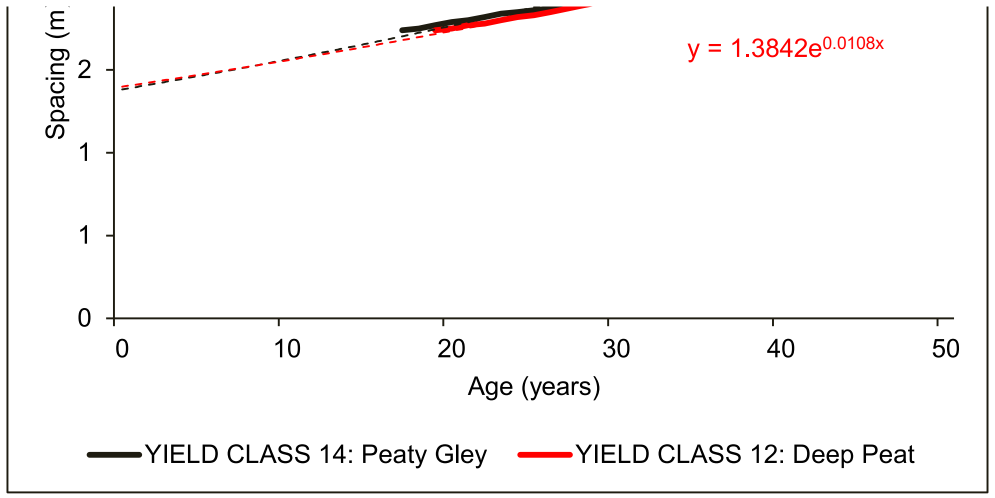
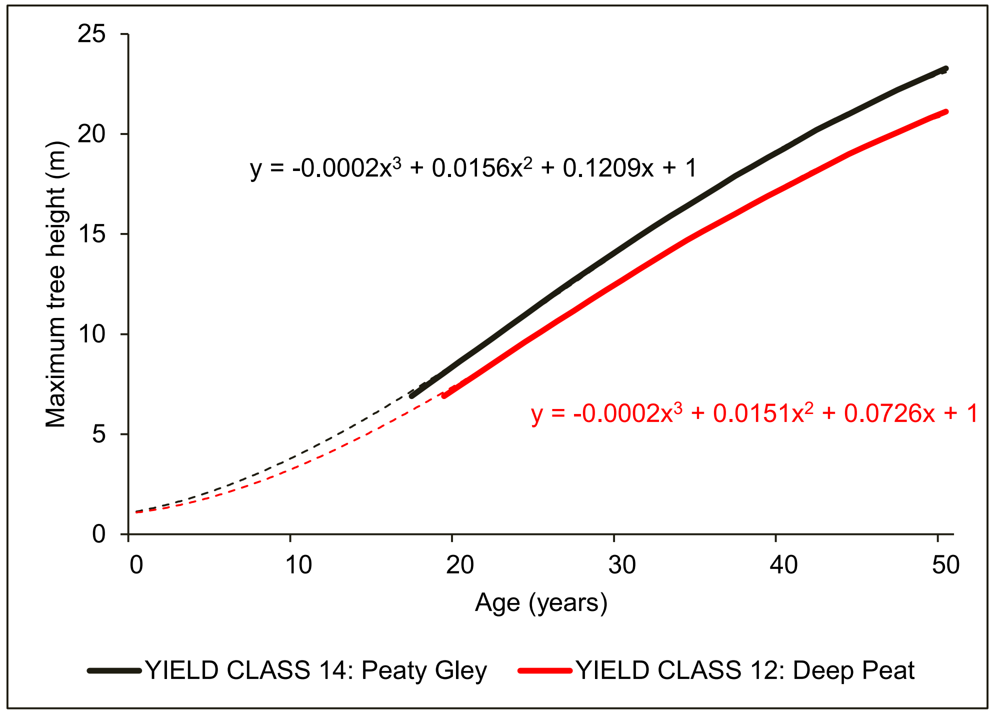
14	1.7	46	20.67	569.4	2.44	21.8
14	1.7	47	21.09	585	2.47	22.2
14	1.7	48	21.47	598.6	2.5	22.56
14	1.7	49	21.85	612.2	2.52	22.92
14	1.7	50	22.22	625.8	2.55	23.28

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





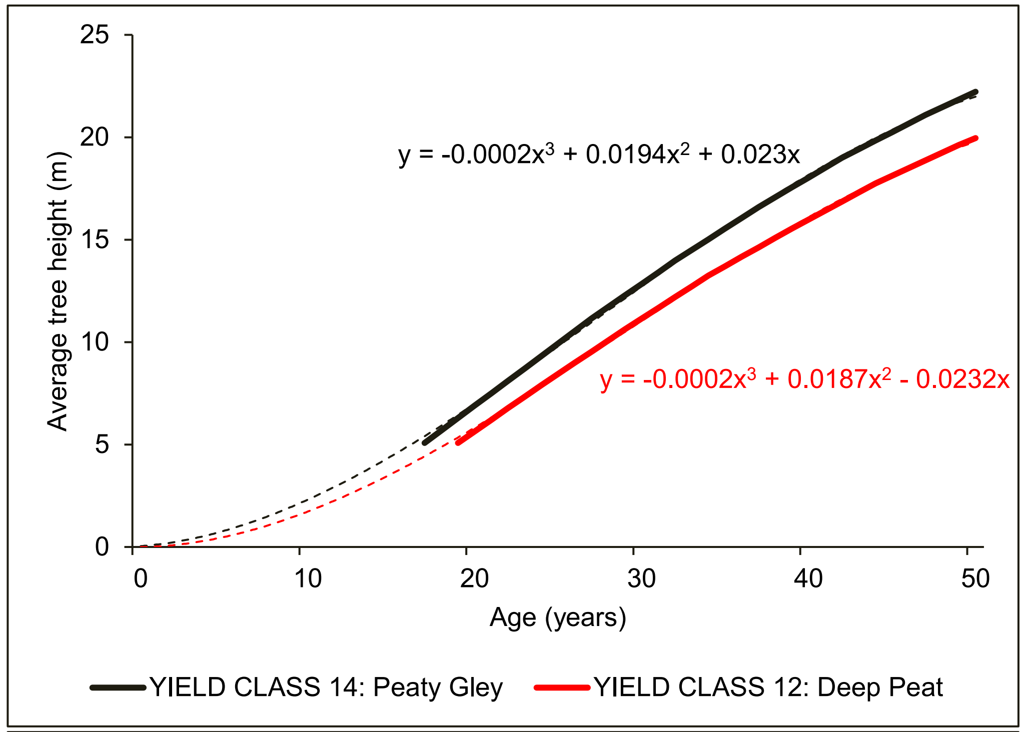
12	1.7	48	19.25	519	2.36	20.44
12	1.7	49	19.63	533	2.39	20.8
12	1.7	50	19.96	544.8	2.41	21.12

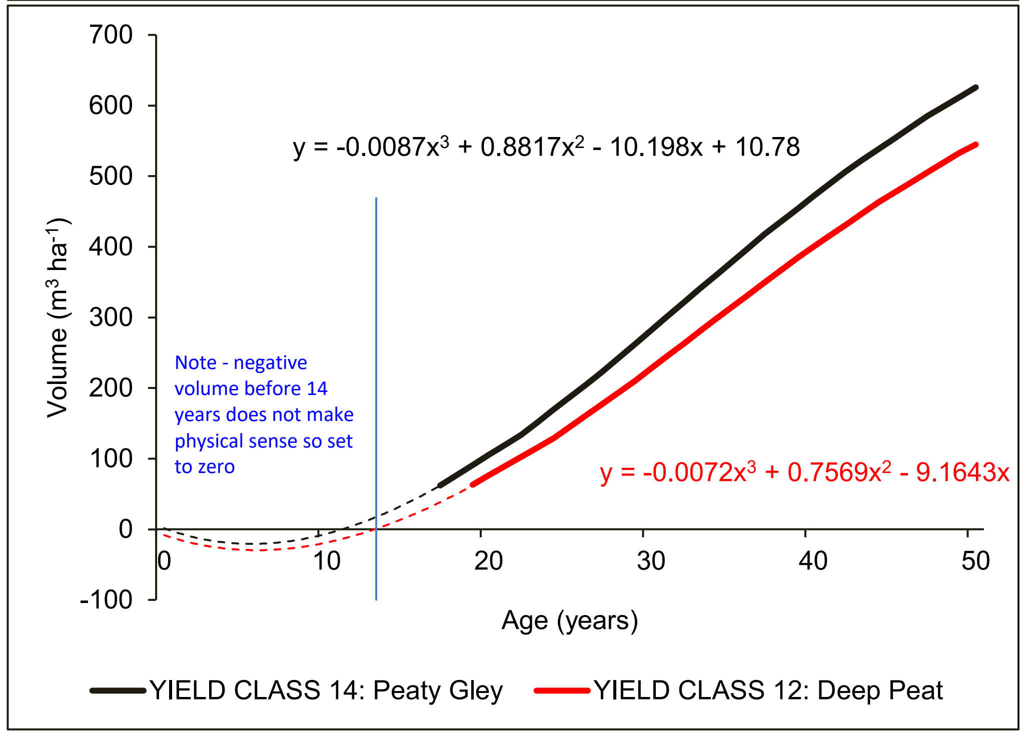
Average stand data
Data obtained from Forestry Commission growth and yield tables (Edwards & Christie, 1981)

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





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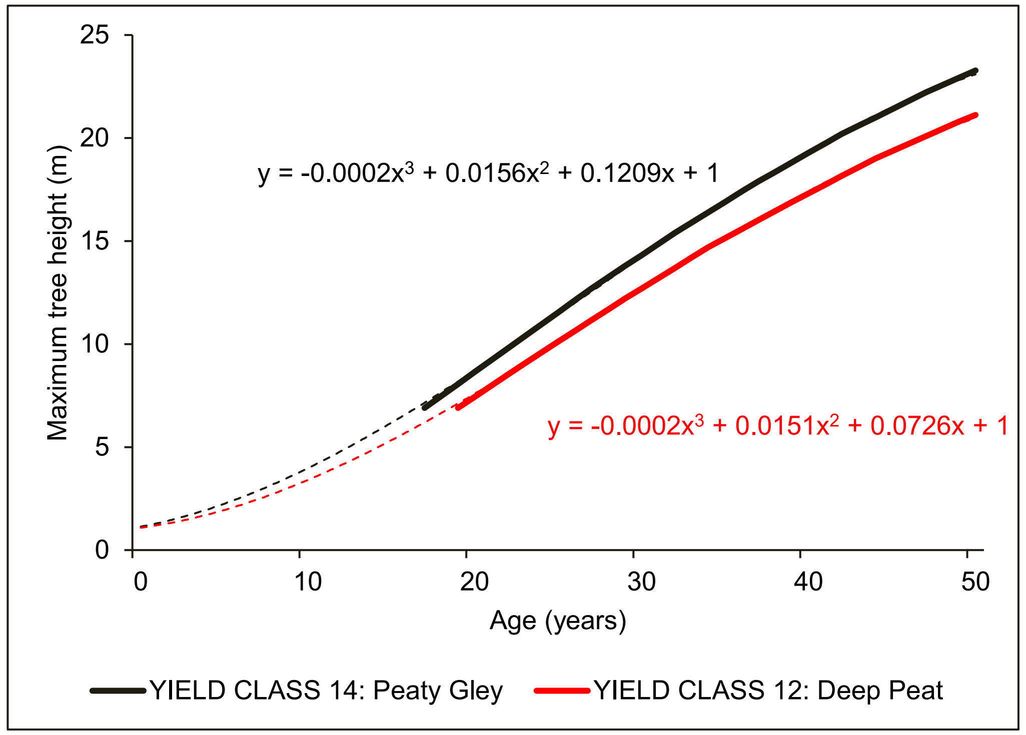
14	1.7	44	19.84	538.2	2.39	21
14	1.7	45	20.25	553.8	2.41	21.4
14	1.7	46	20.67	569.4	2.44	21.8
14	1.7	47	21.09	585	2.47	22.2
14	1.7	48	21.47	598.6	2.5	22.56
14	1.7	49	21.85	612.2	2.52	22.92
14	1.7	50	22.22	625.8	2.55	23.28

YIELD CLASS 12: Deep Peat

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



12	1.7	45	18.12	477	2.28	19.36
12	1.7	46	18.50	491	2.31	19.72
12	1.7	47	18.87	505	2.33	20.08
12	1.7	48	19.25	519	2.36	20.44
12	1.7	49	19.63	533	2.39	20.8
12	1.7	50	19.96	544.8	2.41	21.12

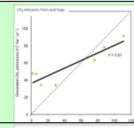
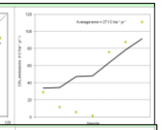
Gains due to site improvement

Note: Note, CO_2 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).

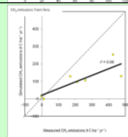
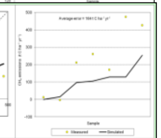
Selected Methodology = Site specific (required for planning applications)
Type of peatland = Acid Bog

Reduction in GHG emissions due to improvement of site	Expected result				Minimum result				Maximum result			
Improvement of...	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)	30	0	30	40	30	0	30	40	30	0	30	40
Area to be improved (ha)	88	0	0	33	0	0	0	0	88	0	0	0
Average air temperature at site (°C)	9.2	9.2	9.2	9.2	6.5	6.5	6.5	6.5	11.89	11.89	11.89	11.89
Depth of peat drained (m)	0.46	0.46	0.27	0.46	0.46	0.46	0.27	0.46	0.46	0.46	0.27	0.46
Depth of peat above water table before improvement (m)	0.30	0.00	0.00	0.30	0.10	0.00	0.00	0.10	0.46	0.00	0.00	0.46
Depth of peat above water table after improvement (m)	0.10	0.00	0.00	0.10	0.30	0.00	0.00	0.30	0.05	0.00	0.00	0.46
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)	15	0	30	5	5	0	30	5	30	0	30	5
Improved period (years)	15	0	0	35	25	0	0	35	0	0	0	35
Methane emissions from improved land												
Site specific methane emission from improved soil on acid bogs (t CH_4-C ha^{-1} yr^{-1})	0.141	0.496	0.496	0.141	-0.001	0.486	0.486	-0.001	0.275	0.505	0.505	0.007
Site specific methane emission from improved soil on fens (t CH_4-C ha^{-1} yr^{-1})	0.210	0.560	0.560	0.210	0.025	0.558	0.558	0.025	0.345	0.561	0.561	0.004
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})	0.141	0.496	0.496	0.141	-0.001	0.486	0.486	-0.001	0.275	0.505	0.505	0.007
CH_4 emissions from improved land (t CO_2 equiv.)	2791	0	0	2454	0	0	0	0	9050	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})	2.70	0.32	0.32	2.70	10.65	-0.40	-0.40	10.65	1.98	1.03	1.03	18.08
Site specific CO_2 emissions from improved soil on fens (t CO_2 ha^{-1} yr^{-1})	7.32	5.23	5.23	7.32	31.38	3.71	3.71	31.38	7.17	6.74	6.74	53.72
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})	2.70	0.32	0.32	2.70	10.65	-0.40	-0.40	10.65	1.98	1.03	1.03	18.08
CO_2 emissions from improved land (t CO_2)	1826	0	0	1606	0	0	0	0	2229	0	0	0
Total GHG emissions from improved land (t CO_2 equiv.)	**4617**	**0**	**0**	**4059**	**0**	**0**	**0**	**0**	**11280**	**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)	15	0	30	5	5	0	30	5	30	0	30	5
Improved period (years)	15	0	0	35	25	0	0	35	0	0	0	35
Methane emissions from unimproved land												
Site specific methane emission from unimproved soil on acid bogs (t CH_4-C ha^{-1} yr^{-1})	0.008	0.496	0.496	0.008	0.132	0.486	0.486	0.132	0.007	0.505	0.505	0.007
Site specific methane emission from unimproved soil on fens (t CH_4-C ha^{-1} yr^{-1})	0.027	0.560	0.560	0.027	0.208	0.558	0.558	0.208	0.004	0.561	0.561	0.004
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})	0.008	0.496	0.496	0.008	0.132	0.486	0.486	0.132	0.007	0.505	0.505	0.007
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})	11.37	0.32	0.32	11.37	1.98	-0.40	-0.40	1.98	18.08	1.03	1.03	18.08
Site specific CO_2 emissions from unimproved soil on fens (t CO_2 ha^{-1} yr^{-1})	32.90	5.23	5.23	32.90	5.80	3.71	3.71	5.80	53.72	6.74	6.74	53.72
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})	11.37	0.32	0.32	11.37	1.98	-0.40	-0.40	1.98	18.08	1.03	1.03	18.08
CO_2 emissions from unimproved land (t CO_2)	15007	0	0	13195	0	0	0	0	39773	0	0	0
Total GHG emissions from unimproved land (t CO_2 equiv.)	**15007**	**0**	**0**	**13195**	**0**	**0**	**0**	**0**	**39773**	**0**	**0**	**0**
RESULTS												
4. Reduction in GHG emissions due to improvement of site												
Total GHG emissions from improved land (t CO_2 equiv.)	4617	0	0	4059	0	0	0	0	11280	0	0	0
Total GHG emissions from unimproved land (t CO_2 equiv.)	15007	0	0	13195	0	0	0	0	39773	0	0	0
Reduction in GHG emissions due to improvement (t CO_2 equiv.)	**10390**	**0**	**0**	**9135**	**0**	**0**	**0**	**0**	**28493**	**0**	**0**	**0**
Additional CO_2 payback time of windfarm due to site improvement												
…coal-fired electricity generation (months)	**-1**	**0**	**0**	**-1**	**0**	**0**	**0**	**0**	**-3**	**0**	**0**	**0**
…grid-mix of electricity generation (months)	**-6**	**0**	**0**	**-5**	**0**	**0**	**0**	**0**	**-14**	**0**	**0**	**0**
…fossil fuel - mix of electricity generation (months)	**-2**	**0**	**0**	**-2**	**0**	**0**	**0**	**0**	**-6**	**0**	**0**	**0**

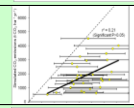
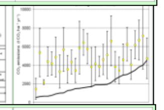
Note: Methane emissions from acid bogs. Equation derived by regression analysis against 57 measurements (Nayak et al, 2009). The equation derived was
R_{CH4} = (1/1000) x (500 × exp(-0.1234 × (Wx100)) + ((3.529 × T) - 36.67))
where R_{CH4} is the annual rate of CH_4 emissions (t CH_4-C (ha)$^{-1}$ yr^{-1}),
T = average annual air temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 = 0.54, P > 0.05).
Evaluation against 7 independent experiments shows a significant association (r^2 = 0.81; P>0.05) and an average error of 27 t CH_4-C ha^{-1} yr^{-1} (significance not defined due to lack of replicates - Smith et al, 1997).

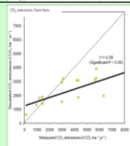
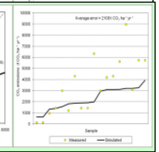
Note: Methane emissions from fens. Equation derived by regression analysis against experimental data from 35 measurements (Nayak et al, 2009). The equation derived was
R_{CH4} = (1/1000) x (-10+563.62 x exp(-0.097 x (W x 100))+(0.662 x T))
where R_{CH4} is the annual rate of CH_4 emissions (t CH_4-C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

R_{CO2} = (3.667/1000) x ((6700 x exp(-0.26 x exp(-0.0515 × ((Wx100)-50)))) + ((72.54 × T) - 800))
where R_{CO2} is the annual rate of CO_2 emissions (t CO_2 (ha)$^{-1}$ yr^{-1}),
T = average annual peat temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 =0.53 P > 0.05).
Evaluation against 29 independent experiments shows a significant association (r^2 = 0.21; P>0.05) and an average error of 3023 t CO_2 ha^{-1} yr^{-1} which is non-significant (P<0.05) (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_{CO2} = (3.667/1000) x (16244 x exp(-0.175 x exp(-0.073 x ((Wx100)-50)))+(153.23 x T))
where R_{CO2} is the annual rate of CO_2 emissions (t CO_2 (ha)$^{-1}$ yr^{-1}),
T = average annual peat temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 = 0.42, P > 0.05).
Evaluation against 18 independent experiments shows a significant association (r^2 = 0.56; P>0.05) and an average error of 2108 t CO_2 ha^{-1} yr^{-1} (significance not defined due to lack of replicates-Smith et al, 1997)

Note: Methane emissions from acid bogs. As above

Note: Methane emissions from fens. As above

Note: CO_2 emissions from acid bogs. As above

Note: CO_2 emissions from fens. As above

Click here to move to Payback Time Click here

Gains due to site improvement

Note: Note, CO_2 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 the 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 patters, 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 Ltd
1. Windfarm CO2 emission saving	F49	=IF(F19=1,365*24*F11*F10*G21/100,SUM(I49,L49,O49,R49,U49)) changed to =IF(D19=1,365*24*F11*F10*G21/100,SUM(I49,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'!C$65 changed to ='Core input data'!E$65	
5c. Volume of peat drained	E48	Similar to above	
5c. Volume of peat drained	G33	=IF(G23>0,($C9+G31+$C9)*($C9+G32+$C9)-(G31*G32),0) changed to =IF(G23>0,($d9+G31+$d9)*($d9+G32+$d9)-(G31*G32),0)	
5c. Volume of peat drained	J33,M33,P33,S33	Similar to above	
5c. Volume of peat drained	H33	=IF(H23>0,($C9+H31+$C9)*($C9+H32+$C9)-(H31*H32),0) changed to =IF(H23>0,($e9+H31+$e9)*($e9+H32+$e9)-(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 CO_2 emissions	D33	=D$31/D9 changed to =D$31/E9	Sarah Lister, Natural Power
Payback Time and CO_2 emissions	D34,D35	Similar to above	
Payback Time and CO_2 emissions	E33	=E$31/E9 changed to =E$31/D9	
Payback Time and CO_2 emissions	E34, E35	Similar to above	
Payback Time and CO_2 emissions	D31	=D19+D25 changed to =D19+E25	
Payback Time and CO_2 emissions	E31	=E19+E25 changed to =E19+D25	
6. CO_2 loss by DOC & POC loss	C11	Contents deleted	Ffion Causer, Natural Power
6. CO_2 loss by DOC & POC loss	D11, E11	Similar to above	
6. CO_2 loss by DOC & POC loss	C26	=(C9+C12+C13+C14+C15+(C10+C17+C18+C19+C20)/C21)/3.66 changed to =((C9+C12+C13+C14+C15)/3.66)+(((C10+C17+C18+C19+C20)/C21)*(12/16))	
6. CO_2 loss by DOC & POC loss	D26,E26	Similar to above	
Do I need to use this tool		Wording changed to clarify that the tool SHOULD be used with highly organic soils, but COULD also be used with sites undergoing drainage or deforestation	SEPA
Core input data	C12	Set to 25 and fixed to comply with planning applications for Section 36 (planning period = 25 years)	
Core input data	Row 25	Average depth of peat at site not used - therefore removed	
1. Windfarm CO_2 emission saving	D48	Set to AVERAGE(G48,J48,M48,P48,S48) to ensure a value is provided	
1. Windfarm CO_2 emission saving	E37	24*365*$D11 changed to 24*365*E11	Sarah Lister, Natural Power
1. Windfarm CO_2 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. CO_2 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	
8. CO_2 gain - site improvement	Row 15	Deleted	
	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. CO_2 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		

CHANGES IN VERSION 2.7.2

Worksheet	Cells	Change	Comment	Thanks to...
8. CO_2 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	Similar to above		
	D13	='Core input data'!C85 changed to =IF('Core input data'!C86>'Core input data'!C87,'Core input data'!C85,0)		
	H13,L13	Similar to above		
	E13	='Core input data'!C90 changed to =IF('Core input data'!C91>'Core input data'!C92,'Core input data'!C90,0)		
	I13, M13	Similar to above		
	F13	='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 included 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 CO_2 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
	G62-T62	Similar to above		
Forestry input data	C23	Units changed from g CO_2 km^{-1} to g CO_2 km^{-1} t^{-1}		
Core input data	Row 25	Insert input for average depth of peat at site	Limit improvements following restoration to the depth of the peat	Susana Sebastian, SEPA
8. CO_2 gain - site improvement	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 D17-N17 C21 D21-N21	='Core input data'!C83 changed to =IF('Core input data'!C83<C15,'Core input data'!C83,C15) Similar to above C12-C20 changed to =IF(C12-C20>0,C12-C20,0) Similar to above		
Core input data 8. CO2 gain - site improvement	Rows 85, 91, 97 C12 D12-N12 (excl. E12, I12 & M12)	Insert period of time when the improvement can be guaranteed to work (years) ='Core input data'!C12 changed to ='Core input data'!C85 Similar to above	Improvements in C sequestration should continue for as long as the improvement can be guaranteed.	Rob McCall, NRW
Payback Time and CO2 emissions	Row 37 C37 D637,E37	Insert ratio of soil carbon loss to gain by restoration =IF(C26<0,-(C17+C18)/C26,0) Similar to above	Include calculation of ratio of soil losses to gains	Rob McCall, NRW
Payback Time and CO2 emissions	Row 38 C38 D637,E37	Insert ratio of C emissions to power generation =((C20+C26)*1000000)/(C12*1000) Similar to above	Include calculation of C emissions to power generation	Susana Sebastian, SEPA
5. Loss of soil CO2 5e. Emission rates from soils	D11 E11 D31 E31 D33 E33	=D8+D9 changed to =MIN(D8+D9,E8+E9) =E8+E9 changed to =MAX(D8+D9,E8+E9) ='Core input data'!E24 changed to ='Core input data'!G24 ='Core input data'!G24 changed to ='Core input data'!E24 ='Core input data'!E28 changed to ='Core input data'!G28 ='Core input data'!G28 changed to ='Core input data'!E28	Correct use of minimum and maximum wrt water table depth at very low depths	Peter Batten
8. CO2 gain - site improvement	G17 H17-J17 K17 L17-N17	=IF('Core input data'!E83<G15,'Core input data'!E83,G15) changed to =IF('Core input data'!G83<G15,'Core input data'!G83,G15) 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) Similar to above	Correct use of minimum and maximum depth of water table after restoration	Jo Smith, University of Aberdeen
8. CO2 gain - site improvement	G12 H12-J12 K12 L12-N12	='Core input data'!E85 changed to ='Core input data'!G85 Similar to above ='Core input data'!G85 changed to ='Core input data'!E85 Similar to above	Correct use of min/max period when restoration can be restored	Jo Smith, University of Aberdeen
8. CO2 gain - site improvement	C34 D34-N34 C53 D53-N53	=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$23=1,C32,C33)) Similar to above =IF('Core input data'!$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)) Similar to above	Correct selection of emission factor when soil type is fen	Elizabeth Keen, Peter Brett Associates LLP

CHANGES IN VERSION 2.9.0

Worksheet	Cells	Change	Comment	Thanks to...
Core input data	B94 B95	"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)" "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)"	Confusing wording as water table depth may always be entered as zero.	Clare Wharmby - Carbon Forecast
8. CO2 gain - site improvement	C47 D47-N47	=(23*16/12)*C$13*C$40*C46*(C$19/365) changed to =(23*16/12)*C$13*C$40*C46*(C$38/365) Similar to above	Error in formula using the improved flooded period instead of the unimproved flooded period	Elizabeth Keen - Peter brett Associates
7c. Average stand data 7ii. Forestry CO2 loss - detail	Rows 13-29 Rows 168-86 F31 G31-T31	Stand data extended from 17 year to 0 years Similar to above =IF (F29>0,IF(F27="Deep Peat",(VLOOKUP(F29,'7c. Average stand data'!$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)), Similar to above	If forest stand is less than 17 years old, the calculations fail	Brenda Park - AMEC

7ii. Forestry CO2 loss - detail	G35 H35,J35,K35,M35,N35,P35,Q35,S35,T35	=IF('Forestry input data'!$F$33=1,"Yes", "No") changed to =IF('Forestry input data'!$D$33=1,"Yes", "No") Similar to above	Use of felled wood as biofuel not correctly read in min and max calculations	Jo Smith - University of Aberdeen
7ii. Forestry CO2 loss - detail	F16 G16-T16	='7a. C sequest. in trees (3PG)'!$F$24 changed to =IF(F12>0,'7a. C sequest. in trees (3PG)'!F$24,0) Similar to above	Avoid #NA	Claire Frost - AECOM
Forestry input data	Note: Emissions from felling and timber removal.	"the emissions are 6657 g CO_2 m^{-3}" changed to "the emissions are 6675 g CO_2 m^{-3}"		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 D637,E37	=IF(C26<0,-(C17+C18)/C26,"No gains!") Similar to above	Ensure no restoration is highlghted as no gains rather than appearing	Sarah Lister, Natural Power
Payback Time and CO2 emissions	C38 D637,E37	=((12/44)*(C20+C26)*1000000)/(C12*1000) Similar to above	Express ratio as CO2 rather than C emissions to power generation	Sarah Lister, Natural Power

CHANGES IN VERSION 2.10.0

Worksheet	Cells	Change	Comment	Thanks to...
8. CO2 gain - site improvement	K13 L13-N13 G13 H13-J13	=IF('Core input data'!G82>'Core input data'!G83,'Core input data'!G81,0) changed to =IF('Core input data'!G82>'Core input data'!E83,'Core input data'!G81,0) Similar to above =IF('Core input data'!E82>'Core input data'!E83,'Core input data'!E81,0) changed to =IF('Core input data'!E82>'Core input data'!G83,'Core input data'!E81,0) Similar to above	Change to correct test for improvement in restored area.	Sarah Lister, Natural Power
Payback Time and CO2 emissions	B22 B23 - B26 D38 C38, E38	"8a. Gains due to improvement of degraded bogs" changed to "8a. Change in emissions due to improvement of degraded bogs" Similar to above =((D20+D26)*1000000)/(D12*1000) changed to =(D32*1000)/(E12) Similar to above	Confusion over labelling of "gains" due to restoration and improvement Error in min / max calculation	Sarah Lister, Natural Power Peter Batten
1. Windfarm CO2 emission saving	H39 I39-U39 H40 I40-U40 H44 I40-U40 G49 H48-U49	='Forestry input data'!$F28 changed to =G39 Similar to above =OFFSET($D$24,H39,1) changed to =OFFSET($D$24,H39,2) Similar to above =OFFSET($D$24,H39,4) changed to =OFFSET($D$24,H39,5) Similar to above =24*365*G11*G10*G48/100 changed to =IF(G10<=0,0,24*365*G11*G10*G48/100) Similar to above	The power curve code for Min and Max were not correctly retrieved, because the dropdowns located in the tab Forestry Input Data cells F28 and H28 do not have any value associated to them. Column in offset incorrectly specified Column in offset incorrectly specified Incorrect calculation of annual energy output when less than 5 areas of forestry included.	Carlos Ruiz, SEPA

2. CO_2 loss due to turbine life	C19-T19	0.173 changed to 0.316	The emission rate of 173kg/m3 is the rate for "mass foundations". However foundations for wind turbines are reinforced, so the rate is changed to that for Reinforced Foundations, and revised to the new emission rate, from the Table 7 in http://www.concretecentre.com/sustainability/energy_efficiency/embodied_co2.aspx	Carlos Ruiz, SEPA
	C23	=IF('Core input data'!$C$20=1,$C9+C20,$C13+C20) changed to =IF('Core input data'!$C$20=1,$C9,$C13+C20)	Direct input of emissions includes cement already	
	D23-E23	Similar to above		
5a. Volume of peat removed	F26	=F20*((F23*F24)+(F22*(F21-F23)/2)+(F21*(F22-F24)/2)+((F21-F23)*(F22-F24))/2) changed to =IF(F25>0,(F20*(F25/3 * (F21*F22 + F23*F24 + SQRT(F21*F22*F23*F24))))/F25,0)	Error in formula	Carlos Ruiz, SEPA
	G26-T26	Similar to above		
5c. Volume of peat drained	C34	=C33*C23 changed to =F34+I34+L34+O34+R34		Carlos Ruiz, SEPA
	D34-T34	Similar to above		
	C55	='Core input data'!C70 changed to =C52*(C9+C9)		
	D55-E55	Similar to above		
	C73	=C72+C9 changed to =IF(C70>0,C72+C9,0)		
	D73-E73	Similar to above		
5d. CO_2 loss from drained peat	C43	=C8*(C35+C36)*((C42*(365-C34)))/365 changed to =C8*(C35+C36)*(((C42*C34)/365)+(C29*(365-C34)/365))	Accounts for emissions during both flooded and unflooded times of the year in an undrained soil	Carlos Ruiz, SEPA
	D43,E43	Similar to above		
	C40	=C8*(C35+C36)*C39*((C38*C34))/365 changed to =C8*(C35+C36)*C39*(((C38*C34)/365)+(C25*(365-C34)/365))		
	D40,E40	Similar to above		
	D50	=D47-D48 changed to =IF(D47-D48<E47-E48,D47-D48,E47-E48)	Protection against unusual conditions that result in incorrect order for min and max calculations	Carlos Ruiz, SEPA
	E50	Similar to above		
5e. Emission rates from soils	D31	='Core input data'!G24 changed to ='Core input data'!E24	Correction from previous min/max change	Carlos Ruiz, SEPA
	E31	='Core input data'!E24 changed to ='Core input data'!G24		
Core input data	C103	=IF(C105=2,IF(C106=2,2,1),1) changed to =IF(C105>1,IF(C106>1,2,1),1)		Carlos Ruiz, SEPA
	E103, G103, C107, E107, G107	Similar to above		
7a. C sequest. in trees (3PG)	E24	=AVERAGE(F24,I24,L24,O24,R24) changed to =AGGREGATE(1,6,F24,I24,L24,O24,R24)	Correction to avoid error when some areas of foresttry are not filled.	Carlos Ruiz, SEPA
	F24, G24, E25-G25, E26-G26	Similar to above		
	F25	=VLOOKUP(F15,$C62:$AQ212,9,TRUE) changed to =VLOOKUP(F15,$B62:$AQ212,10,TRUE)	Correction to formula so that it looks in the age column	
	G25-T25	Similar to above		
	F26	=SUM(OFFSET(((INDIRECT(ADDRESS(MATCH(F19,$B62:$B112,0)+61,9,4)))),0,1, F19,1)) changed to =SUM(OFFSET(((INDIRECT(ADDRESS(MATCH(F18,$B62:$B112,0)+61,9,4)))),0,1, F19,1))	Change to correct lookup of net primary production of replanted forestry	
	G26-T26	Similar to above		

7d. Wind speed ratios	Insert row 9	Years after planting when felling occurs	Changes to calculate final height of replanted forestry by accounting for years after felling when replanting occurs and age of seedlings as well as lifetime of windfarm - previously only accounted for lifetime of windfarm.	Carlos Ruiz, SEPA
	C9	='Forestry input data'!D41		
	D9-Q9	Similar to above		
	Insert row 10	Age of seedings on plant (yr)		
	C10	='Forestry input data'!D42		
	D10-Q10	Similar to above		
	C21	=VLOOKUP(C11,'7c. Average stand data'!$D$30:$H$63,2,TRUE) changed to =VLOOKUP(C11-C9+C10,'7c. Average stand data'!$D$30:$H$63,2,TRUE)		
	D21-Q21	Similar to above		
	C22	=OFFSET('7c. Average stand data'!$D30,C8-'7c. Average stand data'!$D30+C11,1,1) changed to =IF(C8+C11<=50,OFFSET('7c. Average stand data'!$D30,C8-'7c. Average stand data'!$D30+C11,1,1),OFFSET('7c. Average stand data'!$D30,C8-'7c. Average stand data'!$D30+C11-50+C10-C9,1,1))	Change to allow for normal harvesting of forestry during the lifetime of the windfarm	
	D22-Q22	Similar to above		
	C52	=IF((0.75+0.03*(LN(C43/C44)))*C44*POWER(C18/C44,0.8)+C46<C49,(0.75+0.03*(LN(C43/C44)))*C44*POWER(C18/C44,0.8)+C46,C49) changed to =IF((0.75+0.03*(LN(C42/C44)))*C44*POWER(C18/C44,0.8)+C46<C49,(0.75+0.03*(LN(C42/C44)))*C44*POWER(C18/C44,0.8)+C46,C49)	Changes to correct formula for height of new internal boundary layer over forest - previously used roughness of group in gap instead of roughness of ground in forested area	
	D52-Q52	Similar to above		
	C54	=IF((0.75+0.03*LN(C44/C43))*C45*POWER(C19/C21,0.8)+C47<C49,(0.75+0.03*LN(C44/C45))*C45*POWER(C19/C45,0.8)+C47,C49) changed to =IF((0.75+0.03*LN(C44/C45))*C45*POWER(C19/C45,0.8)+C47<C49,(0.75+0.03*LN(C44/C45))*C45*POWER(C19/C45,0.8)+C47,C49)	Changes to correct the calculation of height of boundary layer in replanted area	
	D54-Q54	Similar to above		
Construction input data	C13	"Depth of hole dug when constructing foundations (m)" changed to "Average depth of peat removed when constructing foundations (m)"	Changes in wording to improve clarity of input data	Carlos Ruiz, SEPA
	C20, C34, C41, C55, C62, C76, C83, C97, C104	Similar to above		
1. Windfarm CO_2 emission saving	H17	='Core input data'!$C$41 changed to ='Core input data'!$E$41	Correction of error	Carlos Ruiz, SEPA
	D48	=AVERAGE(G48,J48,M48,P48,S48) changed to =AGGREGATE(1,6,G48,J48,M48,P48,S48)	Changes to average capacity factor only over forestry areas that have valid data	Jo Smith, University of Aberdeen
	E48,F48	Similar to above		
2. CO_2 loss due to turbine life	D9	='Core input data'!E21*D12*'Core input data'!E14*'1. Windfarm CO2 emission saving'!D48/100 changed to ='Core input data'!E21*D12*'Core input data'!E14*'1. Windfarm CO2 emission saving'!E48/100	Changed so that minimum and maximum emission factors are used	Carlos Ruiz, SEPA
	E9	Similar to above		
Forestry input data	F31	Dropdown menu linked to cell D31	Change to set soil type in forestry areas of exp., min and max to same value	Carlos Ruiz, SEPA
	H31	Similar to above		
	F50	Dropdown menu linked to cell D50		
	H50	Similar to above		
	F69	Dropdown menu linked to cell D69		
	H69	Similar to above		
	F88	Dropdown menu linked to cell D88		
	H88	Similar to above		
	F107	Dropdown menu linked to cell D107		
	H107	Similar to above		
7ii. Forestry CO_2 loss - detail	F37	='7a. C sequest. in trees (3PG)'!$F$25 changed to ='7a. C sequest. in trees (3PG)'!F$25	Change to correctly reference different forestry areas	Carlos Ruiz, SEPA
	G37-T37	Similar to above		
	F52	='7a. C sequest. in trees (3PG)'!$F19 changed to ='7a. C sequest. in trees (3PG)'!F19		
	G52-T52	Similar to above		
	F53	='7a. C sequest. in trees (3PG)'!F26 changed to ='7a. C sequest. in trees (3PG)'!$F26		
	G53-T53	Similar to above		
	I38	='Forestry input data'!$D39 changed to ='Forestry input data'!$D58	Change to refer to different forestry areas	
	J38-T38	Similar to above		
	D61	='Forestry input data'!$D23/1000000 changed to ='Forestry input data'!$F23/1000000	Change to reference the correct cell	
	G61,J61,M61,P61,S61	Similar to above		

	E61	='Forestry input data'!$D23/1000000 changed to ='Forestry input data'!$H23/1000000		
	H61,K61,N61,Q61,T61	Similar to above		
	G63	=IF(G55>0,(G57*'Core input data'!$C41)-G62,0) changed to =IF(G55>0,(G57*'Core input data'!$E41)-G62,0)		
	H83-T63	Similar to above		
Core input data	E23	Menu linked to cell C23	Change to allow only one soil type	Carlos Ruiz, SEPA
	G23	Similar to above		
8. CO2 gain - site improvement	D62	=-12*D60/'1. Windfarm CO2 emission saving'!$D53 changed to =-12*D60/'1. Windfarm CO2 emission saving'!$E53	Change to allow use of different counterfactual emission factors	Carlos Ruiz, SEPA
	E62-N62;D63-N63;D64-N64	Similar to above		

CHANGES IN VERSION 2.11.0

Worksheet	Cells	Change	Comment	Thanks to...
5e. Emission rates from soils	D21	=IF('Core input data'!D23=1,D11,D16) changed to =IF('Core input data'!C23=1,D11,D16)		Peter Batten
	E21	=IF('Core input data'!E23=1,D11,D16) changed to =IF('Core input data'!C23=1,D11,D16)		
	D22,E22,D23,E23	Similar to above		

CHANGES IN VERSION 2.12.0

Worksheet	Cells	Change	Comment	Thanks to...
Core input data	C27,E27,G27	Cell validated to be betweeen 0.01 and 1000	Avoids incorrect entry of zero for extent of drainage	Carlos Ruiz, SEPA
Payback and CO2 emissions	C37	=IF(C26>0,(C17+C18)/C26,"No gains!") changed to =IF(C26>0,(C17+C18)/C26,"No gains!")	Error introduced by change in sign of C26	
	D37	=IF(D26<0,-(D17+D18)/D26,"No gains!") changed to	Error introduced by change in sign of D26 plus correction in use of minimum and maximum values	Alexa Morrison, RSPB
	E37	Similar to D37		
2. CO2 loss due to turbine life	C9,D9,E9	='Core input data'!C21*C12*'Core input data'!C14*'1. Windfarm CO2 emission saving'!D48/100 to ='Core input data'!C21*C12*'Core input data'!C14	Corrected to remove dependence on capacity factor	Clare Wharmby

CHANGES IN VERSION 2.13.0

CHANGES MADE BY SEPA - REPLICATED IN VERSION 2.14

CHANGES IN VERSION 2.14.0

Worksheet	Cells	Change	Comment	Thanks to...
5a. Volume of peat removed	F37	=IF($C$31=1,'Core input data'!C54,'Construction input data'!D13) -> =IF($C$31=1,'Core input data'!C54,'Construction input data'!D20)	Correction to use depth of hardstanding instead of depth of foundations	Clare Wharmby - Carbon Forecast
	G37,H37	Similar to above		
	I37	=IF($C$31=1,0,'Construction input data'!$D34) -> =IF($C$31=1,0,'Construction input data'!D41)		
	J37 - T37	Similar to above		

CHANGES IN VERSION 2.15.0

Worksheet	Cells	Change	Comment	Thanks to...
Core input data	C39-C41	Counterfactual emission factors added and source references updated	This should continue to be updated with the latest emission factors	Change implemented by Karen Dobbie, SEPA (5/12/25)
	E, G	Similar to above		
Instruction sheet		Updated to reflect new version and link to where to request a copy of the spreadsheet added		

1. Windfarm CO_2 emission saving	J25	'Forestry input data'!H29 -> ='Forestry input data'!H30		Jacob O'Sullivan - Forest Research
5a. Volume of peat removed	C71	=C13+F26+F38+C61+C66 -> =C13+C26+C38+C61+C66	Error in cell referencing	
	D71, E71	Similar to above		
5d. CO_2 loss from drained peat	E50	=IF(E47-E48>D47-D49,E47-E48,D47-D48) -> =IF(E47-E48>D47-D48,E47-E48,D47-D48)	D49 is an empty cell - incorrect reference	
7d. Wind speed ratios	C26	=OFFSET($B62,C14,1,1,1) -> =OFFSET($C$62,C$14,0)		
	C27	=OFFSET($C62,C14,1,1,1) -> =OFFSET($C$62,C$14,1)		
	C28	=OFFSET($D62,C14,1,1,1) -> =OFFSET($C$62,C$14,2)		
	C29	=OFFSET($E62,C14,1,1,1) -> =OFFSET($C$62,C$14,3)		
	D26	=OFFSET($B62,D14,1,1,1) -> =OFFSET($G$62,D$14,0)		
	D27	=OFFSET($C62,D14,1,1,1) -> =OFFSET($G$62,D$14,1)		
	D28	=OFFSET($D62,D14,1,1,1) -> =OFFSET($G$62,D$14,2)		
	D29	=OFFSET($E62,D14,1,1,1) -> =OFFSET($G$62,D$14,3)		
	E26 - BJ29	Similar to above		
Payback and CO_2 emissions	C37, D37 and E37	Payback and CO2 emissions tab updated: C37 =IF(C26<0,(C17+C18)/-C26,"No gains!") D37 =IF(D26<0,(D17+D18)/-E26,"No gains!") E37 =IF(E26<0,(E17+E18)/-D26,"No gains!")	Description: Payback and CO_2 emissions tab updated to correct logic error that caused the ratio of soil carbon loss to gain by restoration to always return "No gains!", even where restoration gains were present. Change: Conditional test amended to correctly identify soil carbon gains (represented as negative C37 =IF(C26<0,(C17+C18)/-C26,"No gains!") D37 =IF(D26<0,(D17+D18)/-E26,"No gains!") E37 =IF(E26<0,(E17+E18)/-D26,"No gains!")	Change approved by Karen Dobbie, SEPA(16/06/2026)
Core Input Data	C12, E12 and G12	Description: Lifetime of windfarm (years) cells unlocked to allow project lifespans beyond 25 years to be captured accurately.	Rationale: Increasing number of developments are submitting applications with operational lifetimes of 30, 35 or 40 years.	Change requested by C Abernethy, Energy Consents Unit(12/06/2026)