

Scottish Government Windfarm Carbon Assessment Tool - Version 2.14.1

27/01/2023

This spreadsheet calculates payback time for windfarm sited on peatlands using methods given in

Nayak et al, 2008 (<http://www.scotland.gov.uk/Publications/2008/06/25114657/0>)

and revised equations for GHG emissions (Nayak, D.R., Miller, D., Nolan, A., Smith, P. and Smith, J.U., 2010, Calculating carbon budgets of wind farms on Scottish peatland. Mires and Peat 4: Art. 9. Online: (http://www.mires-and-peat.net/map04/map_04_09.htm)

Version 2.0.0 - Adapted to include detail of forestry management, Smith et al., 2011.

<http://www.scotland.gov.uk/WindFarmsAndCarbon>

Version 2.14.0 - Corrections to calculation of peat removed for handstanding

plus corrections to emission factors and changes as detailed in previous worksheets

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

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

INSTRUCTIONS

A There are 6 worksheets giving instructions, data entry and outputs, ...

Instructions

Do I need to use this tool?

...Click here to find out

[Click here](#)

Core input data

... Data needed in all calculations

[Click here](#)

Forestry input data

... Extra details sometimes needed for forestry calculations

Construction input data

... Extra details sometimes needed for construction calculations

Payback time and CO₂ emissions

[Click here](#)

...and 8 numbered worksheets showing calculations:

1. Windfarm CO₂ emission saving

2. CO₂ loss due to turbine life

3. CO₂ loss due to backup

4. Loss of CO₂ Fixing Pot.

5. Loss of soil CO₂

5a. Volume of peat removed

5b. CO₂ loss from removed peat

5c. Volume of peat drained

5d. CO₂ loss from drained peat

5e. Emission rates

6. CO₂ loss by DOC & POC loss

7i. Forestry CO₂ loss - simple

7ii. Forestry CO₂ loss - detailed

7a. C sequest. in trees (3PG)

7b. C seq. in soil under trees

7c. Average stand data

7d. Windspeed ratios

8. CO₂ gain - site improvement

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

References

Frequently asked questions

Notes on calculations are given in pale green text boxes....

[Click here to see example of Notes Box](#)

Protocols for measurements are given in pale yellow comment boxes....

[Click here to see example of Protocol Box](#)

Assumptions are given in pale blue text boxes....

[Click here to see example of Assumptions Box](#)

Contributors:

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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 DEFAULT!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 to return to Instructions

Input data	Expected values	Record source of data	Possible range of values			Record source of data
	Enter expected value here		Enter minimum value here	Enter maximum value here		
Windfarm characteristics						
Dimensions	8	Ch 2	8	Ch 2	8	Ch 2
No. of turbines	40	Ch 2	40	Ch 2	40	Ch 2
Lifetime of windfarm (years)	6	Ch 2	6	Ch 2	6	Ch 2
Power rating of turbines (turbine capacity) (MW)	Direct input of capacity factor		Direct input of capacity factor		Direct input of capacity factor	
Capacity factor	35.0		31.5		38.5	
Enter estimated capacity factor (percentage efficiency)	5		5		5	
Backup	10		10		10	
Extra capacity required for backup (%)	Calculate wrt installed capac		Calculate wrt installed capac		Calculate wrt installed capac	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)						
Carbon dioxide emissions from turbine life- (eg. manufacture, construction, decommissioning)						
Characteristics of peatland before windfarm development						
Type of peatland	Acid bc		Acid bc		Acid bc	
Average annual air temperature at site °C)	10.1	Ch 15	10.1	Ch 15	10.1	Ch 15
Average depth of peat at site (m)	0.34	PRSA	0.34	PRSA	0.34	PRSA
C Content of dry peat (%) by weight)	0		0		0	
Average extent of drainage around drainage features at site (m)	10.00		5.00		15.00	
Average water table depth at site (m)	5.00		0.10		10.00	Ch 9
Dry soil bulk density (g cm ⁻³)	0.00		0.00		0.00	
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	10		5		15	
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha ⁻¹ yr ⁻¹)	0.25		0.12		0.31	
Forestry Plantation Characteristics						
Method used to calculate CO ₂ loss from forest felling	Enter simple data		Enter simple data		Enter simple data	
Area of forestry plantation to be felled (ha)	0		0		0	
Average rate of carbon sequestration in timber (tC ha ⁻¹ yr ⁻¹)	3.60	Ch 8	2.40	Ch 8	4.40	Ch 8
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)	0.945		0.945		0.945	
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.207		0.207		0.207	
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.424		0.424		0.424	
Borrow pits						
Number of borrow pits	1		1		1	
Average length of pits (m)	90.28	Ch 2	90.28	Ch 2	90.28	Ch 2
Average width of pits (m)	90.28	Ch 2	90.28	Ch 2	90.28	Ch 2
Average depth of peat removed from pit (m)	0.34	PRSA	0.34	PRSA	0.34	PRSA
Foundations and hard-standing area associated with each turbine						
Method used to calculate CO ₂ loss from foundations and hard-standing	Rectangular with vertical wal		Rectangular with vertical wal		Rectangular with vertical wal	
Average length of turbine foundations (m)	25.5	Ch 2	25.5	Ch 2	25.5	Ch 2
Average width of turbine foundations (m)	25.5	Ch 2	25.5	Ch 2	25.5	Ch 2
Average depth of peat removed from turbine foundations (m)	0.30	Ch 2	0.10	Ch 2	0.50	Ch 2
Average length of hard-standing (m)	80	Ch 2	75	Ch 2	85	Ch 2
Average width of hard-standing (m)	68	Ch 2	65	Ch 2	70	Ch 2
Average depth of peat removed from hard-standing (m)	0.34	PRSA	0.34	PRSA	0.34	PRSA
Access tracks						
Total length of access track (m)	5830	Ch 2	5830	Ch 2	5830	Ch 2
Existing track length (m)	3790	Ch 2	3790	Ch 2	3790	Ch 2
Length of access track that is floating road (m)	0	Ch 2	0	Ch 2	0	Ch 2
Floating road width (m)	0	Ch 2	0	Ch 2	0	Ch 2
Floating road depth (m)	0.00	Ch 2	0.00	Ch 2	0.00	Ch 2
Length of floating road that is drained (m)	0	Ch 2	0	Ch 2	0	Ch 2
Average depth of drains associated with floating roads (m)	0.00	Ch 2	0.00	Ch 2	0.00	Ch 2
Length of access track that is excavated road (m)	2040	Ch 2	2040	Ch 2	2040	Ch 2
Excavated road width (m)	4.5	Ch 2	4.5	Ch 2	4.5	Ch 2
Average depth of peat excavated for road (m)	0.34	PRSA	0.34	PRSA	0.34	PRSA
Length of access track that is rock filled road (m)	0		0		0	
Rock filled road width (m)	0		0		0	
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)	0		0		0	
Area of additional peat excavated (m ²)	0.0		0.0		0.0	
Peat Landslide Hazard						
WebLink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	PRSA	negligible	PRSA	negligible	PRSA
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)		drains drains drains		drains drains drains		drains drains drains
Water table depth in degraded bog before improvement (m)		drains drains drains		drains drains drains		drains drains drains
Water table depth in degraded bog after improvement (m)		drains drains drains		drains drains drains		drains drains drains
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	2	drains drains drains	2	drains drains drains	2	drains drains drains
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	2	drains drains drains	2	drains drains drains	2	drains drains drains
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)	0.00		0.00		0.00	
Water table depth in felled area after improvement (m)	0.00		0.00		0.00	
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2		2		2	
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	2		2		2	
Restoration of peat removed from borrow pits						
Area of borrow pits to be restored (ha)	8,150		8150		8150	
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)	1		1		1	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	2		2		2	
Early removal of drains from foundations and handstanding						
Water table depth around foundations and handstanding before restoration (m)	0.00		0.00		0.00	
Water table depth around foundations and handstanding after restoration (m)	0.00		0.00		0.00	
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0		0		0	
Restoration of site after decommissioning						
Will the hydrology of the site be restored on decommissioning?	Yes		Yes		Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	Not applic		Not applic		Not applic	
Will you attempt to block all artificial ditches and facilitate rewetting?	Not applic		Not applic		Not applic	
Will the habitat of the site be restored on decommissioning?	Yes		Yes		Yes	
Will you control grazing on degraded areas?	Not applic		Not applic		Not applic	
Will you manage areas to favour reintroduction of species	Not applic		Not applic		Not applic	

Choice of methodology for calculating emission factors

IPCC default

Core input data

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Forestry input data

ENTER DETAILS OF FORESTRY MANAGEMENT HERE!

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

(1) for estimating compensatory planting woodland carbon

<http://tinyurl.com/woodlandcarboncode>

(2) for UK policy

<http://tinyurl.com/FCPolicy>

(3) FC Scotland Control of Woodland Removal (including Compensatory Planting)

<http://tinyurl.com/FCScotlandCompPlant>

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

Click here to move to Payback Time

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Click here to return to Instructions

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Input data	Expected values		Possible range of values			
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Windfarm characteristics						
Location						
Distance to nearest biofuel plant (km)						
Dimensions						
Total wind farm area (ha)						
Performance						
Height of turbines (m)						
Average site windspeed (m s ⁻¹)						
Estimated downtime for maintenance etc (%)						
Emissions due to forestry operations						
Emissions from felling (g CO ₂ m ⁻²)						
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!)						
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 2						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t ⁻¹)						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 3						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t ⁻¹)						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 4						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t ⁻¹)						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						
AREA 5						
Number of turbines in this area						
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)						
Major soil sub-group						
Species						
Felled Forest Biomass used as biofuel?						
Felling regime						
Age of forestry when felled for windfarm (yr)						
Area felled around each turbine (ha)						
Width of forest around felled area (m)						
Value of felled forestry as a biomass fuel (MWh t ⁻¹)						
(Carbon : Biomass) ratio of felled forestry						
Replanting regime						
Years after felling when replanting occurs						
Age of seedlings on planting (yr)						
Area replanted around each turbine (ha)						

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

Note: **Emissions from felling and timber removal**. Based on emissions factors from UK taken from Morison et al (2011). If clearfelling assumed to be performed by harvester and timber is assumed extracted with forwarder, the emissions are 6675 g CO₂ m⁻².

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

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

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

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

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

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

Forestry input data

ENTER DETAILS OF FORESTRY MANAGEMENT HERE!

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

Click here to move to Payback Time

[Click here](#)

Click here to return to Instructions

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Construction input data

ENTER DETAILS OF CONSTRUCTION HERE!

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

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

Input data	Expected values		Possible range of values			
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Construction design Note - total number of turbines already specified:						
	8		8		8	
AREA 1						
Number of turbines in this area	8	Ch 2	8	Ch 2	8	Ch 2
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular		Rectangular	
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular		Rectangular	
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?	No		No		No	
Volume of Concrete						
Volume of concrete used (m ³)						
AREA 2						
Number of turbines in this area						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m ³)						
AREA 3						
Number of turbines in this area						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m ³)						
AREA 4						
Number of turbines in this area						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m ³)						
AREA 5						
Number of turbines in this area						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m ³)						

Results

PAYBACK TIME AND CO₂ EMISSIONS

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

Click here to return to Input data

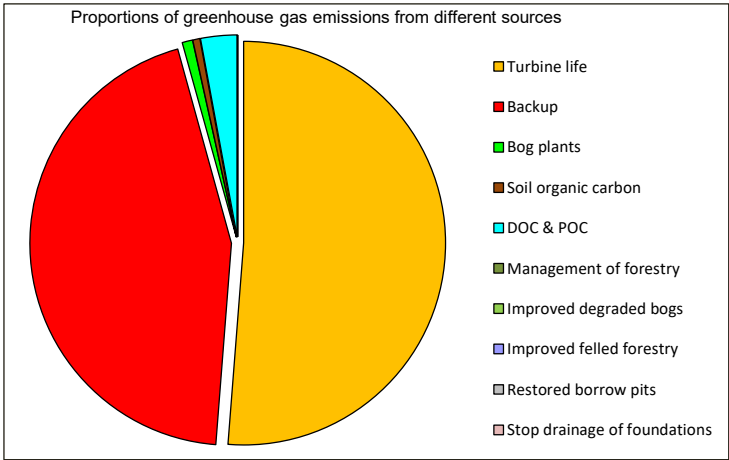
Click here to return to Instructions

Click here

Click here

	Exp.	Min.	Max.
1. Windfarm CO ₂ emission saving over...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	139074	125166	152981
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	30464	27417	33510
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	62399	56159	68639
Energy output from windfarm over lifetime (MWh)	5886720	5298048	6475392
Total CO ₂ losses due to wind farm (t CO ₂ eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	41108	41108	41108
3. Losses due to backup	35657	35657	35657
4. Losses due to reduced carbon fixing potential	669	198	1215
5. Losses from soil organic carbon	460	-2298	4124
6. Losses due to DOC & POC leaching	2330	326	5861
7. Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	80224	74991	87965
8. Total CO ₂ gains due to improvement of site (t CO ₂ eq.)			
8a. Change in emissions due to improvement of degraded bogs	0	0	0
8b. Change in emissions due to improvement of felled forestry	0	0	0
8c. Change in emissions due to restoration of peat from borrow pits	0	0	0
8d. Change in emissions due to removal of drainage from foundations & hardstanding	0	0	0
Total change in emissions due to improvements	0	0	0

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO ₂ eq.)	80224	74991	87965
Carbon Payback Time			
...coal-fired electricity generation (years)	0.6	0.5	0.7
...grid-mix of electricity generation (years)	2.6	2.2	3.2
...fossil fuel - mix of electricity generation (years)	1.3	1.1	1.6
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	No gains!	No gains!	No gains!
Ratio of CO ₂ eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	14	12	17

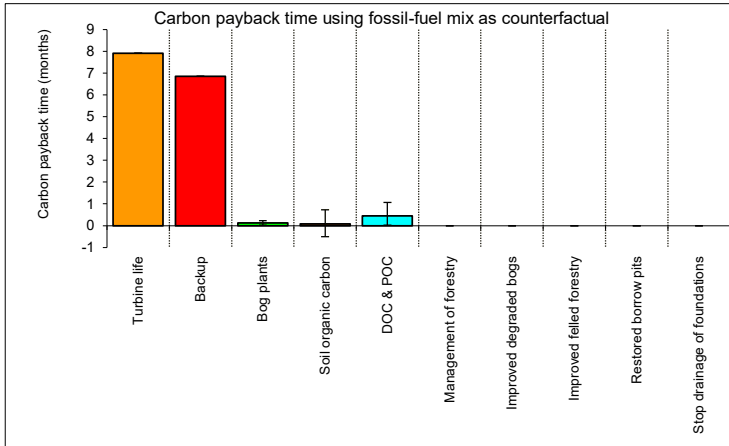
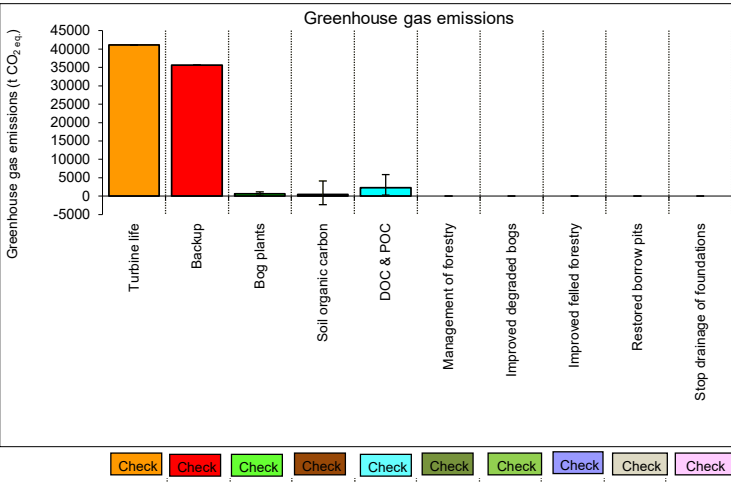


Data used in barchart of carbon payback time using fossil-fuel mix as counterfactual

Greenhouse gas emissions	Exp.	Min	Max
Turbine life	41108	0	0
Backup	35657	0	0
Bog plants	669	471	546
Soil organic carbon	460	2758	3665
DOC & POC	2330	2004	3531
Management of forestry	0	0	0
Improved degraded bogs	0	0	0
Improved felled forestry	0	0	0
Restored borrow pits	0	0	0
Stop drainage of foundations	0	0	0

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

Greenhouse gas emissions	Exp.	Min.	Max.	Carbon payback time (months)	Exp.	Min.	Max.
Turbine life	41108	0	0	8	0	0	0
Backup	35657	0	0	7	0	0	0
Bog plants	669	471	546	0	0	0	0
Soil organic carbon	460	2758	3665	0	1	1	1
DOC & POC	2330	2004	3531	0	0	1	1
Management of forestry	0	0	0	0	0	0	0
Improved degraded bogs	0	0	0	0	0	0	0
Improved felled forestry	0	0	0	0	0	0	0
Restored borrow pits	0	0	0	0	0	0	0
Stop drainage of foundations	0	0	0	0	0	0	0
	80224			15			



Results

PAYBACK TIME AND CO₂ EMISSIONS

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

Click here to return to Input data

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Windfarm CO₂ emission saving

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

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

Values taken from input sheet	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Power Generation Characteristics																		
No. of turbines	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	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Power of windfarm (MW)	48	48	48	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)	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424

Calculation of capacity factor	1	Direct input of capacity factor		
		Exp	Min	Max
Entered capacity factor (%)		35	31.5	38.5

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

Calculation of capacity factor from forestry management	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Wind speed ratio calculated in 7d				#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####
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)	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560
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		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Direct input of capacity factor																		
Capacity factor(%)	35	32	39	35	32	39	35	32	39	35	32	39	35	32	39	35	32	39
Annual energy output from windfarm (MW yr ⁻¹)	147168	132451	161885	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RESULTS	Total			Area 1			Area 2			Area 3			Area 4			Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Windfarm CO ₂ emission saving over...																		
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	139074	125166	152981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	30464	27417.4	33510.2	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)	62399	56159.3	68639.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Windfarm CO₂ emission saving

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

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

Method used to estimate CO₂ emissions from turbine life (eg. manufacture, construction, decommissioning)?

Calculate wrt installed capacity

	Exp	Min	Max
Direct input of emissions due to turbine life (t CO ₂ windfarm ⁻¹)	0	0	0
Calculation of emissions due to turbine life from energy output			
CO ₂ emissions due to turbine life (tCO ₂ turbine ⁻¹)	5139	5139	5139
No. of turbines	8	8	8
Total calculated CO ₂ emission of the wind farm due to turbine life (t CO ₂ windfarm ⁻¹)	41108	41108	41108

	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 in construction	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. manufacture, construction, decommissioning)	41108	41108	41108
Additional CO ₂ payback time of windfarm due to turbine life (eg. manufacture, construction, decommissioning)			
...coal-fired electricity generation (months)	4	4	3
...grid-mix of electricity generation (months)	16	18	15
...fossil fuel - mix of electricity generation (months)	8	9	7

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

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



Embodied carbon dioxide (CO₂e) of concretes used in buildings

CONCRETE APPLICATION	Concrete designation	CO ₂ e (kgCO ₂ e/m ³) ¹			CO ₂ e (kgCO ₂ e/tonne) ¹		
		CEM I concrete	30% fly ash concrete	50% ggbs concrete	CEM I concrete	30% fly ash concrete	50% ggbs concrete
Blinding, mass fill, strip footings, mass foundations, trench foundations ²	GEN1	177	126	101	77	55	44
Reinforced Foundations ²	RC25/30**	316	263	197	133	111	83
Ground floors ²	RC28/35	316	261	186	134	110	79
Structural in situ floors, superstructure, walls, basements ²	RC32/40**	369	313	231	154	131	96
High strength concrete ²	RC40/50**	432	351	269	178	146	111
		CO ₂ e (kgCO ₂ e/m ³)			CO ₂ e (kgCO ₂ e/tonne)		
Unreinforced Precast flooring ³		-			165		
Reinforced precast flooring ³		-			171		
Average Generic Concrete Block ⁴		-			84		

* Includes 30kg/m³ steel reinforcement

** Includes 100kg/m³ steel reinforcement

Area 5
Max
0
0.316
0

Core input data

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Input data	Expected values	Record source of data	Possible range of values			Record source of data
	Enter expected value here		Enter minimum value here	Enter maximum value here		
Windfarm characteristics						
Dimensions	8	Ch 2	8	Ch 2	8	Ch 2
No. of turbines	40	Ch 2	40	Ch 2	40	Ch 2
Lifetime of windfarm (years)	6	Ch 2	6	Ch 2	6	Ch 2
Power rating of turbines (turbine capacity) (MW)	Direct input of capacity factor		Direct input of capacity factor		Direct input of capacity factor	
Capacity factor	35.0		31.5		38.5	
Enter estimated capacity factor (percentage efficiency)	5		5		5	
Backup	10		10		10	
Extra capacity required for backup (%)	Calculate wrt installed capac		Calculate wrt installed capac		Calculate wrt installed capac	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)						
Carbon dioxide emissions from turbine life- (eg. manufacture, construction, decommissioning)						
Characteristics of peatland before windfarm development						
Type of peatland	Acid bc		Acid bc		Acid bc	
Average annual air temperature at site °C)	10.1	Ch 15	10.1	Ch 15	10.1	Ch 15
Average depth of peat at site (m)	0.34	PRSA	0.34	PRSA	0.34	PRSA
C Content of dry peat (%) by weight)	0		0		0	
Average extent of drainage around drainage features at site (m)	10.00		5.00		15.00	
Average water table depth at site (m)	5.00		0.10		10.00	Ch 9
Dry soil bulk density (g cm ⁻³)	0.00		0.00		0.00	
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	10		5		15	
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha ⁻¹ yr ⁻¹)	0.25		0.12		0.31	
Forestry Plantation Characteristics						
Method used to calculate CO ₂ loss from forest felling	Enter simple data		Enter simple data		Enter simple data	
Area of forestry plantation to be felled (ha)	0		0		0	
Average rate of carbon sequestration in timber (tC ha ⁻¹ yr ⁻¹)	3.60	Ch 8	2.40	Ch 8	4.40	Ch 8
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)	0.945		0.945		0.945	
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.207		0.207		0.207	
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.424		0.424		0.424	
Borrow pits						
Number of borrow pits	1		1		1	
Average length of pits (m)	90.28	Ch 2	90.28	Ch 2	90.28	Ch 2
Average width of pits (m)	90.28	Ch 2	90.28	Ch 2	90.28	Ch 2
Average depth of peat removed from pit (m)	0.34	PRSA	0.34	PRSA	0.34	PRSA
Foundations and hard-standing area associated with each turbine						
Method used to calculate CO ₂ loss from foundations and hard-standing	Rectangular with vertical wal		Rectangular with vertical wal		Rectangular with vertical wal	
Average length of turbine foundations (m)	25.5	Ch 2	25.5	Ch 2	25.5	Ch 2
Average width of turbine foundations (m)	25.5	Ch 2	25.5	Ch 2	25.5	Ch 2
Average depth of peat removed from turbine foundations (m)	0.30	Ch 2	0.10	Ch 2	0.50	Ch 2
Average length of hard-standing (m)	80	Ch 2	75	Ch 2	85	Ch 2
Average width of hard-standing (m)	68	Ch 2	65	Ch 2	70	Ch 2
Average depth of peat removed from hard-standing (m)	0.34	PRSA	0.34	PRSA	0.34	PRSA
Access tracks						
Total length of access track (m)	5830	Ch 2	5830	Ch 2	5830	Ch 2
Existing track length (m)	3790	Ch 2	3790	Ch 2	3790	Ch 2
Length of access track that is floating road (m)	0	Ch 2	0	Ch 2	0	Ch 2
Floating road width (m)	0	Ch 2	0	Ch 2	0	Ch 2
Floating road depth (m)	0.00	Ch 2	0.00	Ch 2	0.00	Ch 2
Length of floating road that is drained (m)	0	Ch 2	0	Ch 2	0	Ch 2
Average depth of drains associated with floating roads (m)	0.00	Ch 2	0.00	Ch 2	0.00	Ch 2
Length of access track that is excavated road (m)	2040	Ch 2	2040	Ch 2	2040	Ch 2
Excavated road width (m)	4.5	Ch 2	4.5	Ch 2	4.5	Ch 2
Average depth of peat excavated for road (m)	0.34	PRSA	0.34	PRSA	0.34	PRSA
Length of access track that is rock filled road (m)	0		0		0	
Rock filled road width (m)	0		0		0	
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)	0		0		0	
Area of additional peat excavated (m ²)	0.0		0.0		0.0	
Peat Landslide Hazard						
WebLink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	PRSA	negligible	PRSA	negligible	PRSA
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)		drains drains drains		drains drains drains		drains drains drains
Water table depth in degraded bog before improvement (m)		drains drains drains		drains drains drains		drains drains drains
Water table depth in degraded bog after improvement (m)		drains drains drains		drains drains drains		drains drains drains
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	2	drains will not have its drained blocke d so is omitted from this calculat ion	2	drains will not have its drained blocke d so is omitted from this calculat ion	2	drains will not have its drained blocke d so is omitted from this calculat ion
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	2	drains will not have its drained blocke d so is omitted from this calculat ion	2	drains will not have its drained blocke d so is omitted from this calculat ion	2	drains will not have its drained blocke d so is omitted from this calculat ion
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)	0.00		0.00		0.00	
Water table depth in felled area after improvement (m)	0.00		0.00		0.00	
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2		2		2	
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	2		2		2	
Restoration of peat removed from borrow pits						
Area of borrow pits to be restored (ha)	8,150		8150		8150	
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)	1		1		1	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	2		2		2	
Early removal of drains from foundations and handstanding						
Water table depth around foundations and handstanding before restoration (m)	0.00		0.00		0.00	
Water table depth around foundations and handstanding after restoration (m)	0.00		0.00		0.00	
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0		0		0	
Restoration of site after decommissioning						
Will the hydrology of the site be restored on decommissioning?	Yes		Yes		Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	Not applic		Not applic		Not applic	
Will you attempt to block all artificial ditches and facilitate rewetting?	Not applic		Not applic		Not applic	
Will the habitat of the site be restored on decommissioning?	Yes		Yes		Yes	
Will you control grazing on degraded areas?	Not applic		Not applic		Not applic	
Will you manage areas to favour reintroduction of species	Not applic		Not applic		Not applic	

Choice of methodology for calculating emission factors

IPCC default

Core input data

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

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Forestry input data

ENTER DETAILS OF FORESTRY MANAGEMENT HERE!

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

(1) for estimating compensatory planting woodland carbon

<http://tinyurl.com/woodlandcarboncode>

(2) for UK policy

<http://tinyurl.com/FCPolicy>

(3) FC Scotland Control of Woodland Removal (including Compensatory Planting)

<http://tinyurl.com/FCScotlandCompPlant>

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

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Input data	Expected values		Possible range of values		Record source of data
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	
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 ⁻²)					
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	User-defined		User-defined		
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	Deep Peat		Deep Peat		
Species	Scots pine		Scots pine		
Felled Forest Biomass used as biofuel?	No		No		
Felling regime					
Age of forestry when felled for windfarm (yr)					
Area felled around each turbine (ha)					
Width of forest around felled area (m)					
Value of felled forestry as a biomass fuel (MWh t ⁻¹)					
(Carbon : Biomass) ratio of felled forestry					
Replanting regime					
Years after felling when replanting occurs					
Age of seedlings on planting (yr)					
Area replanted around each turbine (ha)					
AREA 2					
Number of turbines in this area					
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)					
Major soil sub-group					
Species					
Felled Forest Biomass used as biofuel?					
Felling regime					
Age of forestry when felled for windfarm (yr)					
Area felled around each turbine (ha)					
Width of forest around felled area (m)					
Value of felled forestry as a biomass fuel (MWh t ⁻¹)					
(Carbon : Biomass) ratio of felled forestry					
Replanting regime					
Years after felling when replanting occurs					
Age of seedlings on planting (yr)					
Area replanted around each turbine (ha)					
AREA 3					
Number of turbines in this area					
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)					
Major soil sub-group					
Species					
Felled Forest Biomass used as biofuel?					
Felling regime					
Age of forestry when felled for windfarm (yr)					
Area felled around each turbine (ha)					
Width of forest around felled area (m)					
Value of felled forestry as a biomass fuel (MWh t ⁻¹)					
(Carbon : Biomass) ratio of felled forestry					
Replanting regime					
Years after felling when replanting occurs					
Age of seedlings on planting (yr)					
Area replanted around each turbine (ha)					
AREA 4					
Number of turbines in this area					
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)					
Major soil sub-group					
Species					
Felled Forest Biomass used as biofuel?					
Felling regime					
Age of forestry when felled for windfarm (yr)					
Area felled around each turbine (ha)					
Width of forest around felled area (m)					
Value of felled forestry as a biomass fuel (MWh t ⁻¹)					
(Carbon : Biomass) ratio of felled forestry					
Replanting regime					
Years after felling when replanting occurs					
Age of seedlings on planting (yr)					
Area replanted around each turbine (ha)					
AREA 5					
Number of turbines in this area					
Power curve - NOT USED! (In CORE INPUT DATA sheet you have selected to input capacity factor directly. No need to select!)					
Major soil sub-group					
Species					
Felled Forest Biomass used as biofuel?					
Felling regime					
Age of forestry when felled for windfarm (yr)					
Area felled around each turbine (ha)					
Width of forest around felled area (m)					
Value of felled forestry as a biomass fuel (MWh t ⁻¹)					
(Carbon : Biomass) ratio of felled forestry					
Replanting regime					
Years after felling when replanting occurs					
Age of seedlings on planting (yr)					
Area replanted around each turbine (ha)					

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

Note: Emissions from felling and timber removal. Based on emissions factors from UK taken from Morison et al (2011). If clearfelling assumed to be performed by harvester and timber is assumed extracted with forwarder, the emissions are 6675 g CO₂ m⁻².

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

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

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

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

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

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

Forestry input data

ENTER DETAILS OF FORESTRY MANAGEMENT HERE!

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

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Construction input data

ENTER DETAILS OF CONSTRUCTION HERE!

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

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Payback Time
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Core input data

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Input data	Expected values		Possible range of values			
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Construction design Note - total number of turbines already specified: 8 8 8						
AREA 1						
Number of turbines in this area	8	Ch 2	8	Ch 2	8	Ch 2
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular		Rectangular	
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular		Rectangular	
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?	No		No		No	
Volume of Concrete						
Volume of concrete used (m ³)						
AREA 2						
Number of turbines in this area						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m ³)						
AREA 3						
Number of turbines in this area						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m ³)						
AREA 4						
Number of turbines in this area						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m ³)						
AREA 5						
Number of turbines in this area						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding						
Length at surface (m)						
Width at surface (m)						
Length at bottom (m)						
Width at bottom (m)						
Piling						
Is piling used?						
Volume of Concrete						
Volume of concrete used (m ³)						

Results

PAYBACK TIME AND CO₂ EMISSIONS

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

Click here to return to Input data

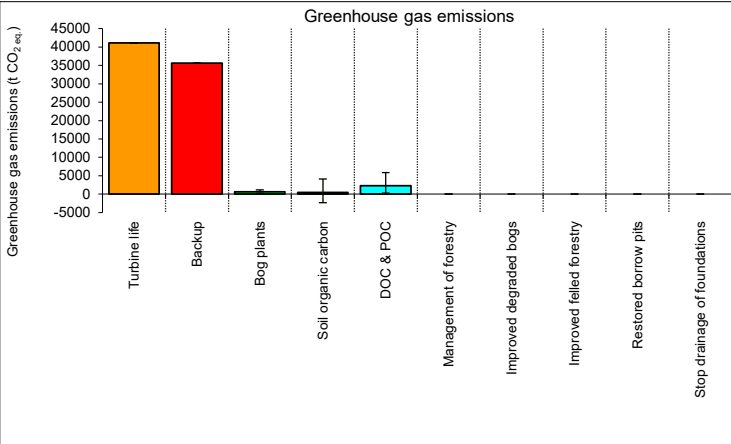
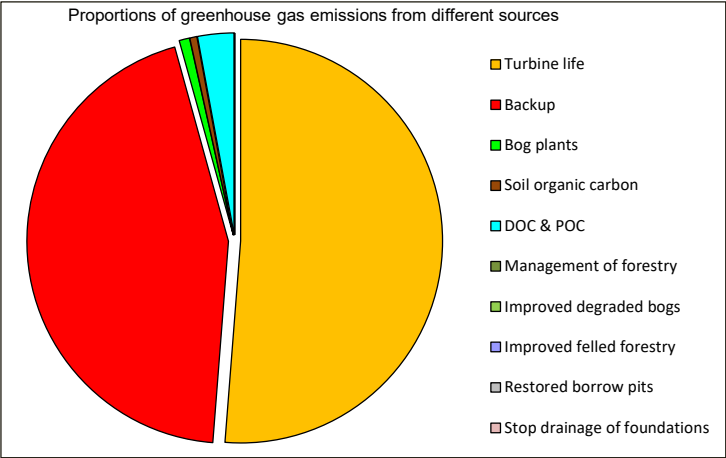
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	Exp.	Min.	Max.
1. Windfarm CO ₂ emission saving over...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	139074	125166	152981
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	30464	27417	33510
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	62399	56159	68639
Energy output from windfarm over lifetime (MWh)	5886720	5298048	6475392
Total CO ₂ losses due to wind farm (t CO ₂ eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	41108	41108	41108
3. Losses due to backup	35657	35657	35657
4. Losses due to reduced carbon fixing potential	669	198	1215
5. Losses from soil organic matter	460	-2298	4124
6. Losses due to DOC & POC leaching	2330	326	5861
7. Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	80224	74991	87965
8. Total CO ₂ gains due to improvement of site (t CO ₂ eq.)			
8a. Change in emissions due to improvement of degraded bogs	0	0	0
8b. Change in emissions due to improvement of felled forestry	0	0	0
8c. Change in emissions due to restoration of peat from borrow pits	0	0	0
8d. Change in emissions due to removal of drainage from foundations & hardstanding	0	0	0
Total change in emissions due to improvements	0	0	0

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO ₂ eq.)	80224	74991	87965
Carbon Payback Time			
...coal-fired electricity generation (years)	0.6	0.5	0.7
...grid-mix of electricity generation (years)	2.6	2.2	3.2
...fossil fuel - mix of electricity generation (years)	1.3	1.1	1.6
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	No gains!	No gains!	No gains!
Ratio of CO ₂ eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	14	12	17



Check

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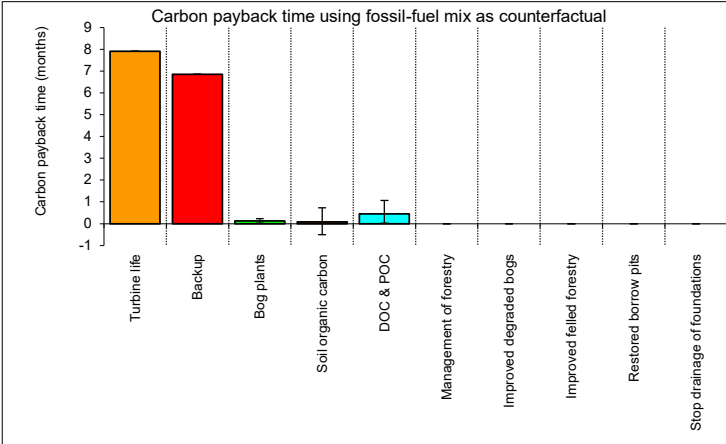
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Results

PAYBACK TIME AND CO₂ EMISSIONS

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

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

Greenhouse gas emissions	Exp.	Min.	Max.
Turbine life	41108	0	0
Backup	35657	0	0
Bog plants	669	471	546
Soil organic carbon	460	2758	3665
DOC & POC	2330	2004	3531
Management of forestry	0	0	0
Improved degraded bogs	0	0	0
Improved felled forestry	0	0	0
Restored borrow pits	0	0	0
Stop drainage of foundations	0	0	0

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

Greenhouse gas emissions	Exp.	Min.	Max.	Carbon payback time (months)	Exp.	Min.	Max.
Turbine life	41108	0	0	8	0	0	0
Backup	35657	0	0	7	0	0	0
Bog plants	669	471	546	0	0	0	0
Soil organic carbon	460	2758	3665	0	1	1	1
DOC & POC	2330	2004	3531	0	0	1	1
Management of forestry	0	0	0	0	0	0	0
Improved degraded bogs	0	0	0	0	0	0	0
Improved felled forestry	0	0	0	0	0	0	0
Restored borrow pits	0	0	0	0	0	0	0
Stop drainage of foundations	0	0	0	0	0	0	0
	80224			15			

Windfarm CO₂ emission saving

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

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Values taken from input sheet	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Power Generation Characteristics																		
No. of turbines	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	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Power of windfarm (MW)	48	48	48	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)	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945	0.945
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207	0.207
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424

Calculation of capacity factor	1	Direct input of capacity factor		
		Exp	Min	Max
Entered capacity factor (%)		35	31.5	38.5

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

Calculation of capacity factor from forestry management	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Wind speed ratio calculated in 7d				#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####
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)	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560	52560
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		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Direct input of capacity factor																		
Capacity factor(%)	35	32	39	35	32	39	35	32	39	35	32	39	35	32	39	35	32	39
Annual energy output from windfarm (MW yr ⁻¹)	147168	132451	161885	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RESULTS	Total			Area 1			Area 2			Area 3			Area 4			Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Windfarm CO ₂ emission saving over...																		
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	139074	125166	152981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	30464	27417.4	33510.2	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)	62399	56159.3	68639.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Windfarm CO₂ emission saving

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

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

Method used to estimate CO₂ emissions from turbine life (eg. manufacture, construction, decommissioning): Calculate wrt installed capacity

	Exp	Min	Max
Direct input of emissions due to turbine life (t CO ₂ windfarm ⁻¹)	0	0	0
Calculation of emissions due to turbine life from energy output			
CO ₂ emissions due to turbine life (tCO ₂ turbine ⁻¹)	5139	5139	5139
No. of turbines	8	8	8
Total calculated CO ₂ emission of the wind farm due to turbine life (t CO ₂ windfarm ⁻¹)	41108	41108	41108

	Exp	Min	Max	Construction Area 1			Construction Area 2			Construction Area 3			Construction Area 4			Construction Area 5		
Calculation of emissions due to cement used in construction	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
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 in construction	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. manufacture, construction, decommissioning)	41108	41108	41108
Additional CO ₂ payback time of windfarm due to turbine life (eg. manufacture, construction, decommissioning)			
...coal-fired electricity generation (months)	4	4	3
...grid-mix of electricity generation (months)	16	18	15
...fossil fuel - mix of electricity generation (months)	8	9	7

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

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



Embodied carbon dioxide (CO₂e) of concretes used in buildings

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

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

Emissions due to backup power generation

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

	Expected	Minimum	Maximum
Reserve capacity required for backup			
No. of turbines	8	8	8
Power rating of turbines (turbine capacity) (MW)	6	6	6
Power of wind farm (MW h ⁻¹)	48	48	48
Rated capacity (MW yr ⁻¹)	420480	420480	420480
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)	2102	2102	2102

Carbon dioxide emissions due to backup power generation

Coal-fired plant emission factor (t CO ₂ MWh ⁻¹)	0.945	0.945	0.945
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.207	0.207	0.207
Fossil fuel - mix emission factor (t CO ₂ MWh ⁻¹)	0.424	0.424	0.424
Lifetime of windfarm (years)	40	40	40
Annual emissions due to backup from...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	1987	1987	1987
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	435	435	435
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	891	891	891

RESULTS**Total emissions due to backup from...**

...coal-fired electricity generation (tCO ₂)	79471	79471	79471
...grid-mix of electricity generation (tCO ₂)	17408	17408	17408
...fossil fuel - mix of electricity generation (tCO ₂)	35657	35657	35657

Additional CO₂ payback time of windfarm due to backup

...coal-fired electricity generation (months)	7	8	6
...grid-mix of electricity generation (months)	7	8	6
...fossil fuel - mix of electricity generation (months)	7	8	6

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/DL, 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 ~50%), 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 improvement in grid management techniques, emissions due to backup power generation may become more significant. The extra capacity needed for backup power generation is currently estimated to be 5% of the rated capacity of the wind plant if wind power contributes more than 20% to the national grid (Dale et al. 2004). Moving towards the SG target of 50% electricity generation from renewable sources, more short-term capacity may be required in terms of pumped-storage hydro-generated power, or a better mix of offshore and onshore wind generating capacity. Grid management techniques are anticipated to reduce this extra capacity, with improved demand side management, smart meters, grid reinforcement and other developments. However, given current grid management techniques, it is suggested that 5% extra capacity should be assumed for backup power generation if wind power contributes more than 20% to the national grid. At lower contributions, the extra capacity required for backup should be assumed to be zero. These assumptions should be revisited as technology improves.

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

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Emissions due to backup power generation

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

Emissions due to loss of bog plants

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

	Expected	Minimum	Maximum
Area where carbon accumulation by bog plants is lost			
Total area of land lost due to windfarm construction (m ²)	66052	61532	70132
Total area affected by drainage due to windfarm construction (m ²)	79851	38386	124157
Total area where fixation by plants is lost (m ²)	145904	99918	194289
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

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

RESULTS

Total loss of carbon accumulation by bog plants			
Total area where fixation by plants is lost (ha)	15	10	19
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 CO₂)	669	198	1215
Additional CO₂ payback time of windfarm due to loss of CO₂ fixing potential			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0

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Emissions due to loss of bog plants

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

Emissions due to loss of soil organic carbon

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

		Expected result	Minimum result	Maximum result
Check	CO ₂ loss due to windfarm construction			
	CO ₂ loss from removed peat (t CO ₂ equiv)	-6154	-5160	-7188
Check	CO ₂ loss from drained peat (t CO ₂ equiv)	6614	2861	11312
RESULTS				
Total CO₂ loss from peat (removed + drained) (t CO₂ equiv)		460	-2298	4124
Additional CO₂ payback time of windfarm due to loss of soil CO₂				
...coal-fired electricity generation (months)		0	0	0
...grid-mix of electricity generation (months)		0	-1	1
...fossil fuel - mix of electricity generation (months)		0	0	1

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Emissions due to loss of soil organic carbon

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

Volume of Peat Removed

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

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

Peat removed from borrow pits	Exp	Total Min	Max
Number of borrow pits	1	1	1
Average length of pits (m)	90.28	90.28	90.28
Average width of pits (m)	90.28	90.28	90.28
Average depth of peat removed from pit (m)	0.34	0.34	0.34
Area of land lost in borrow pits (m ²)	8150.48	8150.48	8150.48
Volume of peat removed from borrow pits (m ³)	2771.16	2771.16	2771.16

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
Length at surface (m)				26	26	26	0	0	0	0	0	0	0	0	0	0	0	0
Width at surface (m)				26	26	26	0	0	0	0	0	0	0	0	0	0	0	0
Length at bottom (m)				26	26	26	0	0	0	0	0	0	0	0	0	0	0	0
Width at bottom (m)				26	26	26	0	0	0	0	0	0	0	0	0	0	0	0
Depth of foundations (m)				0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
"Area" of land lost in hard-standing (m ²)	5202	5202	5202	5202	5202	5202	0	0	0	0	0	0	0	0	0	0	0	0
Volume of peat removed from foundation area (m ³)	1560.6	520.2	2601	1560.6	520.2	2601	0	0	0	0	0	0	0	0	0	0	0	0

Peat removed from hard-standing	Total			Construction Area 1			Construction Area 2			Construction Area 3			Construction Area 4			Construction Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Method used to calculate CO ₂ loss from foundations	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
Length at surface (m)				80	75	85	0	0	0	0	0	0	0	0	0	0	0	0
Width at surface (m)				68	65	70	0	0	0	0	0	0	0	0	0	0	0	0
Length at bottom (m)				80	75	85	0	0	0	0	0	0	0	0	0	0	0	0
Width at bottom (m)				68	65	70	0	0	0	0	0	0	0	0	0	0	0	0
Depth of hardstanding (m)				0	0.34	0.34	0	0	0	0	0	0	0	0	0	0	0	0
Area of land lost in hard-standing (m ²)	43520	39000	47600	43520	39000	47600	0	0	0	0	0	0	0	0	0	0	0	0
Volume of peat removed from hardstandingarea (m ³)	14796.8	13260	16184	14796.8	13260	16184	0	0	0	0	0	0	0	0	0	0	0	0

Peat removed from access tracks	Exp	Total Min	Max
<u>Floating roads</u>			
Length of access track that is floating road (m)	0	0	0
Floating road width (m)	0	0	0
Floating road depth (m)	0	0	0
Area of land lost in floating roads (m ²)	0	0	0
Volume of peat removed for floating roads	0	0	0
<u>Excavated roads</u>			
Length of access track that is excavated road (m)	2040	2040	2040
Excavated road width (m)	4.5	4.5	4.5
Average depth of peat excavated for road (m)	0.34	0.34	0.34
Area of land lost in excavated roads (m ²)	9180	9180	9180
Volume of peat removed for excavated roads	3121.2	3121.2	3121.2
<u>Rock-filled roads</u>			
Length of access track that is rock filled road (m)	0	0	0
Rock filled road width (m)	0	0	0
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)	9180	9180	9180
Total volume of peat removed due to access tracks (m ³)	3121.2	3121.2	3121.2

<u>Additional peat excavated -</u> (not already accounted for above)			
Volume of additional peat excavated (m ³)	0	0	0
Area of additional peat excavated (m ²)	0	0	0

RESULTS	Exp	Total Min	Max
Total volume of peat removed (m ³) due to windfarm construction	22249.8	19672.6	24677.4
Total area of land lost due to windfarm construction (m ²)	66052	61532.5	70132.5

Click here to move to 5b. CO2 loss from removed peat

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[Click here](#)**Volume of Peat Removed**

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

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

CO₂ loss from removed peats

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

	Expected	Minimum	Maximum
CO₂ loss from removed peat			
C Content of dry peat (% by weight)	0	0	0
Dry soil bulk density (g cm ⁻³)	0.00	0.00	0.00
% C contained in removed peat that is lost as CO ₂	100	100	100
Total volume of peat removed (m³) due to windfarm construction	22250	19673	24677
CO ₂ loss from removed peat (t CO ₂)	0	0	0

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

CO₂ loss from undrained peat left in situ			
Total area of land lost due to windfarm construction (ha)	7	6	7
CO ₂ loss from undrained peat left in situ (t CO ₂ ha ⁻¹)	932	839	1025
CO ₂ loss from undrained peat left in situ (t CO ₂)	6154	5160	7188

CO₂ loss attributable to peat removal only			
CO ₂ loss from removed peat (t CO ₂)	0	0	0
CO ₂ loss from undrained peat left in situ (t CO ₂)	6154	5160	7188
RESULTS			
CO₂ loss attributable to peat removal only (t CO₂)	-6154	-5160	-7188

Click here to move to 5. Loss of soil CO₂

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CO₂ loss from removed peats

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

Volume of peat drained

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

Extent of drainage around each metre of drainage ditch	Total		
	Exp	Min	Max
Average extent of drainage around drainage features at site (m)	10	5	15

Peat affected by drainage around borrow pits	Total		
	Exp	Min	Max
Number of borrow pits	1	1	1
Average length of pits (m)	90	90	90
Average width of pits (m)	90	90	90
Average depth of peat removed from pit (m)	0.3	0.3	0.3
Area affected by drainage per borrow pit (m ²)	4011	1906	6317
Total area affected by drainage around borrowpits (m ²)	4011	1906	6317
Total volume affected by drainage around borrowpits (m ³)	682	324	1074

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)				26	26	26	0	0	0	0	0	0	0	0	0	0	0	0
Average width of turbine foundations at base(m)				26	26	26	0	0	0	0	0	0	0	0	0	0	0	0
Average depth of peat removed from turbine foundations (m)				0.3	0.1	0.5	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)				80	75	85	0	0	0	0	0	0	0	0	0	0	0	0
Average width of hard-standing at base (m)				68	65	70	0	0	0	0	0	0	0	0	0	0	0	0
Average depth of peat removed from hard-standing (m)				0.3	0.3	0.3	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)				0.3	0.3	0.5	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)				106	101	111	0	0	0	0	0	0	0	0	0	0	0	0
Total width of foundation and hardstanding (m)				94	91	96	0	0	0	0	0	0	0	0	0	0	0	0
Area affected by drainage of foundation and hardstanding area (m ²)	4380	2010	7080	4380	2010	7080	0	0	0	0	0	0	0	0	0	0	0	0
Total area affected by drainage of foundation and hardstanding area (m ²)	35040	16080	56640	35040	16080	56640	0	0	0	0	0	0	0	0	0	0	0	0
Total volume affected by drainage of foundation and hardstanding area (m ³)	5957	2734	14160	5957	2734	14160	0	0	0	0	0	0	0	0	0	0	0	0

Peat affected by drainage of access tracks	Total		
	Exp	Min	Max
Floating roads			
Length of floating road that is drained (m)	0	0	0
Floating road width (m)	0.0	0.0	0.0
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)	2040	2040	2040
Excavated road width (m)	5	5	5
Average depth of peat excavated for road (m)	0.3	0.3	0.3
Area affected by drainage of excavated roads (m ²)	40800	20400	61200
Volume affected by drainage of excavated roads (m ³)	6936	3468	10404
Rock-filled roads			
Length of rock filled road that is drained (m)	0	0	0
Rock filled road width (m)	0	0	0
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 ³)	0	0	0
Total area affected by drainage of access track (m ²)	40800	20400	61200
Total volume affected by drainage of access track (m ³)	6936	3468	10404

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	Exp	Total Min	Max
Volume of additional peat excavated (m ³)	0.0	0.0	0.0
Area of additional peat excavated (m ²)	0.0	0.0	0.0
Average depth of excavated peat (m)	0	0	0
Radius of area excavated (m)	0	0	0
Radius of excavated and drained area (m)	0	0	0
Total area affected by drainage (m ²)	0	0	0
Total volume affected by drainage (m ³)	0.00	0.00	0.00

Assumption: Area excavated is assumed to be a circle

RESULTS	Exp	Total Min	Max
Total area affected by drainage due to windfarm (m ²)	79851	38386	124157
Total volume affected by drainage due to windfarm (m ³)	13574.7	6525.552	25637.86

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Volume of peat drained

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

CO₂ loss due to drainage

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

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	Expected	Minimum	Maximum
Drained Land			
Total area affected by drainage due to wind farm construction (ha)	8	4	12
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 Decommissionin

Check	Total volume affected by drainage due to wind farm (m ³)	13575	6526	25638
	C Content of dry peat (% by weight)	0	0	0
	Dry soil bulk density (g cm ⁻³)	0.00	0.00	0.00
	Total GHG emissions from Drained Land (t CQ equiv.)	0	0	0
	Total GHG Emissions from Undrained Land (t CQ equiv.)	0	0	0

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 Decommissionin**1. Losses if Land is Drained**

	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)	0.000	0.000	0.000
	Conversion factor: CH ₄ -C to CO ₂ equivalents	30.67	30.67	30.67
	CH ₄ emissions from drained land (t CQ equiv.)	0	0	0
	Carbon Dioxide Emissions from Drained Land			
Check	Rate of carbon dioxide emission in drained soil (t CQha ⁻¹ yr ⁻¹)	35.20	35.20	35.20
	CO ₂ emissions from drained land (t CQ ₂)	14054	6080	24037
	Total GHG emissions from Drained Land (t CQ₂ equiv.)	14054	6080	24037

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

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

2. Losses if Land is Undrained

	Flooded period (days year ⁻¹)	178	178	178
	Lifetime of windfarm (years)	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)	0.04	0.04	0.04
	Conversion factor: CH ₄ -C to CO ₂ equivalents	30.67	30.67	30.67
	CH ₄ emissions from undrained land (t CQ ₂ equiv.)	240	104	410
	Carbon Dioxide Emissions from Undrained Land			
Check	Rate of carbon dioxide emission in undrained soil (t CQha ⁻¹ yr ⁻¹)	0.00	0.00	0.00
	CO ₂ emissions from undrained land (t CQ ₂)	7200	3115	12315
	Total GHG Emissions from Undrained Land (t CQ₂ equiv.)	7440	3219	12725

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

3. CO₂ Losses due to Drainage

Total GHG emissions from drained land (t CQ equiv.)	14054	6080	24037
Total GHG emissions from undrained land (t CQ ₂ equiv.)	7440	3219	12725
RESULTS			
Total GHG emissions due to drainage (t CQ₂ equiv.)	6614	2861	11312

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CO₂ loss due to drainage

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

Emission rates from soils

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

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Selected Methodology = IPCC default 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)

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

Selected emission characteristics (IPCC, 1997)

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

Calculations following ECOSSE based methodology

Drained Land

Total area affected by drainage due to wind farm construction (ha)	8	4	12
Total volume affected by drainage due to wind farm construction (m ³)	13875	6506	25638

Soil Characteristics that Determine Emission Rates

Average annual air temperature at the site (°C)	10.1	10.1	10.1
Average water table depth at site (m)	5.00	10.00	0.10
Average water table depth of drained land (m)	5.00	10.00	0.21

Annual Emission Rates following site specific methodology

Acid bogs

Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	24.32	24.32	7.30
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	24.32	24.32	2.94
Rate of methane emission in drained soil (t CH ₄ -C ha ⁻¹ yr ⁻¹)	-0.001	-0.001	0.038
Rate of methane emission in undrained soil (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.00	0.00	0.14

Fens

Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	65.24	65.24	18.71
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	65.24	65.24	7.82
Rate of methane emission in drained soil (t CH ₄ -C ha ⁻¹ yr ⁻¹)	-0.003	-0.003	0.073
Rate of methane emission in undrained soil (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.00	0.00	0.21

Selected emission characteristics following site specific methodology

Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	24.32	24.32	7.30
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	24.32	24.32	2.94
Rate of methane emission in drained soil (t CH ₄ -C ha ⁻¹ yr ⁻¹)	-0.001	-0.001	0.038
Rate of methane emission in undrained soil (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.00	0.00	0.14

RESULTS

Selected Emission Rates

Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00
Rate of methane emission in drained soil (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000
Rate of methane emission in undrained soil (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.04	0.04	0.04

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

Click here
Click here

Emission rates from soils

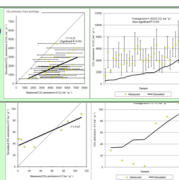
Note: Note, CO₂ losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been thoroughly tested against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

Assumption: The period of flooding is taken to be 178 days yr⁻¹ for acid bogs and 169 days yr⁻¹ based on the monthly mean temperature and the lengths of inundation (IPCC, 1997. Revised 1998 IPCC guidelines for national greenhouse gas inventories, Vol.3, table 5.13)

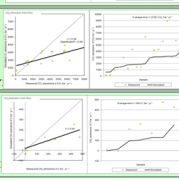
Assumption: The CH₄ emission rate provided for acid bogs is 11 (1.38) mg CH₄-C m⁻² day⁻¹ x 365 days, and for fens is 60 (21-162) mg CH₄-C m⁻² day⁻¹ x 365 days (Swanston & Crutzen, 1995; Johnstone & Smith, 1997)

Assumption: CO₂ emissions on drainage of organic soils for upland crops (e.g. grain, vegetables) are 3.667/6 (7.9-11.3) t CO₂ ha⁻¹ yr⁻¹ in temperate climates (Swanston and Morgan, 1988; J. Soil 74, 755-774)

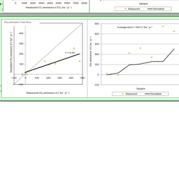
Note: Carbon dioxide emissions from acid bogs. Equation derived by regression analysis against 60 measurements (Nayak et al, 2008). The equation derived was:
 $R_{CO_2} = (3.667/1000) \times ((6700 \times \exp(-0.25 \times \exp(-0.0515 \times ((W \times 100) - 50)))) + ((72.54 \times T) - 800))$
where R_{CO_2} is the annual rate of CO₂ emissions (t CO₂ ha⁻¹ yr⁻¹),
T = average annual air temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements ($r^2=0.63$, $P < 0.05$).
Evaluation against 29 independent experiments shows a significant association ($r^2=0.21$, $P < 0.05$) and an average error of 3023 t CO₂ ha⁻¹ yr⁻¹ which is non-significant (P=0.06) (Smith et al., 1997).



Measurements (Nayak et al, 2008). The equation derived was:
 $R_{CH_4} = (1/1000) \times (500 \times \exp(-0.1234 \times (W \times 100))) + ((3.529 \times T) - 36.67)$
where R_{CH_4} is the annual rate of CH₄ emissions (t CH₄-C ha⁻¹ yr⁻¹),
T = average annual air temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements ($r^2=0.64$, $P < 0.05$).
Evaluation against 7 independent experiments shows a significant association ($r^2=0.81$, $P < 0.05$) and an average error of 277 t CH₄-C ha⁻¹ yr⁻¹ (significance not defined due to lack of replicates - Smith et al., 1997).



Note: Carbon dioxide emissions from fens. Equation derived by regression analysis against 44 measurements (Nayak et al, 2008). The equation derived was:
 $R_{CO_2} = (3.667/1000) \times ((6244 \times \exp(-0.175 \times \exp(-0.073 \times ((W \times 100) - 50)))) + ((153.23 \times T))$
where R_{CO_2} is the annual rate of CO₂ emissions (t CO₂ ha⁻¹ yr⁻¹),
T = average annual air 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 10 independent experiments shows a significant association ($r^2=0.66$, $P < 0.05$) and an average error of 102 t CO₂ ha⁻¹ yr⁻¹ (significance not defined due to lack of replicates - Smith et al., 1997).



Note: Methane emissions from fens. Equation derived by regression analysis against experimental data from 36 measurements (Nayak et al, 2008). The equation derived was:
 $R_{CH_4} = (1/1000) \times ((1453.62 \times \exp(-0.097 \times ((W \times 100) - 0.862 \times T)))$
where R_{CH_4} is the annual rate of CH₄ emissions (t CH₄-C ha⁻¹ yr⁻¹),
T = average annual air temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements ($r^2=0.41$, $P < 0.05$).
Evaluation against 7 independent experiments shows a significant association ($r^2=0.69$, $P < 0.05$) and an average error of 164 t CH₄-C ha⁻¹ yr⁻¹ (significance not defined due to lack of replicates - Smith et al., 1997).



Emissions due to loss of DOC and POC

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

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

	Expected	Minimum	Maximum
Total C loss			
Gross CO ₂ loss from restored drained land (t CO ₂)	6854	2965	11722
Gross CH ₄ loss from restored drained land (t CO ₂ equiv.)	0	0	0
Gross CO ₂ loss from improved land (t CO ₂)			
Degraded Bog	0	0	0
Felled Forestry	0	0	0
Borrow Pits	0	0	0
Foundations & Hardstanding	0	0	0
Gross CH ₄ loss from improved land (t CO ₂ equiv.)			
Degraded Bog	0	0	0
Felled Forestry	0	0	0
Borrow Pits	0	0	0
Foundations & Hardstanding	0	0	0
Conversion factor: CH ₄ -C to CO ₂ equivalents	30.6667	30.6667	30.6667
% total soil C losses, lost as DOC	26	7	40
% DOC loss emitted as CO ₂ over the long term	100	100	100
% total soil C losses, lost as POC	8	4	10
% POC loss emitted as CO ₂ over the long term	100	100	100
Total gaseous loss of C (t C)	1873	810	3203
Total C loss as DOC (t C)	487	57	1281
Total C loss as POC (t C)	150	32	320

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

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

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

Assumption: POC loss ranges between 4-10% of the total gaseous loss if calculated from the reported values and is 8% of the total gaseous loss if calculated from the mean of reported maximum and minimum value in Worrall 2009. POC range is (7 - 22.4 MgC/KM²/yr) (Worrall et al, 2009).

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

RESULTS

Total CO₂ loss due to DOC leaching (t CO₂)	1782	208	4689
Total CO₂ loss due to POC leaching (t CO₂)	548	119	1172
Total CO₂ loss due to DOC & POC leaching (t CO₂)	2330	326	5861
Additional CO₂ payback time of windfarm due to DOC & POC			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	1	0	2
...fossil fuel - mix of electricity generation (months)	0	0	1

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Emissions due to loss of DOC and POC

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

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

Emissions due to forest felling - calculation using simple management data

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

	Expected	Minimum	Maximum
Emissions due to forestry felling			
Area of forestry plantation to be felled (ha)	0	0	0
Carbon sequestered (tC ha ⁻¹ yr ⁻¹)	3.6	2.4	4.4
Lifetime of windfarm (years)	40	40	40
Carbon sequestered over the lifetime of the windfarm (t C ha ⁻¹)	144	96	176
RESULTS			
Total carbon loss due to felling of forestry (t CO₂)	0	0	0
Additional CO₂ payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0

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Emissions due to forest felling - calculation using simple management data

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

CO₂ loss from forests - calculation using detailed management information

Forest carbon calculator (Perks et al., 2009)

	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Loss of carbon sequestration due to felling of forestry for the wind farm																		
Number of turbines	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area felled around each turbine (ha)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of forestry plantation to be felled for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area replanted around each turbine (ha)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of forestry plantation to be replanted (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area deforested for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon sequestered per hectare for lifetime of the wind farm (t CO ₂ e ⁻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				Deep Peat	Deep Peat	Deep Peat	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 (t CO ₂ e ⁻¹ yr ⁻¹)				5.00	5.00	5.00	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				Deep Peat	Deep Peat	Deep Peat	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 ⁻²)	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 (t CO ₂ 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)	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424
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 km ⁻¹)				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				Deep Peat	Deep Peat	Deep Peat	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 (t CO ₂ ha ⁻¹)				272	272	272	#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)	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424	0.424
Savings in CO ₂ emissions associated with using replanted forestry as a biofuel (t CO ₂)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance to nearest biomass power plant (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emissions of CO ₂ associated with transportation (t CO ₂ km ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon equivalent of transportation (t CO ₂ km ⁻¹)				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 CO₂ payback time of windfarm due to management of forestry																		
...coal-fired electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...grid-mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CO₂ loss from forests - calculation using detailed management information

Forest carbon calculator (Perks et al., 2009)

Carbon sequestration in soil under trees

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

Carbon Sequestration in Soil

Under Trees: Lookup
Table

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

Average stand data

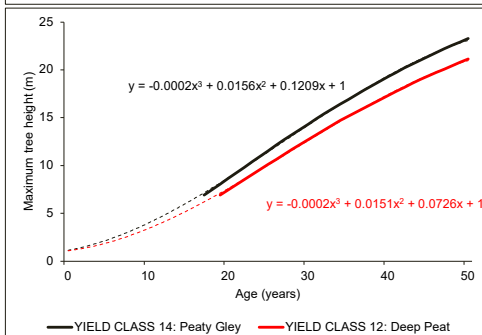
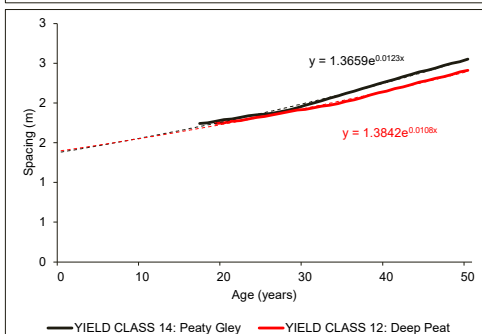
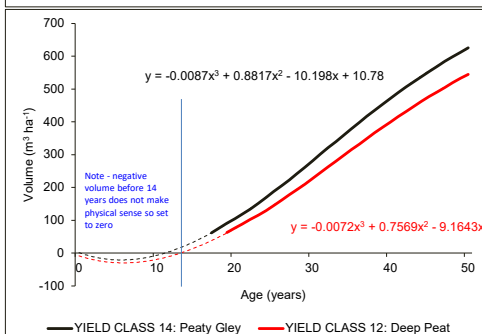
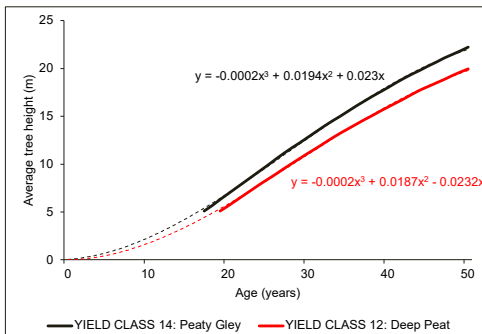
Data obtained from Forestry Commission growth and yield tables (Edwards & Christie, 1981)

STAND_ID
SPECIES ForestGALES
Sitka Spruce**YIELD CLASS 14: Peaty Gley**

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

YIELD CLASS 12: Deep Peat

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



Note: Wind speed ratios derived from WINDFLOW model (Gardiner, 2004)

[illegible]

RESULTS Wind speed ratios (used in worksheet 1)	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
Standard Forestry Practice															
No felling	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Felled	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Felled & replanted	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!

BACKGROUND CALCULATIONS

[illegible]

Model results

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

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Gains due to site improvement

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

Selected Methodology = IPCC default

Type of peatland = Acid Bog

Reduction in GHG emissions due to improvement of site	Expected result				Minimum result				Maximum result			
	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Handstanding	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Handstanding	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Handstanding
1. Description of site												
Improvement of...												
Period of time when effectiveness of the improvement can be guaranteed (years)	2	2	2	40	2	2	2	40	2	2	2	40
Area to be improved (ha)	0	0	0	0	0	0	0	0	0	0	0	0
Average air temperature at site (°C)	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1
Depth of peat drained (m)	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Depth of peat above water table before improvement (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Depth of peat above water table after improvement (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Losses with improvement												
Flooded period (days year ⁻¹)	178	178	178	178	178	178	178	178	178	178	178	178
Time required for hydrology and habitat to return to its previous state on restoration (years)	2	2	1	0	2	2	1	0	2	2	1	0
Improved period (years)	0	0	1	40	0	0	1	40	0	0	1	40
Methane emissions from improved land												
Site specific methane emission from improved soil on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499
Site specific methane emission from improved soil on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560
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)	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Carbon dioxide emissions from improved land												
Site specific CO ₂ emission from improved soil on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Site specific CO ₂ emissions from improved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
IPCC annual rate of carbon dioxide emission on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IPCC annual rate of carbon dioxide emission on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Selected annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂ emissions from improved land (t CO ₂)	0	0	0	0	0	0	0	0	0	0	0	0
Total GHG emissions from improved land (t CO₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
3. Losses without improvement												
Flooded period (days year ⁻¹)	0	0	0	0	0	0	0	0	0	0	0	0
Time required for hydrology and habitat to return to its previous state on restoration (years)	2	2	1	0	2	2	1	0	2	2	1	0
Improved period (years)	0	0	1	40	0	0	1	40	0	0	1	40
Methane emissions from unimproved land												
Site specific methane emission from unimproved soil on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499	0.499
Site specific methane emission from unimproved soil on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560	0.560
IPCC annual rate of methane emission on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IPCC annual rate of methane emission on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Selected annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CH ₄ emissions from unimproved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Carbon dioxide emissions from unimproved land												
Site specific CO ₂ emission from unimproved soil on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Site specific CO ₂ emissions from unimproved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
IPCC annual rate of carbon dioxide emission on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20
IPCC annual rate of carbon dioxide emission on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20
Selected annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20
CO ₂ emissions from unimproved land (t CO ₂)	0	0	0	0	0	0	0	0	0	0	0	0
Total GHG emissions from unimproved land (t CO₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
RESULTS												
4. Reduction in GHG emissions due to improvement of site												
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Reduction in GHG emissions due to improvement (t CO₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Additional CO₂ payback time of windfarm due to site improvement												
... coal-fired electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0
... grid-mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0
... fossil fuel - mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0

Click here to move to Payback Time [Click here](#)**Gains due to site improvement**

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

Note: Methane emissions from acid bogs. Equation derived by regression analysis against 57 measurements (Nayak et al. 2009). The equation derived was $R_{CH_4} = (1/1000) \times (500 \times \exp(-0.1234 \times (W \times 100))) + (3.529 \times T) - 36.67$ where R_{CH_4} is the annual rate of CH₄ emissions (t CH₄-C ha⁻¹ yr⁻¹), T is average annual air temperature (°C) and W is the water table depth (m).

The equation shows a significant correlation with measurements ($r^2 = 0.54$, $P > 0.05$). Evaluation against 7 independent experiments shows a significant association ($r^2 = 0.81$, $P > 0.05$) and an average error of 27 t CH₄-C ha⁻¹ yr⁻¹ (significance not defined due to lack of replicates - Smith et al. 1997).

Note: Methane emissions from fens. Equation derived by regression analysis against experimental data from 35 measurements (Nayak et al. 2009). The equation derived was $R_{CH_4} = (1/1000) \times (-10 \times 563.62 \times \exp(-0.097 \times (W \times 100))) + (0.662 \times T)$ where R_{CH_4} is the annual rate of CH₄ emissions (t CH₄-C ha⁻¹ yr⁻¹), T is average annual air temperature (°C) and W is the water table depth (m).

The equation shows a significant correlation with measurements ($r^2 = 0.41$, $P > 0.05$). Evaluation against 7 independent experiments shows a significant association ($r^2 = 0.69$, $P > 0.05$) and an average error of 164 t CH₄-C ha⁻¹ yr⁻¹ (significance not defined due to lack of replicates - Smith et al. 1997).

$R_{CO_2} = (3.667/1000) \times (6700 \times \exp(-0.26 \times \exp(-0.0515 \times ((W \times 100) - 50)))) + ((72.54 \times T) - 800)$ where R_{CO_2} is the annual rate of CO₂ emissions (t CO₂ ha⁻¹ yr⁻¹), T is average annual peat temperature (°C) and W is the water table depth (m).

The equation shows a significant correlation with measurements ($r^2 = 0.53$, $P > 0.05$). Evaluation against 29 independent experiments shows a significant association ($r^2 = 0.21$, $P > 0.05$) and an average error of 3023 t CO₂ ha⁻¹ yr⁻¹ which is non-significant ($P > 0.05$) (Smith et al. 1997).

Note: Carbon dioxide emissions from fens. Equation derived by regression analysis against 44 measurements (Nayak et al. 2009). The equation derived was $R_{CO_2} = (3.667/1000) \times (16244 \times \exp(-0.175 \times \exp(-0.073 \times ((W \times 100) - 50)))) + (153.23 \times T)$ where R_{CO_2} is the annual rate of CO₂ emissions (t CO₂ ha⁻¹ yr⁻¹), T is 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 CO₂ 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: CO₂ emissions from acid bogs. As aboveNote: CO₂ emissions from fens. As above

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Frequently Asked Questions

Click here to email question

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 Mclver (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	C88, 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(L49,L49,O49,R49,U49)) changed to =IF(D19>1,365*24*(F11*F10*G21/100,SUM(L49,L49,O49,R49,U49))	Cameron McIver, Cameron Ecology Ltd

CHANGES IN VERSION 2.3.0

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

CHANGES IN VERSION 2.4.0

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

CHANGES IN VERSION 2.5.0

Worksheet	Cells	Change	Thanks to...
7ii. Forestry CO2 loss - detail	F55	=F50*F53/F54 changed to =IF(F50>0,F50*F53/F54,0)	Jenny Sneddon, AMEC
7ii. Forestry CO2 loss - detail	G55-T55	Similar to above	
7ii. Forestry CO2 loss - detail	F46	=IF(F35="Yes",F44*F45,0) changed to =IF(F35="Yes",IF(F39>0,F44*F45,0),0)	
7ii. Forestry CO2 loss - detail	G46-T46	Similar to above	
7ii. Forestry CO2 loss - detail	F63	=(F57*Core input data'!\$E41)-F62 changed to =IF(F55>0,(F57*Core input data'!\$C41)-F62,0)	
7ii. Forestry CO2 loss - detail	G63-T63	Similar to above	
7ii. Forestry CO2 loss - detail	G38	=Forestry input data'!\$F39 changed to =Forestry input data'!\$H39	
7ii. Forestry CO2 loss - detail	J38,M38,P38,S38	Similar to above	
7ii. Forestry CO2 loss - detail	H38	=Forestry input data'!\$H39 changed to =Forestry input data'!\$F39	
7ii. Forestry CO2 loss - detail	K38,N38,Q38,T38	Similar to above	
7ii. Forestry CO2 loss - detail	D66	=D27*D24+D32-D47-D63 changed to =D17+D24+D32-E47-E63	
7ii. Forestry CO2 loss - detail	G66, J66, M66, P66, S66	Similar to above	
7ii. Forestry CO2 loss - detail	E66	=E17+E24+E32-E47-E63 changed to =E17+E24+E32-D47-D63	
7ii. Forestry CO2 loss - detail	H66, K66, N66, Q66, T66	Similar to above	
5c. Volume of peat drained	C54	=Core input data'!C68 changed to =Core input data'!C70	SEPA
5c. Volume of peat drained	D54, E54	Similar to above	
5c. Volume of peat drained	D48	=Core input data'!C65 changed to =Core input data'!E65	
5c. Volume of peat drained	E48	Similar to above	
5c. Volume of peat drained	G33	=IF(G23>0,(\$C9+G31+C9)*(\$C9+G32+C9)-(G31*G32),0) changed to =IF(G23>0,(\$D9+G31+C9)*(\$D9+G32+C9)-(G31*G32),0)	
5c. Volume of peat drained	J33,M33,P33,S33	Similar to above	
5c. Volume of peat drained	H33	=IF(H23>0,(\$C9+H31+C9)*(\$C9+H32+C9)-(H31*H32),0) changed to =IF(H23>0,(\$E9+H31+C9)*(\$E9+H32+C9)-(H31*H32),0)	
5c. Volume of peat drained	J33,M33,P33,S33	Similar to above	

CHANGES IN VERSION 2.6.0

Worksheet	Cells	Change	Thanks to...
Payback Time and CO2 emissions	D23	=D23/D9 changed to =D\$31/E9	Sarah Lister, Natural Power
Payback Time and CO2 emissions	D34,D35	Similar to above	
Payback Time and CO2 emissions	E33	=E\$31/E9 changed to =E\$31/D9	
Payback Time and CO2 emissions	E34, E35	Similar to above	
Payback Time and CO2 emissions	D31	=D19+D25 changed to =D19+E25	
Payback Time and CO2 emissions	E31	=E19+E25 changed to =E19+D25	
6. CO2 loss by DOC & POC loss	C11	Contents deleted	Ffion Causer, Natural Power
6. CO2 loss by DOC & POC loss	D11, E11	Similar to above	
6. CO2 loss by DOC & POC loss	C26	=(C9+C12+C13+C14+C15+(C10+C17+C18+C19+C20)/C21)/3.66 changed to =((C9+C12+C13+C14+C15)/3.66)+(((C10+C17+C18+C19+C20)/C21)*(12/16))	
6. CO2 loss by DOC & POC loss	D26,E26	Similar to above	
Do I need to use this tool		Wording changed to clarify that the tool SHOULD be used with highly organic soils, but COULD also be used with sites undergoing drainage or deforestation	SEPA
Core input data	C12	Set to 25 and fixed to comply with planning applications for Section 36 (planning period = 25 years)	
Core input data	Row 25	Average depth of peat at site not used - therefore removed	
1. Windfarm CO2 emission saving	D48	Set to AVERAGE(C48,J48,M48,P48,S48) to ensure a value is provided	
1. Windfarm CO2 emission saving	E37	24*365*D11 changed to 24*365*E11	Sarah Lister, Natural Power
1. Windfarm CO2 emission saving	F37-U37	Similar to above	
5e. Emission rates from soils	C34	=C28/(C27*10000) changed to =MAX(C28/(C27*10000),C33)	Ffion Causer, Natural Power
5e. Emission rates from soils	D34, E34	Similar to above	

CHANGES IN VERSION 2.7.0

Worksheet	Cells	Change	Thanks to...
8. CO2 gain - site improvement	C63	=-12*C61/1. Windfarm CO2 emission saving'!\$D54 changed to =-12*C60/1. Windfarm CO2 emission saving'!\$D54	Sarah Lister, Natural Power
	D63-N63	Similar to above	
	C64	=-12*C62/1. Windfarm CO2 emission saving'!\$D54 changed to =-12*C60/1. Windfarm CO2 emission saving'!\$D54	
	D64-N64	Similar to above	
Core input data	C74 E74, G74 C75 E75, G75	Volume of additional peat excavated added to make the calculation more generalised Similar to above Area of additional peat excavated added to make the calculation more generalised Similar to above	Rob McCall, Countryside Council for Wales
5a. Volume of peat removed	Row 64 - 67 C70 D70, E70 C71	Extra lines added to show the additional peat excavated in this sheet =C14+C27+C39+C62 changed to =C14+C27+C39+C62+C65 Similar to above =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 Row 95	New input: Water table depth in borrow pit before restoration New input: Water table depth around foundations and hardstanding before restoration	Sarah Lister, Natural Power
8. CO2 gain - site improvement	Row 15 C15 (previously C16) I15, M15 D15 (previously D16) J15, N15	Deleted =Core input data'!C45 changed to =Core input data'!C91 Similar to above =Core input data'!C50 changed to =Core input data'!C95 Similar to above	
5d. CO2 loss from drained peat	C43 D43, E43	=C8*(C35+C36)/((C42*C34))/365 changed to =C8*(C35+C36)/((C42*(365-C34)))/365 Similar to above	University of Aberdeen

CHANGES IN VERSION 2.7.2

Worksheet	Cells	Change	Comment	Thanks to...
8. CO ₂ gain - site improvement	C13 G13, K13 D13 H13, L13 E13 I13, M13 F13 J13, N13	Change =Core input data!C80 changed to =IF(Core input data!C81>Core input data!C82,Core input data!C80,0) Similar to above =Core input data!C85 changed to =IF(Core input data!C86>Core input data!C87,Core input data!C85,0) Similar to above =Core input data!C90 changed to =IF(Core input data!C91>Core input data!C92,Core input data!C90,0) Similar to above =5c. Volume of peat drained!C34/10000 changed to =IF(Core input data!C95>Core input data!C96,5c. Volume of peat drained!C34/10000,0) Similar to above		Thanks to... Ffion Causier, Natural Power

CHANGES IN VERSION 2.8.0

5c. Volume of peat drained	Cells Rows 67 - 76 C67-C68, D67-D68, E67-E68 C69 D69, E69 C70 D70, E70 C71 D71, E71 C72 D72, E72 C73 D73, E73 C74 D74, E74 C75 D75, E75 C79 D79, E79 C80 D80, E80	Change Inserted rows to included additional excavated peat in volume of peat drained Title lines =Core input data!C74 Similar to above =Core input data!C75 Similar to above =IF(C70>0,C69/C70,0) Similar to above =SORT(C70/PI()) Similar to above =C72+C9 Similar to above =PI()*C73*C73)-C70 Similar to above =C74*C71 Similar to above =C18+C34+C57+C64 changed to =C18+C34+C57+C64+C74 Similar to above =C19+C35+C58+C65 changed to =C19+C35+C58+C65+C75 Similar to above	Comment Include additional excavated peat in volume of peat drained	Thanks to... Susana Sebastian, SEPA
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
Forestry input data	G62-T62 C23	Similar to above Units changed from g CO ₂ km ⁻² to g CO ₂ km ⁻² t ⁻¹		
Core input data	Row 25 Row 15 C15	Insert input for average depth of peat at site Insert average depth of peat at site =Core input data!C25	Limit improvements following restoration to the depth of the peat	Susana Sebastian, SEPA
8. CO ₂ gain - site improvement	D15-N15 (excl. E15, I15 & M15) E15 I15, M15 C16 D16-N16 C17 D17-N17 C21 D21-N21	Similar to above =Core input data!C46 Similar to above Core input data!C82 changed to =IF(Core input data!C82<C15,Core input data!C82,C15) Similar to above =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	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 CO ₂ emissions	Row 37 C37 D637, E37	Insert ratio of soil carbon loss to gain by restoration =IF(C26<0,(C27+C18)/C26,0) Similar to above	Include calculation of ratio of soil losses to gains	Rob McCall, NRW
Payback Time and CO ₂ 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 CO ₂	D11 E11	=D8+D9 changed to =MIN(D8+D9,E8+E9) =E8+E9 changed to =MAX(D8+D9,E8+E9)	Correct use of minimum and maximum wrt water table depth at very low depths	Peter Batten
5e. Emission rates from soils	D31 E31 D32 E32 E33	=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		
8. CO ₂ 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. CO ₂ 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. CO ₂ gain - site improvement	C34 D34-N34 C53 D53-N53	=IF(Core input data!C8112=2,8. CO ₂ gain - site improvement!C30,8. CO ₂ gain - site improvement!C32) changed to =IF(Core input data!C8112=2,IF(Core input data!C823=1,C30,C31),IF(Core input data!C823=1,C32,C33)) Similar to above =IF(Core input data!C8112=2,8. CO ₂ gain - site improvement!C49,8. CO ₂ gain - site improvement!C51) changed to =IF(Core input data!C8112=2,IF(Core input data!C823=1,C49,C50),IF(Core input data!C823=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 Core input data	Cells B94 B95	Change "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)"	Comment Confusing wording as water table depth may always be entered as zero.	Thanks to... Clare Wharmby - Carbon Forecast
8. CO ₂ gain - site improvement	C47	=((23*16/12)*C813*C440*C46*(C819/365) changed to =((23*16/12)*C813*C440*C46*(C838/365)	Error in formula using the improved flooded period instead of the unimproved flooded period	Elizabeth Keen - Peter brett Associates
7c. Average stand data	Rows 13-29 Rows 168-86	Stand data extended from 17 year to 0 years Similar to above	If forest stand is less than 17 years old, the calculations fail	Brenda Park - AMEC
7ii. Forestry CO ₂ loss - detail	F31	=IF (F29>0,IF(F27="Deep Peat",VLOOKUP(F29,7c. Average stand data!\$D\$87:\$G\$118,3)),(VLOOKUP(F29,7c. Average stand data!\$D\$30:\$G\$63,3)),0) changed to =IF(F29>0,IF(F27="Deep Peat",VLOOKUP(F29,7c. Average stand data!\$D\$68:\$G\$118,3)),0) Similar to above		
7ii. Forestry CO ₂ loss - detail	G31-T31 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 CO ₂ 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 #N/A	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 CO ₂ emissions	C37 D637, E37	=IF(C26<0, (C17+C18)/C26, "No gains") Similar to above	Ensure no restoration is highlighted as no gains rather than	Sarah Lister, Natural Power
Payback Time and CO ₂ emissions	C38 D637, E37	=((12/44)*(C20+C26)*1000000)/(C12*1000) Similar to above	Express ratio as CO ₂ rather than C emissions to power generation	Sarah Lister, Natural Power

CHANGES IN VERSION 210.0

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.	Thanks to... Sarah Lister, Natural Power
Payback Time and CO2 emissions	B22 B23 - B26 D8 C38, E38	"Ba. Gains due to improvement of degraded bogs" changed to "Ba. 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. CO2 loss due to turbine life	C19-T19 C23 D23-E23	0.373 changed to 0.316 =IF('Core input data'!\$C\$20=1,\$C9+C20,\$C13+C20) changed to =IF('Core input data'!\$C\$20=1,\$C9,\$C13+C20) Similar to above	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 Direct input of emissions includes cement already	Carlos Ruiz, SEPA
5a. Volume of peat removed	F26 G26-T26	=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) Similar to above	Error in formula	Carlos Ruiz, SEPA
5c. Volume of peat drained	C34 D34-T34 C55 D55-E55 C73 D73-E73	=C33*C23 changed to =F34*I34+L34*O34+R34 Similar to above ='Core input data'!C70 changed to =C52*(C9+C9) Similar to above =C72+C9 changed to =IF(C70>0,C72+C9,0) Similar to above	 Accounts for emissions during both flooded and unflooded times of the year in an undrained soil	Carlos Ruiz, SEPA
5d. CO2 loss from drained peat	C43 D43,E43 C40 D40,E40 D50 E50	=C8*(C35+C36)*((C42*(365-C34))/365) changed to =C8*(C35+C36)*(((C42*C34)/365)+(C29*(365-C34)/365)) Similar to above =C8*(C35+C36)*C39*((C38*C34)/365) changed to =C8*(C35+C36)*C39*((C38*C34)/365)+(C25*(365-C34)/365)) Similar to above =D47-D48 changed to =IF(D47-D48<E47-E48,D47-D48,E47-E48) Similar to above	Protection against unusual conditions that result in incorrect order for min and max calculations	Carlos Ruiz, SEPA
5e. Emission rates from soils	D31 E31	=Core input data'!G24 changed to =Core input data'!E24 =Core input data'!E24 changed to =Core input data'!G24	Correction from previous min/max change	Carlos Ruiz, SEPA
Core input data	C103 E103, G103, C107, E107, G107	=IF(C105=2,IF(C106=2,2,1),1) changed to =IF(C105=1,IF(C106=1,2,1),1) Similar to above		Carlos Ruiz, SEPA
7a. C sequest. in trees (3PG)	E24 F24, G24, E25-G25, E26-G26 F25 G25-T25 F26 G26-T26	=AVERAGE(F24,I24,L24,O24,R24) changed to =AGGREGATE(1,6,F24,I24,L24,O24,R24) Similar to above =VLOOKUP(F15,\$C62:\$AQ212,9,TRUE) changed to =VLOOKUP(F15,\$B62:\$AQ212,10,TRUE) Similar to above =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)) Similar to above	Correction to avoid error when some areas of forestry are not filled. Correction to formula so that it looks in the age column Change to correct lookup of net primary production of replanted forestry	Carlos Ruiz, SEPA
7d. Wind speed ratios	Insert row 9 C9 D9-Q9 Insert row 10 C10 D10-Q10 C21 D21-Q21 C22 D22-Q22 C52 D52-Q52 C54 D54-Q54	Years after planting when felling occurs =Forestry input data'!D41 Similar to above Age of seedlings on plant (yr) =Forestry input data'!D42 Similar to above =VLOOKUP(C11,'yc. Average stand data'!\$D30:\$H563,2,TRUE) changed to =VLOOKUP(C11,'G9+C10,'yc. Average stand data'!\$D30:\$H563,2,TRUE) Similar to above =OFFSET('yc. Average stand data'!\$D30,C8-'yc. Average stand data'!\$D30,C8-'yc. Average stand data'!\$D30:C11,1,1) changed to =IF(C8<C11<=50,OFFSET('yc. Average stand data'!\$D30,C8-'yc. Average stand data'!\$D30:C11,1,1),OFFSET('yc. Average stand data'!\$D30,C8-'yc. Average stand data'!\$D30:C11-50+C10-C9,1,1)) Similar to above =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) Similar to above =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) Similar to above	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. Change to allow for normal harvesting of forestry during the lifetime of the windfarm 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 Changes to correct the calculation of height of boundary layer in replanted area	Carlos Ruiz, SEPA
Construction input data	C13 C20, C34, C41, C55, C62, C76, C83, C97, C104	"Depth of hole dug when constructing foundations (m)" changed to "Average depth of peat removed when constructing foundations (m)" Similar to above	Changes in wording to improve clarity of input data	Carlos Ruiz, SEPA
1. Windfarm CO2 emission saving	H17 D48 E48,F48	=Core input data'!\$C\$41 changed to =Core input data'!\$E\$41 =AVERAGE(G48,I48,M48,P48,S48) changed to =AGGREGATE(1,6,G48,I48,M48,P48,S48) Similar to above	Correction of error Changes to average capacity factor only over forestry areas that have valid data	Carlos Ruiz, SEPA Jo Smith, University of Aberdeen
2. CO2 loss due to turbine life	D9 E9	=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 Similar to above	Changed so that minimum and maximum emission factors are used	Carlos Ruiz, SEPA
Forestry input data	F31 H31 F50 H50	Dropdown menu linked to cell D31 Similar to above Dropdown menu linked to cell D50 Similar to above	Change to set soil type in forestry areas of exp., min and max to same value	Carlos Ruiz, SEPA

	F69 H69 F88 F107 H107	Dropdown menu linked to cell D69 Similar to above Dropdown menu linked to cell D88 Similar to above Dropdown menu linked to cell D107 Similar to above		
7ii. Forestry CO2 loss - detail	F37 G37-T37 F52 G52-T52 F53 G53-T53 I38 J38-T38 D61 G61,J61,M61,P61,S61 E61 H61,K61,N61,O61,T61 G63 H83-T63	=7a. C sequest. in trees (3PG)!\$F#25 changed to =7a. C sequest. in trees (3PG)!\$F#25 Similar to above =7a. C sequest. in trees (3PG)!\$F19 changed to =7a. C sequest. in trees (3PG)!\$F19 Similar to above =7a. C sequest. in trees (3PG)!\$F26 changed to =7a. C sequest. in trees (3PG)!\$F26 Similar to above =Forestry input data!\$D39 changed to =Forestry input data!\$D58 Similar to above =Forestry input data!\$D23/1000000 changed to =Forestry input data!\$F23/1000000 Similar to above =Forestry input data!\$D23/1000000 changed to =Forestry input data!\$H23/1000000 Similar to above =IF(G55>0,(G57*Core input data!\$C41)-G62,0) changed to =IF(G55>0,(G57*Core input data!\$E41)-G62,0) Similar to above	Change to correctly reference different forestry areas Change to refer to different forestry areas Change to reference the correct cell	Carlos Ruiz, SEPA
Core input data	E23 G23	Menu linked to cell C23 Similar to above	Change to allow only one soil type	Carlos Ruiz, SEPA
8. CO2 gain - site improvement	D62 E62,N62,D63-N63,D64,N64	=-12*D60/1. Windfarm CO2 emission saving!\$D53 changed to =-12*D60/1. Windfarm CO2 emission saving!\$E53 Similar to above	Change to allow use of different counterfactual emission factors	Carlos Ruiz, SEPA

CHANGES IN VERSION 210.

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

CHANGES IN VERSION 212.0

Worksheet	Cells	Change	Comment	Thanks to...
Core input data	C27,E27,G27	Cell validated to be between 0.01 and 1000	Avoids incorrect entry of zero for extent of drainage	Carlos Ruiz, SEPA
Payback and CO2 emissions	C37 D37 E37	=IF(C26>0,(C17+C18)/C26,"No gains!") changed to =IF(C26>0,(C17+C18)/C26,"No gains!") =IF(D26<0,-(D17+D18)/D26,"No gains!") changed to Similar to D37	Error introduced by change in sign of C26 Error introduced by change in sign of D26 plus correction in use of minimum and maximum values	 Alexa Morrison, RSPB
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 213.0

CHANGES MADE BY SEPA - REPLICATED IN VERSION 214

CHANGES IN VERSION 214.0

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