






Appendix C




Geomorphology Target Notes




Target Note	Ordnance Survey Grid Reference	Description	Photographs
001	254597, 610035	Looking generally west from the proposed site entrance to Peat Hill.	
002	254687, 610210	Looking generally west along the northern slope of Peat Hill. Note the dominance of grasses and grazing pasture.	
003	254789, 609760	Looking generally north along the western slope of Peat Hill across BP-A and towards the proposed route of the access track.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
004	254937, 609759	Looking generally northwest along the northern slope of Peat Hill within BP-A at an exposure of igneous bedrock. Note the mineral grasses and grazing pasture.	
005	255086, 609758	Looking generally northwest to Peat Hill across BP-A and across the proposed access route of the hill.	
006	255239, 609959	Looking generally north from Peat Hill to the B741. Note the mineral grasses indicating the absence of significant depths of peat.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
007	255189, 609708	Looking generally west from adjacent to the access track.	
008	255489, 609660	Looking generally south towards Barbeys Hill and across Blood Moss and the proposed locations of the temporary compound and the substation.	
009	255383, 609426	Looking generally north towards Peat Hill across a flush in the foreground.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
010	255090, 609307	Looking generally north towards the proposed location of T16.	
011	255429, 609224	Looking generally southeast towards Chang Hill and Benty Cowan Hill from the access track. Note the steep valley in the distance.	
012	255434, 609020	Looking generally east towards Rigg Hill from the temporary construction compound.	


Target Note	Ordnance Survey Grid Reference	Description	Photographs
013	255467, 609045	Looking north to Peat Hill across Blood Moss showing a potential peat pipe in the foreground, denoted by a line of rushes.	
014	255490, 609011	Looking generally south from the temporary construction compound towards Enoch Hill (right summit), High Chang Hill (left of Enoch Hill) and Barbeys Hill (in foreground).	
015	255419, 608896	Looking generally southeast from the temporary construction compound towards Chang Hill showing the steep sided valleys of Catlock Burn (left) and Littlechange Burn (right).	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
016	255385, 608804	Looking generally northeast over the proposed location of the temporary construction compound and substation towards Peat Hill (left summit).	
017	256096, 608694	Looking southeast from Rigg Hill down in to the steep sided valley of the Crocradie Burn and the confluence with the Catlock Burn (right).	
018	255690, 608502	A peat substrate exposure along near the banks of the Knockburnie Burn. Note the thin organic soils overlying Glacial Till, denoted by the red line.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
019	255450, 608333	Looking north over a flush adjacent to the Knockburnie Burn.	
020	255187, 608205	Looking north across the proposed location of T16 towards Barbeys Hill (foreground) and Enoch Hill in the distance.	
021	256291, 608508	An example of a recent translational failure of the mineral soils along the steep sided valley of the Catlock Burn.	



Target Note	Ordnance Survey Grid Reference	Description	Photographs
022	256085, 608436	Looking downslope from the head of a translational failure on the steep north facing slope of Littlechang Hill.	
023	256092, 608405	Looking generally northeast along the steep sided valley of the Crocradie Burn. Note the numerous translational failures along the valley.	
024	255944, 608345	Looking in a downstream direction along the Littlechang Burn. Note the steepness of the streams gradient and further evidence of translational failures.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
025	255991, 608297	Evidence of translational failure along the valley of the Littlechang Burn.	
026	255991, 608302	Bedrock exposures along the steep sided valley of the Littlechang Burn.	
027	255990, 608203	Exposed superficial deposits along the Littlechang Burn. Note the granular nature of the soils which include coarse gravels, cobbles and boulders.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
028	255947, 608161	Looking generally southeast at a potential peat pipe and pipe collapses extending upslope to the northeast of T2.	
029	255910, 608045	Looking generally north-northwest towards Rigg Hill from T2.	
030	255667, 608060	Looking generally west towards Carsphairn Forest and Lethans Hill to the west of the site. In the foreground is an example of one of the many drainage ditches.	




Target Note	Ordnance Survey Grid Reference	Description	Photographs
031	255788, 607806	An example of the peat profile taken on the northern slope of Barbeys Hill. Note the low water content and the relatively high fibrosity of the sample and the present of sandy clayey substrate at the base of the sample (right).	
032	255847, 607290	Looking generally northeast across Barbeys Hill and the route of the access track to T17 which avoids the haggings in the distance.	
033	256090, 606698	Looking generally north from Enoch Hill along the western site boundary.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
034	256405, 606162	Potential evidence of tension cracking and slope creep of the peat around the location of T19.	
035	256291, 607210	Looking generally south towards High Chang Hill. Note the exposure in the foreground which indicates granular soils.	
036	256484, 606900	Looking generally southeast across the source of Bitch Burn with evidence of haggling and flushes.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
037	256685, 606866	Looking generally southwest towards an area of haggging (in the distance) to the northeast of T7 which is over the horizon.	
038	256687, 606802	A closer example of the hagsgs shown in target note 037.	
039	256784, 606682	A peat exposure at a hagg to the northeast of T7. Note the granular nature of the peat substrate.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
040	256575, 606536	Looking generally southeast across a flush adjacent to the micro-siting allowance for T17.	
041	256885, 608904	Looking generally north towards Dalleagles from the northern slope of Chang Hill.	
042	256787, 608403	Looking across Chang Hill towards Benty Cowan Hill and the location of T14.	


Target Note	Ordnance Survey Grid Reference	Description	Photographs
043	256687, 608003	An example of the shallow soil profile on Chang Hill comprising an organic horizon of <0.5m depth over gleyed sandy clay.	
044	257487, 608606	Looking generally northwest towards High Chang Hill across Trough Burn.	
045	255395, 607909	A potential peat pipe collapse to the south of BP-C.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
046	257661, 607965	A pond formed in shallow peat in the col between Benty Cowan Hill and High Chang Hill located adjacent to the proposed track to T18.	
047	257364, 607808	Looking generally northwest along the route of the tracks to T14 and T18.	
048	257266, 607283	Peat pipe collapses to the north of T10 near the source of the Polga Burn. Collapses are present in front and behind of the person.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
049	257225, 607280	A peat pipe collapse on the Polga Burn. The form of the collapse may indicate that surface water may surcharge into the collapse during heavy rainfall causing scour when flows subside.	
050	257386, 606706	Looking northeast along the Connel Burn from adjacent to T12.	
051	257409, 606692	Evidence of gully formation in the mineral soils to the north of T12.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
052	257849, 607542	Looking across the micro-siting allowance for T15 up towards High Change Hill.	
053	258685, 609008	Looking generally northeast across the source of the Blarene Burn. Note the dominance of mineral soils in this area.	
054	259007, 608401	Looking along the steep sided valley of the Connel Burn.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
055	256108, 607908	Looking southwest towards Barbeys Hill over an area of haggling near T17.	
056	255786, 608211	Looking northeast along the valley of the Crocradie Burn with Rigg Hill to the left and Chang Hill on the right.	
057	257512, 608112	An example of a moss filled grip within the micrositing allowance of T14.	

Target Note	Ordnance Survey Grid Reference	Description	Photographs
058	256128, 606922	A peat slump on the northern slope of Enoch Hill to the northeast of T4.	



Appendix 6.C

Carbon Balance – Average Peat Depth Calculations Spreadsheet

All peat depths roads Average peat depths at turbine locations

0.00	2.40
0.00	0.50
0.00	1.15
0.60	0.85
0.30	2.50
0.21	0.50
0.10	0.70
0.44	0.50
0.75	1.00
0.32	1.15
0.25	1.10
1.72	2.40
0.85	1.50
0.82	0.3
0.50	0.4
0.35	0.44
0.47	0.22
0.44	0.15
0.44	0.26
0.84	0.95 Average
0.86	
0.86	
0.86	
0.49	
0.90	
0.90	
0.82	
0.93	
1.34	
1.65	
0.71	
0.83	
0.91	
2.10	
0.25	
0.12	
0.86	
1.82	
0.70	
0.12	
0.35	
0.37	
0.15	
0.54	
0.22	
0.41	
0.17	
0.69	
0.25	
0.34	
0.65	
0.30	
0.50	
0.30	
0.40	
0.00	
0.00	
0.00	
0.30	
0.60	
0.30	
1.40	
0.60	
0.90	
0.30	
0.40	
0.85	
0.40	
0.60	
0.45	
0.40	
0.70	
0.50	
0.30	
0.30	
0.90	
0.50	
0.60	
0.50	
0.60	
0.30	
0.50	
0.45	
0.00	
0.30	
0.00	
0.60	
0.90	
0.85	
0.60	
1.10	
0.40	
0.90	
1.00	
0.90	
0.30	
0.50	
0.30	
0.50	
0.80	
0.80	
0.60	
0.60	
0.90	
0.90	
0.70	
0.30	
0.60	
0.00	
0.00	
1.30	
0.60	
0.50	
1.80	
0.30	
0.30	
0.40	
0.40	
0.50	
0.60	
1.30	
0.90	
0.00	
0.50	
0.70	
0.70	
0.85	
0.40	
0.50	
1.40	
0.80	
1.90	
1.70	

Track length	m	Total
Floating		1,900
New tracks		11,000
Upgrade		0
Total Length		12,900

Extra peat excavation	Volume m3	Area m2
Primary compound	5,100	10,000
Passing Places	2,550	
Control building	12,276	19,800
Met masts	332	425
Borrow Pit	10,500	30,000
Totals	30,758	60,225

Floating road not requiring drainage
1,900

All peat depths roads Average peat depths at turbine locations

0.90
1.80
0.90
0.70
0.45
0.40
0.90
0.90
0.00
1.10
0.40
0.00
0.60
0.90
0.32
0.87
0.59
0.26
0.60
1.85
1.02
0.43
1.44
0.50
0.52
0.70
0.50
0.34
0.52
0.50
0.66
0.29
0.88
0.64
0.87
2.22
1.26
0.65
0.94
0.92
0.61
0.50
0.23
0.39
0.36
0.44
0.26
0.48
0.22
0.23
0.21
0.69
0.22
0.27
0.39
0.17
0.77
0.41
0.41
0.92
0.39
0.49
0.44
2.27
1.12
0.86
1.08
1.28
1.02
0.65
1.58
0.38
0.60
0.71
1.84
0.84
0.57
0.58
0.56
0.70
0.50
0.62
0.28
0.35
0.79
0.61
0.90
0.61
0.82
0.38
0.82
0.64
0.82
0.54
0.75
0.38
0.64
1.07
0.69
1.41
1.72
0.64
0.66
0.18
0.26
0.45
0.54
0.94
0.85
0.65
0.94
1.03
0.28
0.70
0.20
0.80
1.25
2.30
0.90
1.90
1.70
1.40
2.20
2.25

Peat depths along track (m)	Track length (m)	Track width (m)	Excavated area (m2)	Volumes
1.00	50	6	300	300
1.02	50	6	300	306
1.02	50	6	300	306
1.03	50	6	300	309
1.07	50	6	300	321
1.08	50	6	300	324
1.10	50	6	300	330
1.10	50	6	300	330
1.12	50	6	300	336
1.25	50	6	300	375
1.26	50	6	300	378
1.28	50	6	300	384
1.30	50	6	300	390
1.30	50	6	300	390
1.34	50	6	300	402
1.40	50	6	300	420
1.40	50	6	300	420
1.40	50	6	300	420
1.41	50	6	300	423
1.44	50	6	300	432
1.58	50	6	300	474
1.65	50	6	300	495
1.70	50	6	300	510
1.70	50	6	300	510
1.72	50	6	300	516
1.72	50	6	300	516
1.80	50	6	300	540
1.80	50	6	300	540
1.84	50	6	300	552
1.85	50	6	300	555
1.90	50	6	300	570
1.90	50	6	300	570
2.10	50	6	300	630
2.20	50	6	300	660
2.22	50	6	300	666
2.25	50	6	300	675
2.27	50	6	300	681
2.30	50	6	300	690

These are the sections of floating road, extracted from Peat Excavation Depths. Corresponding parts marked yellow in All Peat Probe Data.

1.55 1,900

17,646

Appendix 6.D Carbon Calculator Spreadsheet

Due to the number of pages the full carbon spreadsheet has been provided in digital format only.

If a paper copy is required, it is available from Eon on request.



Scottish Government Windfarm Carbon Assessment Tool - Version 2.9.0

26/03/2014

This spreadsheet calculates payback time for windfarm sited on peatlands using methods given in Nayak et al, 2008 (<http://www.scotland.gov.uk/Publications/2008/06/25114657/0>) and revised equations for GHG emissions (Nayak, D.R., Miller, D., Nolan, A., Smith, P. and Smith, J.U., 2010, Calculating carbon budgets of wind farms on Scottish peatland. Mires and Peat 4: Art. 9. Online: (http://www.mires-and-peat.net/map04/map_04_09.htm))

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

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

Version 2.9.1 - Equivalent to version 2.8.0 but with worksheets unprotected for your own use. Do not use this version in planning applications.

INSTRUCTIONS

- A** There are 6 worksheets giving instructions, data entry and outputs,
- Instructions
 - Do I need to use this tool?Click here to find out [Click here](#)
 - Core input data Data needed in all calculations [Click here](#)
 - Forestry input data Extra details sometimes needed for forestry calculations
 - Construction input data Extra details sometimes needed for construction calculations
 - Payback time and CO2 emissions [Click here](#)

...and 8 numbered worksheets showing calculations:

1. Windfarm CO₂ emission saving
2. CO₂ loss due to turbine life
3. CO₂ loss due to backup
4. Loss of CO₂ Fixing Pot.
5. Loss of soil CO₂
 - 5a. Volume of peat removed
 - 5b. CO₂ loss from removed peat
 - 5c. Volume of peat drained
 - 5d. CO₂ loss from drained peat
 - 5e. Emission rates
6. CO₂ loss by DOC & POC loss
- 7i. Forestry CO₂ loss - simple
- 7ii. Forestry CO₂ loss - detailed
 - 7a. C sequest. in trees (3PG)
 - 7b. C seq. in soil under trees
 - 7c. Average stand data
 - 7d. Windspeed ratios
8. CO₂ gain - site improvement

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

- References
- Frequently asked questions

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

Protocols for measurements are given in pale yellow comment boxes.... [Click here to see example of Protocol Box](#)

Assumptions are given in pale blue text boxes.... [Click here to see example of Assumptions Box](#)

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Note on official version number

Note on official version number

Version X.Y.Z

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

Officially released versions will always have Z=0

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

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

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

Do I need to use this tool?

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

No ▼

2. Is the soil at the site highly organic?

Yes ▼

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

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

No ▼

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

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

Please move to the Core input data sheet and complete the form to obtain an estimate of C payback time

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

[Click here](#)

[Click here to move on to Core input data sheet](#)

[Click here](#)

Core input data.
 ENTER INPUT DATA HERE! VALUES SHOULD ONLY BE CHANGED ON THIS SHEET. DO NOT USE EXAMPLE VALUES AS DEFAULTS! ENTER YOUR OWN VALUES THAT ARE SPECIFIC TO YOUR PARTICULAR SITE.
 Note: The input parameters include some variables that can be specified by default values, but others that must be site specific. Variables that can be taken from defaults are marked with purple tags on left hand side.

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

Input data	Expected values		Possible range of values			
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Windfarm characteristics						
Dimensions						
No. of turbines	19	Fixed	19		19	
Lifetime of windfarm (years)	25		25		25	
Performance						
Power rating of turbines (turbine capacity) (MW)	3.3		3.3		3.3	
Capacity factor	Direct input of capacity factor		Direct input of capacity factor		Direct input of capacity factor	
Enter estimated capacity factor (percentage efficiency)	27.0		21.8		33.6	
Backup						
Extra capacity required for backup (%)	5		0		5	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10		10		10	
Carbon dioxide emissions from turbine life - (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity		Calculate wrt installed capacity		Calculate wrt installed capacity	
Characteristics of peatland before windfarm development						
Type of peatland	Acid bog		Acid bog		Acid bog	
Average annual air temperature at site (°C)	7.5		3.9		11.2	
Average depth of peat at site (m)	0.68		0.50		1.00	
C Content of dry peat (% by weight)	55		49		62	
Average extent of drainage around drainage features at site (m)	7.50		5.00		10.00	
Average water table depth at site (m)	0.30		0.20		0.40	
Dry soil bulk density (g cm ⁻³)	0.25		0.20		0.45	
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	3		2		5	
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha ⁻¹ yr ⁻¹)	0.25		0.12		0.31	
Forestry Plantation Characteristics						
Method used to calculate CO ₂ loss from forest felling	Enter simple data		Enter simple data		Enter simple data	
Area of forestry plantation to be felled (ha)	0		0		0	
Average rate of carbon sequestration in timber (tC ha ⁻¹ yr ⁻¹)						
Counterfactual emission factors						
To update counterfactual emission factors from the web	Click here (not yet operational)					
Coal-fired plant emission factor (t CO ₂ MWh ⁻¹)	0.907		0.907		0.907	
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.454		0.454		0.454	
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.701		0.701		0.701	
Borrow pits						
Number of borrow pits	1		1		1	
Average length of pits (m)	100		50		150	
Average width of pits (m)	100		50		150	
Average depth of peat removed from pit (m)	1.05		1.00		1.10	
Foundations and hard-standing area associated with each turbine						
Method used to calculate CO ₂ loss from foundations and hard-standing	Enter detailed information		Enter detailed information		Enter detailed information	
Please enter construction data in sheet: Construction input data	27.5		25		27.5	
Average depth of peat removed from turbine foundations (m)	27.5		25		27.5	
	0.95		0.75		1.25	
	50		50		50	
	25		25		25	
Average depth of peat removed from hard-standing (m)	0.69		0.50		1.00	
Access tracks						
Total length of access track (m)	12900		12900		12900	
Existing track length (m)	0		0		0	
Length of access track that is floating road (m)	1900		1800		2000	
Floating road width (m)	6		6		6	
Floating road depth (m)	0.50		0.50		0.50	
Length of floating road that is drained (m)	1900		1900		1900	
Average depth of drains associated with floating roads (m)	0.50		0.50		0.50	
Length of access track that is excavated road (m)	11000		10500		11500	
Excavated road width (m)	6		6		6	
Average depth of peat excavated for road (m)	0.58		0.50		0.70	
Length of access track that is rock filled road (m)						
Rock filled road width (m)						
Rock filled road depth (m)						
Length of rock filled road that is drained (m)						
Average depth of drains associated with rock filled roads (m)						
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)	20258		19500		21000	
Area of additional peat excavated (m ²)	34400.0		33050.0		35595.0	
Peat Landslide Hazard						
Weblink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments						
Improvement of C sequestration at site by blocking drains, restoration of habitat etc						
Improvement of degraded bog						
Area of degraded bog to be improved (ha)						
Water table depth in degraded bog before improvement (m)						
Water table depth in degraded bog after improvement (m)						
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)						
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)						
Improvement of felled plantation land						
Area of felled plantation to be improved (ha)						
Water table depth in felled area before improvement (m)						
Water table depth in felled area after improvement (m)						
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)						
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)						
Restoration of peat removed from borrow pits						
Area of borrow pits to be restored (ha)	5		4		5	
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.20		0.10		0.30	
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.30		0.20		0.40	
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	3.0		2.0		4.0	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	22		23		21	
Early removal of drainage from foundations and hardstanding						
Water table depth around foundations and hardstanding before restoration (m)						
Water table depth around foundations and hardstanding after restoration (m)						
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)						
Restoration of site after decommissioning						
Will the hydrology of the site be restored on decommissioning?	No		No		No	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes		Yes		No	
Will you attempt to block all artificial ditches and facilitate rewetting?	No		No		No	
Will the habitat of the site be restored on decommissioning?	No		No		No	
Will you control grazing on degraded areas?	Yes		Not applicat.		Yes	
Will you manage areas to favour reintroduction of species	No		No		No	

Note: Capacity factor. The capacity factor of any power plant is the proportion of energy produced during a given period with respect to the energy that would have been produced had the wind farm been running continuously and at maximum output (DECC 2004); see also www.bwea.com/wind/capacity/factors.htm.
 Capacity Factor = Electricity generated during the period [MWh] / (Installed capacity [kW] x number of hours in the period [h])
 The average capacity factor between 1998 and 2004 for Scotland was 30% (DTI, 2006, Energy Trends, March 2006). We recommend that a site-specific capacity factor site should be used (as measured during planning stage). The average capacity factor for the United Kingdom, in 2009, was 27%, and 28% for Scotland (Energy Trends, September 2010).

Note: Extra capacity required for backup. If 20% of national electricity is generated by wind energy, the extra capacity required for backup is 5% of the rated capacity of the wind plant (Dale et al 2004, Energy Policy, 32, 1949-56). We suggest this should be 5% of the actual output. If it is assumed that less than 20% of national electricity is generated by wind energy, a lower percentage should be entered (0%).
 The House of Lords Economic Affairs Committee report on The Economics of Renewable Energy (2008) (www.parliament.the-stationery-office.co.uk/pa/ld200708/ld070827/ld070827.htm#36) notes that to cover peak demand a 20% margin of extra capacity has been sufficient to keep the risk of a power cut due to insufficient generation at a very low level. The estimate provided by BERR was a range of 10% to 20% of installed capacity of wind energy. E.ON is reported as proposing that the capacity credit of wind power should be 8%, and The Renewable Energy Foundation proposed the use of the square root of the wind capacity (in GW) as conventional capacity (e.g. 36 GW of wind plant to match 6 GW of conventional plant).

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

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

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

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

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

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

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

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

Note: Fossil Fuel-Mix Emission Factor. The 5 year average emission factor calculated using estimated CO₂ emissions for 2002 and 2003 from the National Atmospheric Emission Inventory (Baggett et al., 2007), and for 2004 to 2006 (Digest of UK Energy Statistics, 2007) is 0.607 tCO₂ MWh⁻¹.

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

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

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

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

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

Note: Peat Landslide Hazard. It is assumed that measures have been taken to limit damage (Scottish Executive, 2006, Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments, Scottish Executive, Edinburgh, pp. 34-36) so that C losses due to peat landslide can be assumed to be negligible. LINK: <http://www.scotland.gov.uk/Publications/2006/12/11623031>.

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

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

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

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

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

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

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

Core input data.
 ENTER INPUT DATA HERE! VALUES SHOULD ONLY BE CHANGED ON THIS SHEET. DO NOT USE EXAMPLE VALUES AS DEFAULTS! ENTER YOUR OWN VALUES THAT ARE SPECIFIC TO YOUR PARTICULAR SITE.
 Note: The input parameters include some variables that can be specified by default values, but others that must be site specific. Variables that can be taken from defaults are marked with purple tags on left hand side.

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

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

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

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

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

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

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

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

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

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

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Construction input data

ENTER DETAILS OF CONSTRUCTION HERE!

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

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

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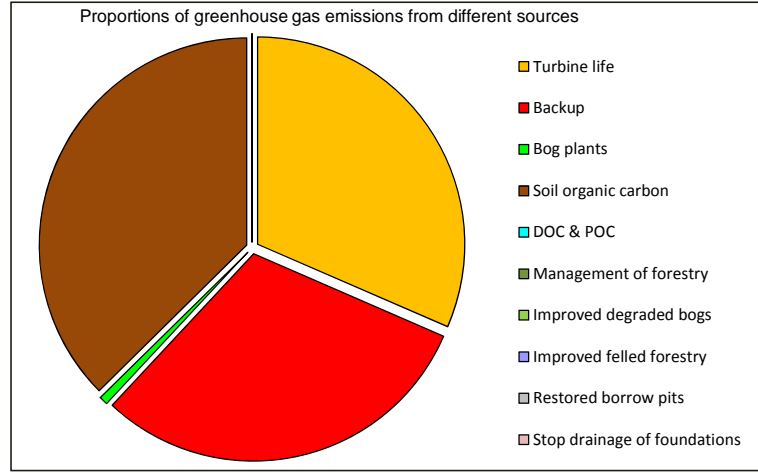
Input data	Expected values		Possible range of values	
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data
Construction design				
Note - total number of turbines already specified: 19				
AREA 1				
Number of turbines in this area	19		19	
Turbine foundations				
Depth of hole dug when constructing foundations (m)	0.3		0.3	
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular	
Length at surface (m)	27.5		25	
Width at surface (m)	27.5		25	
Length at bottom (m)	25		25	
Width at bottom (m)	25		25	
Hardstanding				
Depth of hole dug when constructing hardstanding (m)	0.6		0.6	
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular	
Length at surface (m)	50		50	
Width at surface (m)	25		25	
Length at bottom (m)	50		50	
Width at bottom (m)	25		25	
Piling				
Is piling used?	No		No	
Volume of Concrete				
Volume of concrete used (m ³)	750		500	
AREA 2				
Number of turbines in this area				
Turbine foundations				
Depth of hole dug when constructing foundations (m)				
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular	
Length at surface (m)				
Width at surface (m)				
Length at bottom (m)				
Width at bottom (m)				
Hardstanding				
Depth of hole dug when constructing hardstanding (m)				
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular	
Length at surface (m)				
Width at surface (m)				
Length at bottom (m)				
Width at bottom (m)				
Piling				
Is piling used?	No		No	
Volume of Concrete				
Volume of concrete used (m ³)				
AREA 3				
Number of turbines in this area				
Turbine foundations				
Depth of hole dug when constructing foundations (m)				
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular	
Length at surface (m)				
Width at surface (m)				
Length at bottom (m)				
Width at bottom (m)				
Hardstanding				
Depth of hole dug when constructing hardstanding (m)				
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular	
Length at surface (m)				
Width at surface (m)				
Length at bottom (m)				
Width at bottom (m)				
Piling				
Is piling used?	No		No	
Volume of Concrete				
Volume of concrete used (m ³)				
AREA 4				
Number of turbines in this area				
Turbine foundations				
Depth of hole dug when constructing foundations (m)				
Approximate geometric shape of whole dug when constructing foundations				
Length at surface (m)				
Width at surface (m)				
Length at bottom (m)				
Width at bottom (m)				
Hardstanding				
Depth of hole dug when constructing hardstanding (m)				
Approximate geometric shape of whole dug when constructing hardstanding				
Length at surface (m)				
Width at surface (m)				
Length at bottom (m)				
Width at bottom (m)				
Piling				
Is piling used?				
Volume of Concrete				
Volume of concrete used (m ³)				
AREA 5				
Number of turbines in this area				
Turbine foundations				
Depth of hole dug when constructing foundations (m)				
Approximate geometric shape of whole dug when constructing foundations				
Length at surface (m)				
Width at surface (m)				
Length at bottom (m)				
Width at bottom (m)				
Hardstanding				
Depth of hole dug when constructing hardstanding (m)				
Approximate geometric shape of whole dug when constructing hardstanding				
Length at surface (m)				
Width at surface (m)				
Length at bottom (m)				
Width at bottom (m)				
Piling				
Is piling used?				
Volume of Concrete				
Volume of concrete used (m ³)				

Results
 PAYBACK TIME AND CO₂ EMISSIONS
 Note: The carbon payback time of the windfarm is calculated by comparing the loss of C from the site due to windfarm development with the carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or grid-mix.

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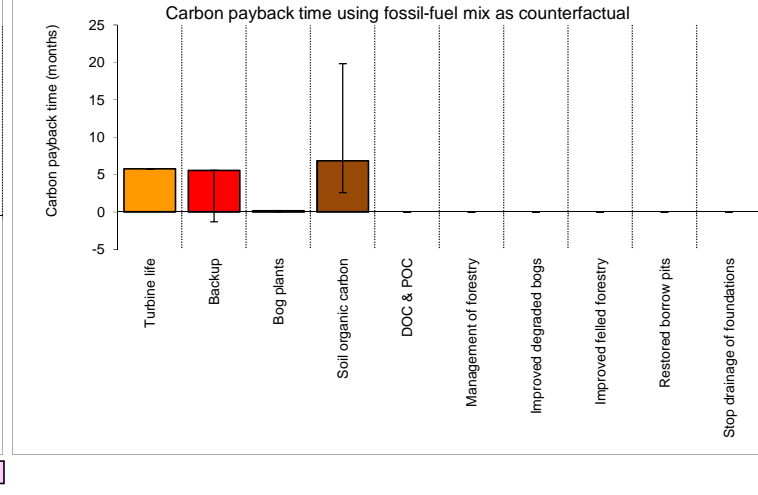
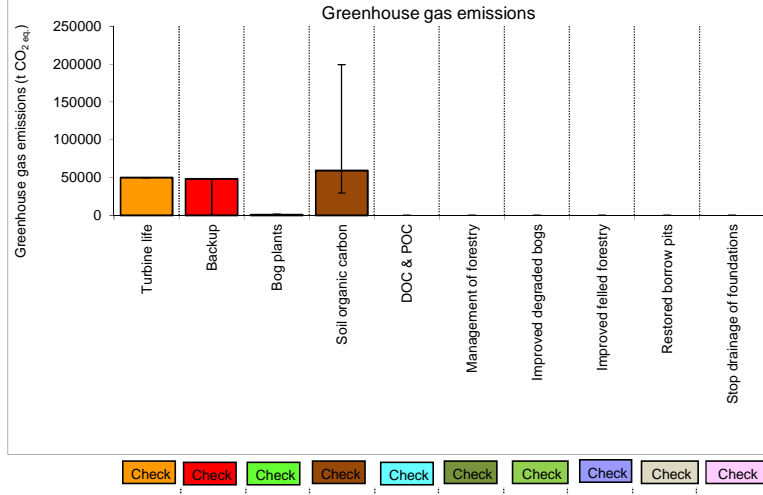
	Exp.	Min.	Max.
1. Windfarm CO₂ emission saving over...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	134506	108601	167535
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	67327	54361	83860
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	103957	83936	129484
Energy output from windfarm over lifetime (MWh)	3707451	2993423	4617836
Total CO₂ losses due to wind farm (t CO₂ eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decommissioning)	49830	49787	49830
3. Losses due to backup	48128	0	48128
4. Losses due to reduced carbon fixing potential	1057	369	1787
5. Losses from soil organic matter	59102	29471	199351
6. Losses due to DOC & POC leaching	0	0	0
7. Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	158117	79627	299096
8. Total CO₂ gains due to improvement of site (t CO₂ eq.)			
8a. Gains due to improvement of degraded bogs	0	0	0
8b. Gains due to improvement of felled forestry	0	0	0
8c. Gains due to restoration of peat from borrow pits	0	0	0
8d. Gains due to removal of drainage from foundations & hardstanding	0	0	0
Total gains	0	0	0

RESULTS			
	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO₂ eq.)	158117	79627	299096
Carbon Payback Time			
...coal-fired electricity generation (years)	1.2	0.5	2.8
...grid-mix of electricity generation (years)	2.3	0.9	5.5
...fossil fuel - mix of electricity generation (years)	1.5	0.6	3.6
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	No gains!	No gains!	No gains!
Ratio of CO₂ eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	43	27	65



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

Greenhouse gas emissions	Exp.	Min	Max
Turbine life	49830	43	0
Backup	48128	48128	0
Bog plants	1057	689	730
Soil organic carbon	59102	29631	140250
DOC & POC	0	0	0
Management of forestry	0	0	0
Improved degraded bogs	0	0	0
Improved felled forestry	0	0	0
Restored borrow pits	0	0	0
Stop drainage of foundations	0	0	0



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

Greenhouse gas emissions	Exp.	Min.	Max.	Carbon payback time (months)		
				Exp.	Min.	Max.
Turbine life	49830	43	0	6	0	0
Backup	48128	48128	0	6	7	0
Bog plants	1057	689	730	0	0	0
Soil organic carbon	59102	29631	140250	7	4	13
DOC & POC	0	0	0	0	0	0
Management of forestry	0	0	0	0	0	0
Improved degraded bogs	0	0	0	0	0	0
Improved felled forestry	0	0	0	0	0	0
Restored borrow pits	0	0	0	0	0	0
Stop drainage of foundations	0	0	0	0	0	0
	158117			18		

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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Check Check Check Check Check Check Check Check Check Check

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	19	19	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Power rating of turbines (turbine capacity) (MW)	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Power of windfarm (MW)	62.7	62.7	62.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estimated downtime for maintenance etc (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Counterfactual emission factors																		
Coal-fired plant emission factor (t CO ₂ MWh ⁻¹)	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907	0.907
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454	0.454
Fossil fuel-mix emission factor (t CO ₂ MWh ⁻¹)	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701

Calculation of capacity factor	1	Direct input of capacity factor		
	Exp	Min	Max	
Entered capacity factor (%)	27	21.8	33.63	

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

Calculation of capacity factor from forestry management	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Wind speed ratio calculated in 7d	0	0	0	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####
Average site windspeed (m s ⁻¹)	28908	28908	28908	28908	28908	28908	28908	28908	28908	28908	28908	28908	28908	28908	28908	28908	28908	28908
Annual theoretical energy output from turbine (MW turbine ⁻¹ yr ⁻¹)																		
Power curve				User-defined	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines
(Power curve code)				1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slope (a)	0	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp
Intercept (b)	0	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp	Exp
Annual power output from an individual turbine (MW turbine ⁻¹ yr ⁻¹)				#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####
Calculated capacity factor (%)				#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####	#####

Calculation of annual energy output from wind farm	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Direct input of capacity factor																		
Capacity factor(%)	27	22	34	27	22	34	27	22	34	27	22	34	27	22	34	27	22	34
Annual energy output from windfarm (MW yr ⁻¹)	148298	119737	184713	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)	134506	108601	167535	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	67327	54360.6	83859.9	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)	103957	83935.6	129484	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)	2616	2616	2616
No. of turbines	19	19	19
Total calculated CO ₂ emission of the wind farm due to turbine life (t CO ₂ windfarm ⁻¹)	49700	49700	49700

	Exp	Total			Construction Area 1			Construction Area 2			Construction Area 3			Construction Area 4			Construction Area 5		
		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)	750	500	750	750	500	750	0	0	0	0	0	0	0	0	0	0	0	0	
CO ₂ emission rate (t CO ₂ m ⁻³ cement)	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	0.173	
Total CO ₂ emissions due to cement used in construction	130	87	130	130	87	130	0	0	0	0	0	0	0	0	0	0	0	0	

RESULTS

Losses due to turbine life (eg. manufacture, construction, decommissioning)	49830	49787	49830
Additional CO ₂ payback time of windfarm due to turbine life (eg. manufacture, construction, decommissioning)			
...coal-fired electricity generation (months)	4	6	4
...grid-mix of electricity generation (months)	9	11	7
...fossil fuel - mix of electricity generation (months)	6	7	5

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

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Embodied carbon dioxide (CO₂) and construction materials

CONCRETE	Concrete type	ECO ₂ (kg/CO ₂ m ³)	ECO ₂ (kg/CO ₂ /mm ²)
Binding, mass fill, strip footings, mps foundations	SEN1 70 mm (CEM I only)	173	75
Trench foundations ¹	SEN1 120 mm [*] (CEM I only)	194	80
Reinforced Foundations ¹	RC30 70 mm ^{***} (CEM I only)	318	132
Ground floors ¹	RC30 70 mm ^{**} (CEM I only)	315	133
Structural: in situ floor, superstructure walls, basements	RC40 70 mm ^{***} (CEM I only)	372	153
High strength concrete ¹	RC50 70mm ^{***} (CEM I only)	430	178
Dense concrete aggregate block ²	Precast block	147	75
Aerated concrete block ²	Precast block	121	240
Dense lightweight aggregate block ²	Precast block	168	120
TIMBER		ECO ₂ (kg/CO ₂ m ³)	ECO ₂ (kg/CO ₂ /mm ²)
Timber, UK Sawn hardwood ⁴		369	473
Timber, UK Sawn softwood ⁴		185	440
Plywood ⁴		309	750
STEEL		ECO ₂ (kg/CO ₂ m ³)	ECO ₂ (kg/CO ₂ /mm ²)
UK Produced structural steel sections ⁵		15,313	1,632

^{*} includes 25 kg/m³ steel reinforcement
^{**} includes 30 kg/m³ steel reinforcement
^{***} includes 100 kg/m³ steel reinforcement

References:
 1. The ECO₂ figures for SEN 1, RC30/40 and RC40/50 were derived using industry agreed representative figures for cementitious materials, aggregates, reinforcement, admixtures and an appropriate figure for water.
 2. BRE Environmental Profiles database, Building Research Establishment (BRE), 2006
 3. Construction from the Environment Division, BRSEAM Centre, Building Research Establishment (BRE), 2002
 4. Hammond, G. & Jones, C., 2006. Inventory of Carbon & Energy (ICE) version 1.5 Beta. Department of Mechanical Engineering, University of Bath, UK
 5. Amato, A and Eaton, K.J. A comparative environmental life cycle assessment of modern office buildings. Steel Construction Institute, 1999

Emissions due to backup power generation

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

	Expected	Minimum	Maximum
Reserve capacity required for backup			
No. of turbines	19	19	19
Power rating of turbines (turbine capacity) (MW)	3.3	3.3	3.3
Power of wind farm (MW h ⁻¹)	62.7	62.7	62.7
Rated capacity (MW yr ⁻¹)	549252	549252	549252
Extra capacity required for backup (%)	5	0	5
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10
Reserve capacity (MWh yr ⁻¹)	2746	0	2746

Carbon dioxide emissions due to backup power generation			
Coal-fired plant emission factor (t CO ₂ MWh ⁻¹)	0.907	0.907	0.907
Grid-mix emission factor (t CO ₂ MWh ⁻¹)	0.454	0.454	0.454
Fossil fuel- mix emission factor (t CO ₂ MWh ⁻¹)	0.701	0.701	0.701
Lifetime of windfarm (years)	25	25	25
Annual emissions due to backup from...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	2491	0	2491
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	1247	0	1247
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	1925	0	1925

RESULTS			
Total emissions due to backup from...			
...coal-fired electricity generation (tCO ₂)	62271	0	62271
...grid-mix of electricity generation (tCO ₂)	31170	0	31170
...fossil fuel - mix of electricity generation (tCO ₂)	48128	0	48128
Additional CO₂ payback time of windfarm due to backup			
...coal-fired electricity generation (months)	6	0	4
...grid-mix of electricity generation (months)	6	0	4
...fossil fuel - mix of electricity generation (months)	6	0	4

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Emissions due to backup power generation

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

Note: Wind generated electricity is inherently variable, providing unique challenges to the electricity generating industry for provision of a supply to meet consumer demand (Netz, 2004). Backup power is required to accompany wind generation to stabilise the supply to the consumer. This backup power will usually be obtained from a fossil fuel source. At a high level of wind power penetration in the overall generating mix, and with current grid management techniques, the capacity for fossil fuel backup may become strained because it is being used to balance the fluctuating consumer demand with a variable and highly unpredictable output from wind turbines (White, 2007). The Carbon Trust (Carbon Trust/DTI, 2004) concluded that increasing levels of intermittent generation do not present major technical issues at the percentages of renewables expected by 2010 and 2020, but the UK renewables target at the time of that report was only 20%. When national reliance on wind power is low (less than ~20%), the additional fossil fuel generated power requirement can be considered to be insignificant and may be obtained from within the spare generating capacity of other power sectors (Dale et al, 2004). However, as the national supply from wind power increases above 20%, without improvements in grid management techniques, emissions due to backup power generation may become more significant. The extra capacity needed for backup power generation is currently estimated to be 5% of the rated capacity of the wind plant if wind power contributes more than 20% to the national grid (Dale et al 2004). Moving towards the SG target of 50% electricity generation from renewable sources, more short-term capacity may be required in terms of pumped-storage hydro-generated power, or a better mix of offshore and onshore wind generating capacity. Grid management techniques are anticipated to reduce this extra capacity, with improved demand side management, smart meters, grid reinforcement and other developments. However, given current grid management techniques, it is suggested that 5% extra capacity should be assumed for backup power generation if wind power contributes more than 20% to the national grid. At lower contributions, the extra capacity required for backup should be assumed to be zero. These assumptions should be revisited as technology improves.

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

Emissions due to loss of bog plants

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

	Expected	Minimum	Maximum
Area where carbon accumulation by bog plants is lost			
Total area of land lost due to windfarm construction (m ²)	158791	144975	176086
Total area affected by drainage due to windfarm construction (m ²)	253133	165451	347902
Total area where fixation by plants is lost (m ²)	411923	310426	523988
Total loss of carbon accumulation			
Carbon accumulation in undrained peats (tC ha ⁻¹ yr ⁻¹)	0.25	0.12	0.31
Lifetime of windfarm (years)	25	25	25
Time required for regeneration of bog plants after restoration (years)	3	2	5
Carbon accumulation up to time of restoration (tCO ₂ eq. ha ⁻¹)	26	12	34

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

RESULTS

Total loss of carbon accumulation by bog plants			
Total area where fixation by plants is lost (ha)	41	31	52
Carbon accumulation over lifetime of windfarm (tCO ₂ eq. ha ⁻¹)	26	12	34
Total loss of carbon fixation by plants at the site (t CO₂)	1057	369	1787
Additional CO₂ payback time of windfarm due to loss of CO₂ fixing potential			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0

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Emissions due to loss of bog plants

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

Emissions due to loss of soil organic carbon

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

	Expected result	Minimum result	Maximum result
CO₂ loss due to windfarm construction			
<input type="checkbox"/> CO ₂ loss from removed peat (t CO ₂ equiv)	40778	21772	112110
<input type="checkbox"/> CO ₂ loss from drained peat (t CO ₂ equiv)	18323	7699	87241
RESULTS			
Total CO₂ loss from peat (removed + drained) (t CO₂ equiv)	59102	29471	199351
Additional CO₂ payback time of windfarm due to loss of soil CO₂			
...coal-fired electricity generation (months)	5	3	14
...grid-mix of electricity generation (months)	11	7	29
...fossil fuel - mix of electricity generation (months)	7	4	18

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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)	100	50	150
Average width of pits (m)	100	50	150
Average depth of peat removed from pit (m)	1.05	1	1.1
Area of land lost in borrow pits (m ²)	10000	2500	22500
Volume of peat removed from borrow pits (m ³)	10500	2500	24750

Peat removed from turbine foundations	Total			Construction Area 1			Construction Area 2			Construction Area 3			Construction Area 4			Construction Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Method used to calculate CO ₂ loss from foundations	Enter detailed information																	
Calculation method code	2																	
No. of turbines	19	19	19	19	19	19	0	0	0	0	0	0	0	0	0	0	0	0
Length at surface (m)				28	25	28	0	0	0	0	0	0	0	0	0	0	0	0
Width at surface (m)				28	25	28	0	0	0	0	0	0	0	0	0	0	0	0
Length at bottom (m)				25	25	25	0	0	0	0	0	0	0	0	0	0	0	0
Width at bottom (m)				25	25	25	0	0	0	0	0	0	0	0	0	0	0	0
Depth of foundations (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of land lost in hard-standing (m ²)	13241	11875	13240.63	13241	11875	13241	0	0	0	0	0	0	0	0	0	0	0	0
Volume of peat removed from foundation area (m ³)	3972.188	3562.5	3972.188	3972.188	3562.5	3972.188	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	Enter detailed information																	
Calculation method code	2																	
No. of turbines	19	19	19	19	19	19	0	0	0	0	0	0	0	0	0	0	0	0
Length at surface (m)				50	50	50	0	0	0	0	0	0	0	0	0	0	0	0
Width at surface (m)				25	25	25	0	0	0	0	0	0	0	0	0	0	0	0
Length at bottom (m)				50	50	50	0	0	0	0	0	0	0	0	0	0	0	0
Width at bottom (m)				25	25	25	0	0	0	0	0	0	0	0	0	0	0	0
Depth of hardstanding (m)				0	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Area of land lost in hard-standing (m ²)	23750	23750	23750	23750	23750	23750	0	0	0	0	0	0	0	0	0	0	0	0
Volume of peat removed from hardstanding area (m ³)	7125	7125	7125	7125	7125	7125	0	0	0	0	0	0	0	0	0	0	0	0

Peat removed from access tracks	Exp	Total Min	Max
Floating roads			
Length of access track that is floating road (m)	1900	1800	2000
Floating road width (m)	6	6	6
Floating road depth (m)	0.5	0.5	0.5
Area of land lost in floating roads (m ²)	11400	10800	12000
Volume of peat removed for floating roads	5700	5400	6000
Excavated roads			
Length of access track that is excavated road (m)	11000	10500	11500
Excavated road width (m)	6	6	6
Average depth of peat excavated for road (m)	0.58	0.5	0.7
Area of land lost in excavated roads (m ²)	66000	63000	69000
Volume of peat removed for excavated roads	38280	31500	48300
Rock-filled roads			
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)	77400	73800	81000
Total volume of peat removed due to access tracks (m ³)	43980	36900	54300

Additional peat excavated - (not already accounted for above)	Exp	Total Min	Max
Volume of additional peat excavated (m ³)	20258	19500	21000
Area of additional peat excavated (m ²)	34400	33050	35595

RESULTS	Exp	Total Min	Max
Total volume of peat removed (m³) due to windfarm construction	85835.2	69587.5	111147
Total area of land lost due to windfarm construction (m²)	158791	144975	176086

Click here to move to 5b. CO2 loss from removed peat [Click here](#)

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Volume of Peat Removed
 Note: % site lost by peat removal is estimated from peat removed in borrow pits, turbine foundations, hard-standing and access tracks.
 If peat is removed for any other reason, this must be added in to the volume of peat removed, area of land lost and % site lost at the bottom of this worksheet.

CO₂ loss from removed peats

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

	Expected	Minimum	Maximum
CO₂ loss from removed peat			
C Content of dry peat (% by weight)	55	49	62
Dry soil bulk density (g cm ⁻³)	0.25	0.20	0.45
% C contained in removed peat that is lost as CO ₂	100	100	100
Total volume of peat removed (m ³) due to windfarm construction	85835	69588	111147
CO ₂ loss from removed peat (t CO ₂)	43279	25007	113714

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

Check

CO₂ loss from undrained peat left in situ			
Total area of land lost due to windfarm construction (ha)	16	14	18
CO ₂ loss from undrained peat left in situ (t CO ₂ ha ⁻¹)	157	223	91
CO ₂ loss from undrained peat left in situ (t CO ₂)	2501	3235	1604

CO₂ loss attributable to peat removal only			
CO ₂ loss from removed peat (t CO ₂)	43279	25007	113714
CO ₂ loss from undrained peat left in situ (t CO ₂)	2501	3235	1604
RESULTS			
CO₂ loss attributable to peat removal only (t CO₂)	40778	21772	112110

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

Peat affected by drainage around borrow pits	Exp	Total Min	Max
Number of borrow pits	1	1	1
Average length of pits (m)	100	50	150
Average width of pits (m)	100	50	150
Average depth of peat removed from pit (m)	1.1	1.0	1.1
Area affected by drainage per borrow pit (m ²)	3225	1100	6400
Total area affected by drainage around borrowpits (m ²)	3225	1100	6400
Total volume affected by drainage around borrowpits (m ³)	1693	550	3520

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	19	19	19	19	19	19	0	0	0	0	0	0	0	0	0	0	0	0
Average length of turbine foundations at base (m)				25	25	25	0	0	0	0	0	0	0	0	0	0	0	0
Average width of turbine foundations at base(m)				25	25	25	0	0	0	0	0	0	0	0	0	0	0	0
Average depth of peat removed from turbine foundations (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
Average length of hard-standing at base (m)				50	50	50	0	0	0	0	0	0	0	0	0	0	0	0
Average width of hard-standing at base (m)				25	25	25	0	0	0	0	0	0	0	0	0	0	0	0
Average depth of peat removed from hard-standing (m)				0.6	0.6	0.6	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)				0.6	0.6	0.6	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)				75	75	75	0	0	0	0	0	0	0	0	0	0	0	0
Total width of foundation and hardstanding (m)				50	50	50	0	0	0	0	0	0	0	0	0	0	0	0
Area affected by drainage of foundation and hardstanding area (m ²)	2100	1350	2900	2100	1350	2900	0	0	0	0	0	0	0	0	0	0	0	0
Total area affected by drainage of foundation and hardstanding area (m ²)	39900	25650	55100	39900	25650	55100	0	0	0	0	0	0	0	0	0	0	0	0
Total volume affected by drainage of foundation and hardstanding area (m ³)	11970	7695	16530	11970	7695	16530	0	0	0	0	0	0	0	0	0	0	0	0

Peat affected by drainage of access tracks	Exp	Total Min	Max
Floating roads			
Length of floating road that is drained (m)	1900	1900	1900
Floating road width (m)	6.0	6.0	6.0
Average depth of drains associated with floating roads (m)	0.50	0.50	0.50
Area affected by drainage of floating roads (m ²)	39900	30400	49400
Volume affected by drainage of floating roads (m ³)	9975	7600	12350
Excavated Road			
Length of access track that is excavated road (m)	11000	10500	11500
Excavated road width (m)	6	6	6
Average depth of peat excavated for road (m)	0.6	0.5	0.7
Area affected by drainage of excavated roads (m ²)	165000	105000	230000
Volume affected by drainage of excavated roads (m ³)	47850	26250	80500
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)	204900	135400	279400
Total volume affected by drainage of access track (m ³)	57825	33850	92850

Peat affected by drainage of cable trenches	Exp	Total Min	Max
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0
Average depth of peat cut for cable trenches (m)	0.0	0.0	0.0
Total area affected by drainage of cable trenches (m ²)	0	0	0
Total volume affected by drainage of cable trenches (m ³)	0.00	0.00	0.00

Drainage around additional peat excavated	Exp	Total Min	Max
Volume of additional peat excavated (m ³)	20258.0	19500.0	21000.0
Area of additional peat excavated (m ²)	34400.0	33050.0	35595.0
Average depth of excavated peat (m)	1	1	1
Radius of area excavated (m)	105	103	106
Radius of excavated and drained area (m)	112	108	116
Total area affected by drainage (m ²)	5108	3301	7002
Total volume affected by drainage (m ³)	3007.98	1808.28	4449.21

Assumption: Area excavated is assumed to be a circle

RESULTS	Exp	Total Min	Max
Total area affected by drainage due to windfarm (m ²)	253133	165451	347902
Total volume affected by drainage due to windfarm (m ³)	74496.1	43903.28	117349.2

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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)	25	17	35
Will the habitat of the site be restored on decommissioning?	No	No	No

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

Check Total volume affected by drainage due to wind farm (m ³)	74496	43903	117349
C Content of dry peat (% by weight)	55	49	62
Dry soil bulk density (g cm ⁻³)	0.25	0.20	0.45
Total GHG emissions from Drained Land (t CO₂ equiv.)	37562	15777	120059
Total GHG Emissions from Undrained Land (t CO₂ equiv.)	19239	8078	32818

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

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

1. Losses if Land is Drained

Flooded period (days year ⁻¹)	0	0	0
Lifetime of windfarm (years)	25	25	25
Time required for regeneration of bog plants after restoration (years)	3	2	5
Methane Emissions from Drained Land			
Check Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.002	0.006	-0.015
Conversion factor: CH ₄ -C to CO ₂ equivalents	30.67	30.67	30.67
CH ₄ emissions from drained land (t CO ₂ equiv.)	46	88	-484
Carbon Dioxide Emissions from Drained Land			
Check Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	11.57
CO ₂ emissions from drained land (t CO ₂)	7737	7122	12076
Total GHG emissions from Drained Land (t CO₂ equiv.)	7784	7211	11592

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

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

2. Losses if Land is Undrained

Flooded period (days year ⁻¹)	178	178	178
Lifetime of windfarm (years)	25	25	25
Time required for regeneration of bog plants after restoration (years)	3	2	5
Methane Emissions from Undrained Land			
Check Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	0.01	0.02
Conversion factor: CH ₄ -C to CO ₂ equivalents	30.67	30.67	30.67
CH ₄ emissions from undrained land (t CO ₂ equiv.)	23	43	304
Carbon Dioxide Emissions from Undrained Land			
Check Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	5.36
CO ₂ emissions from undrained land (t CO ₂)	3964	3649	2865
Total GHG Emissions from Undrained Land (t CO₂ equiv.)	3987	3692	3169

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

3. CO₂ Losses due to Drainage

Total GHG emissions from drained land (t CO ₂ equiv.)	37562	15777	120059
Total GHG emissions from undrained land (t CO ₂ equiv.)	19239	8078	32818
RESULTS			
Total GHG emissions due to drainage (t CO₂ equiv.)	18323	7699	87241

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CO₂ loss due to drainage

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

Emission rates from soils

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

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

Calculations following IPCC default methodology	Expected	Minimum	Maximum
Emission characteristics of acid bogs (IPCC, 1997)			
Flooded period (days year ⁻¹)	178	178	178
Annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.04015	0.04015	0.04015
Annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2

Emission characteristics of fens (IPCC, 1997)			
Flooded period (days year ⁻¹)	169	169	169
Annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219
Annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2

Selected emission characteristics (IPCC, 1997)			
Flooded period (days year ⁻¹)	178	178	178
Annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.04015	0.04015	0.04015
Annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	35.2	35.2	35.2

Calculations following ECOSSE based methodology			
Drained Land			
Total area affected by drainage due to wind farm construction (ha)	25	17	35
Total volume affected by drainage due to wind farm construction (m ³)	74496	43903	117349

Soil Characteristics that Determine Emission Rates			
Average annual air temperature at the site (°C)	7.5	11.2	3.9
Average water table depth at site (m)	0.30	0.40	0.20
Average water table depth of drained land (m)	0.30	0.40	0.34

Annual Emission Rates following site specific methodology			
Acid bogs			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	11.57
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	5.36
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.002	0.006	-0.015
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	0.01	0.02
Fens			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	31.94	47.57	35.50
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	31.94	47.57	14.29
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.026	0.009	0.014
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.03	0.01	0.07

Selected emission characteristics following site specific methodology			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	11.57
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	5.36
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.002	0.006	-0.015
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	0.01	0.02

RESULTS

Selected Emission Rates			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	11.57
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	10.92	15.94	5.36
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.002	0.006	-0.015
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	0.01	0.02

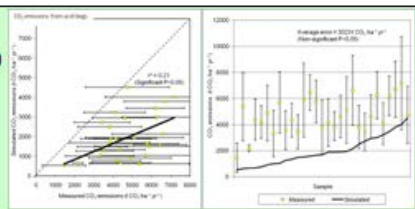
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Assumption: The period of flooding is taken to be 178 days yr⁻¹ for acid bogs and 169 days yr⁻¹ based on the monthly mean temperature and the lengths of inundation (IPCC, 1997, Revised 1996 IPCC guidelines for national greenhouse gas inventories, Vol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

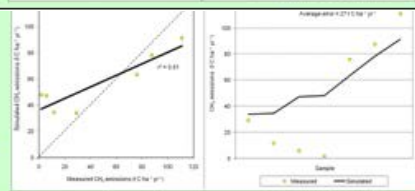
Assumption: The CH₄ emission rate provided for acid bogs is 11 (1-38) mg CH₄-C m⁻² day⁻¹ x 365 days; and for fens is 60 (21-162) mg CH₄-C m⁻² day⁻¹ x 365 days (Aselmann & Crutzen, 1989, J.Atmos.Chem. 8, 307-358)

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

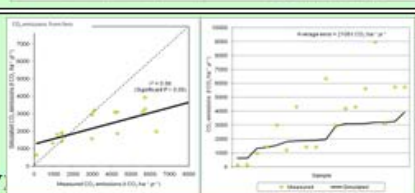
Note: Carbon dioxide emissions from acid bogs. Equation derived by regression analysis against 60 measurements (Nayak et al, 2009). The equation derived was $R_{CO_2} = (3.667/1000) \times ((6700 \times \exp(-0.26 \times \exp(-0.0515 \times ((W \times 100) - 50)))) + ((72.54 \times T) - 800))$ where R_{CO_2} is the annual rate of CO₂ emissions (t CO₂ (ha)⁻¹ yr⁻¹), T = average annual peat temperature (°C) and W is the water table depth (m). The equation shows a significant correlation with measurements (r²=0.53 P>0.05). Evaluation against 29 independent experiments shows a significant association (r²=0.21; P>0.05) and an average error of 3023 t CO₂ ha⁻¹ yr⁻¹ which is non-significant (P<0.05) (Smith et al, 1997).



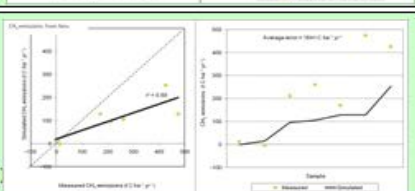
measurements (Nayak et al, 2009). The equation derived was $R_{CH_4} = (1/1000) \times (500 \times \exp(-0.1234 \times (W \times 100))) + ((3.529 \times T) - 36.67)$ where R_{CH_4} is the annual rate of CH₄ emissions (t CH₄-C (ha)⁻¹ yr⁻¹), T = average annual air temperature (°C) and W is the water table depth (m). The equation shows a significant correlation with measurements (r²=0.54, P>0.05). Evaluation against 7 independent experiments shows a significant association (r²=0.81; P>0.05) and an average error of 27 t CH₄-C ha⁻¹ yr⁻¹ (significance not defined due to lack of replicates - Smith et al, 1997).



Note: Carbon dioxide emissions from fens. Equation derived by regression analysis against 44 measurements (Nayak et al, 2009). The equation derived was $R_{CO_2} = (3.667/1000) \times (16244 \times \exp(-0.175 \times \exp(-0.073 \times ((W \times 100) - 50))) + (153.23 \times T))$ where R_{CO_2} is the annual rate of CO₂ emissions (t CO₂ (ha)⁻¹ yr⁻¹), T = average annual peat temperature (°C) and W is the water table depth (m). The equation shows a significant correlation with measurements (r²=0.42, P>0.05). Evaluation against 18 independent experiments shows a significant association (r²=0.56; P>0.05) and an average error of 2108 t CO₂ ha⁻¹ yr⁻¹ (significance not defined due to lack of replicates - Smith et al, 1997).



Note: Methane emissions from fens. Equation derived by regression analysis against experimental data from 35 measurements (Nayak et al, 2009). The equation derived was $R_{CH_4} = (1/1000) \times (-10 + 563.62 \times \exp(-0.097 \times (W \times 100))) + (0.662 \times T)$ where R_{CH_4} is the annual rate of CH₄ emissions (t CH₄-C (ha)⁻¹ yr⁻¹), T = average annual air temperature (°C) and W is the water table depth (m). The equation shows a significant correlation with measurements (r²=0.41, P>0.05). Evaluation against 7 independent experiments shows a significant association (r²=0.69; P>0.05) and an average error of 164 t CH₄-C ha⁻¹ yr⁻¹ (significance not defined due to lack of replicate - Smith et al, 1997).



Emission rates from soils

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

Emissions due to loss of DOC and POC

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

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

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

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

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

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

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

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

RESULTS			
Total CO ₂ loss due to DOC leaching (t CO ₂)	0	0	0
Total CO ₂ loss due to POC leaching (t CO ₂)	0	0	0
Total CO₂ loss due to DOC & POC leaching (t CO₂)	0	0	0
Additional CO₂ payback time of windfarm due to DOC & POC			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0

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Emissions due to loss of DOC and POC

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

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

Emissions due to forest felling - calculation using simple management data

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

	Expected	Minimum	Maximum
Emissions due to forestry felling			
Area of forestry plantation to be felled (ha)	0	0	0
Carbon sequestered (tC ha ⁻¹ yr ⁻¹)	0	0	0
Lifetime of windfarm (years)	25	25	25
Carbon sequestered over the lifetime of the windfarm (t C ha ⁻¹)	0	0	0
RESULTS			
Total carbon loss due to felling of forestry (t CO₂)	0	0	0
Additional CO₂ payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0

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Emissions due to forest felling - calculation using simple management data

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

CO₂ loss from forests - calculation using detailed management information

Forest carbon calculator (Perks et al, 2009)

	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Loss of carbon sequestration due to felling of forestry for the wind farm																		
Number of turbines	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area felled around each turbine (ha)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of forestry plantation to be felled for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area replanted around each turbine (ha)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of forestry plantation to be replanted (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area deforested for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon sequestered per hectare for lifetime of the wind farm (t C ha ⁻¹)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total potential carbon sequestration loss due to felling of forestry for the wind farm (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cleared Forest Floor Emissions																		
Soil type				Peaty Gley	Peaty Gley	Peaty Gley	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat
Life time of wind farm (years)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Area deforested for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon released per hectare unforrested (t C ha ⁻¹ yr ⁻¹)				3.98	3.98	3.98	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total emissions due to cleared land (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emissions from harvesting operations																		
Soil type				Peaty Gley	Peaty Gley	Peaty Gley	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat
Emissions from harvesting operations (g CO ₂ m ⁻³)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Age of forest to be felled (years)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area of forestry plantation to be felled for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volume of wood felled (m ³ ha ⁻¹)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emissions due to harvesting operations (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Savings from use of felled forestry as biofuel																		
Is timber used as biofuel?				No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Area of forestry plantation to be felled for wind farm (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon in felled forestry (t C ha ⁻¹)				282	282	282	282	282	282	282	282	282	282	282	282	282	282	282
(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)	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701
Savings in CO ₂ emissions associated with using felled forestry as a biofuel (t CO ₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance to nearest biomass power plant (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emissions of CO ₂ associated with transportation by each km distance (t CO ₂ km ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total emissions of CO ₂ associated with transportation (t CO ₂ eq)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil fuel equivalent saving (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Savings from use of replanted forestry as a biofuel																		
Area of replanted forestry (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soil type				Peaty Gley	Peaty Gley	Peaty Gley	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat	Deep Peat
Number of years replanted forestry grown on site (years)				25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Carbon in replanted forestry when felled (t C ha ⁻¹)				149	149	149	149	149	149	149	149	149	149	149	149	149	149	149
(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)	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701	0.701
Savings in CO ₂ emissions associated with using replanted forestry as a biofuel (t CO ₂)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance to nearest biomass power plant (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emissions of CO ₂ associated with transportation (t CO ₂ km ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon equivalent of transportation (t CO ₂ eq)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil fuel equivalent saving (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RESULTS																		
Total Carbon loss associated with forest management (t CO₂)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Additional CO₂ payback time of windfarm due to management of forestry																		
...coal-fired electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...grid-mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CO₂ loss from forests - calculation using detailed management information

Forest carbon calculator (Perks et al, 2009)

Carbon sequestration in trees

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

The model calculates gross primary productivity (GPP) and then net primary productivity (NPP) through a standard set of 8 efficiency NPP to root, leaf and foliage. A soil model calculates the size of old and young carbon pools, respiration losses from these pools and from the net ecosystem productivity (NEP).

The model does not need temperature data. The impact of the environment of the site is included by adjusting the environmental modifier based on the soil class and temperature. Light use efficiency (LUE) refers to quantum use efficiency (QUE) in using incoming light to convert the model for many species even for a growing such as 'tomatoes' or 'cactuses'.

Values taken from input sheets	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5			
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	
Accumulated temperature (day-degrees °C)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Soil water	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Major Soil Sub Group	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey	Platy grey
Species	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine	Scots pine
Age of forestry when felled for wood (yr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Life span of wood (years)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Years after felling when replanting occurs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Age of seedlings on planting (yr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Years when replanted forestry will be grown on land farm site	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25

RESULTS

Calculated Net Primary Production	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Net loss in forest primary production over lifetime of wood form (t C ha ⁻¹)	#N/A	#N/A	#N/A	139	139	139	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Total forest net primary production at felling for wood form (t C ha ⁻¹)	#N/A	#N/A	#N/A	282	282	282	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Net primary production of replanted forestry assuming same species replanted and managed over lifespan of wood form (t C ha ⁻¹)	#N/A	#N/A	#N/A	143	143	143	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

BACKGROUND CALCULATIONS

Parameter	Units	Species	Selected Value				
			Area 1	Area 2	Area 3	Area 4	Area 5
Average annual photosynthetically active radiation	2800 MJ m ⁻² yr ⁻¹		2800	2800	2800	2800	2800
Light extinction coefficient	0.5		0.5	0.5	0.5	0.5	0.5
Specific leaf area	6 m ² kg ⁻¹ C		6	6	6	6	6
Free root longevity	1 yr		1	1	1	1	1
Minimum light-use efficiency	0.0012 kg C MJ ⁻¹ day ⁻¹		0.0012	0.0012	0.0012	0.0012	0.0012
Total reduction factor for net environmental effects	0.47		0.47	0.47	0.47	0.47	0.47
Allocation to stage	0.26		0.26	0.26	0.26	0.26	0.26
Coefficient for allocation response to nitrogen	1.00		1.00	1.00	1.00	1.00	1.00
Age for 50% reduction in light use efficiency	100 yr		100	100	100	100	100
Initial nitrogen	0.005 kg C m ⁻²		0.005	0.005	0.005	0.005	0.005
Arbitrary units	0.00		0.00	0.00	0.00	0.00	0.00
Arbitrary units	0.00		0.00	0.00	0.00	0.00	0.00

Age (years)	Thinning regime	Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
		State variables	Light interception	Primary production	State variables	Light interception	Primary production	State variables	Light interception	Primary production	State variables	Light interception	Primary production	State variables	Light interception	Primary production
0	0.00	0.0000	0.00	13.19	1912	608	0.1	0.1	0.1	0.0000	0.00	0.00	0.0000	0.00	0.00	0.00
1	0.00	0.0074	0.04	20.32	2188	695	0.0	0.1	0.1	0.0074	0.04	0.04	0.0074	0.04	0.04	0.04
2	0.00	0.0114	0.07	27.62	2768	805	0.0	0.2	0.2	0.0114	0.07	0.07	0.0114	0.07	0.07	0.07
3	0.00	0.0164	0.10	35.16	3360	937	0.0	0.2	0.2	0.0164	0.10	0.10	0.0164	0.10	0.10	0.10
4	0.00	0.0242	0.15	44.30	4071	1077	0.0	0.2	0.2	0.0242	0.15	0.15	0.0242	0.15	0.15	0.15
5	0.00	0.0344	0.21	54.94	4812	1233	0.1	0.2	0.2	0.0344	0.21	0.21	0.0344	0.21	0.21	0.21
6	0.00	0.0473	0.28	67.11	5585	1404	0.1	0.3	0.3	0.0473	0.28	0.28	0.0473	0.28	0.28	0.28
7	0.00	0.0624	0.37	80.83	6393	1591	0.1	0.3	0.3	0.0624	0.37	0.37	0.0624	0.37	0.37	0.37
8	0.00	0.0803	0.48	96.18	7239	1795	0.1	0.3	0.3	0.0803	0.48	0.48	0.0803	0.48	0.48	0.48
9	0.00	0.1015	0.60	113.20	8124	2027	0.1	0.4	0.4	0.1015	0.60	0.60	0.1015	0.60	0.60	0.60
10	0.00	0.1265	0.74	131.99	9049	2287	0.1	0.4	0.4	0.1265	0.74	0.74	0.1265	0.74	0.74	0.74
11	0.00	0.1558	0.94	152.58	10108	2574	0.2	0.5	0.5	0.1558	0.94	0.94	0.1558	0.94	0.94	0.94
12	0.00	0.1890	1.19	174.99	11313	2889	0.2	0.5	0.5	0.1890	1.19	1.19	0.1890	1.19	1.19	1.19
13	0.00	0.2265	1.49	200.24	12674	3234	0.2	0.6	0.6	0.2265	1.49	1.49	0.2265	1.49	1.49	1.49
14	0.00	0.2688	1.85	229.34	14200	3611	0.3	0.6	0.6	0.2688	1.85	1.85	0.2688	1.85	1.85	1.85
15	0.00	0.3160	2.27	262.29	15893	4023	0.3	0.7	0.7	0.3160	2.27	2.27	0.3160	2.27	2.27	2.27
16	0.00	0.3693	2.76	299.11	17754	4472	0.3	0.7	0.7	0.3693	2.76	2.76	0.3693	2.76	2.76	2.76
17	0.00	0.4290	3.33	340.82	19784	4961	0.3	0.8	0.8	0.4290	3.33	3.33	0.4290	3.33	3.33	3.33
18	0.00	0.4954	4.00	387.44	21984	5493	0.4	0.8	0.8	0.4954	4.00	4.00	0.4954	4.00	4.00	4.00
19	0.00	0.5688	4.79	439.97	24354	6071	0.4	0.9	0.9	0.5688	4.79	4.79	0.5688	4.79	4.79	4.79
20	0.19	0.6494	5.71	498.92	26894	6700	0.4	0.9	0.9	0.6494	5.71	5.71	0.6494	5.71	5.71	5.71
21	0.00	0.7376	6.78	564.29	29604	7384	0.5	0.9	0.9	0.7376	6.78	6.78	0.7376	6.78	6.78	6.78
22	0.00	0.8338	7.99	636.08	32494	8127	0.5	0.9	0.9	0.8338	7.99	7.99	0.8338	7.99	7.99	7.99
23	0.00	0.9379	9.36	714.29	35574	8934	0.6	0.9	0.9	0.9379	9.36	9.36	0.9379	9.36	9.36	9.36
24	0.00	1.0498	10.91	798.92	38854	9809	0.6	0.9	0.9	1.0498	10.91	10.91	1.0498	10.91	10.91	10.91
25	0.18	1.2802	13.75	899.05	42354	10756	0.6	1.0	1.0	1.2802	13.75	13.75	1.2802	13.75	13.75	13.75
26	0.00	1.5199	16.99	1015.98	46084	11781	0.6	1.0	1.0	1.5199	16.99	16.99	1.5199	16.99	16.99	16.99
27	0.00	1.7693	20.64	1149.71	50054	12889	0.6	1.0	1.0	1.7693	20.64	20.64	1.7693	20.64	20.64	20.64
28	0.00	2.0288	24.71	1299.24	54274	14084	0.6	1.0	1.0	2.0288	24.71	24.71	2.0288	24.71	24.71	24.71
29	0.20	2.2988	29.21	1464.57	58754	15371	0.6	1.0	1.0	2.2988	29.21	29.21	2.2988	29.21	29.21	29.21
30	0.17	2.5798	34.14	1645.70	63494	16756	0.6	1.0	1.0	2.5798	34.14	34.14	2.5798	34.14	34.14	34.14
31	0.00	2.8718	39.51	1842.73	68494	18244	0.6	1.0	1.0	2.8718	39.51	39.51	2.8718	39.51	39.51	39.51
32	0.00	3.1758	45.34	2055.66	73754	19831	0.6	1.0	1.0	3.1758	45.34	45.34	3.1758	45.34	45.34	45.34
33	0.00	3.4918	51.64	2284.49	79274	21534	0.6	1.0	1.0	3.4918	51.64	51.64	3.4918	51.64	51.64	51.64
34	0.00	3.8198	58.41	2529.22	85054	23359	0.6	1.0	1.0	3.8198	58.41	58.41	3.8198	58.41	58.41	58.41
35	0.14	4.1598	65.64	2790.85	91094	25309	0.6	1.0	1.0	4.1598	65.64	65.64	4.1598	65.64	65.64	65.64
36	0.00	4.5118	73.41	3069.38	97394	27389	0.6	1.0	1.0	4.5118	73.41	73.41	4.5118	73.41	73.41	73.41
37	0.00	4.8758	81.64	3364.71	103954	29599	0.6	1.0	1.0	4.8758	81.64	81.64	4.8758	81.64	81.64	81.64
38	0.00	5.2518	90.34	3676.94	110774	31939	0.6	1.0	1.0	5.2518	90.34	90.34	5.2518	90.34	90.34	90.34
39	0.00	5.6398	99.51	4006.17	117854	34409	0.6	1.0	1.0	5.6398	99.51	99.51	5.6398	99.51	99.51	99.51
40	0.00	6.0398	109.14	4353.40	125194	37019	0.6	1.0	1.0	6.0398	109.14	109.14	6.0398	109.14	109.14	109.14
41	0.00	6.4518	119.24	4719.63	132794	39769	0.6	1.0	1.0	6.4518	119.24	119.24	6.4518	119.24	119.24	119.24
42	0.00	6.8758	129.84	5104.86	140654											

Carbon sequestration in soil under trees

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

Carbon Sequestration in Soil

Under Trees: Lookup
Table

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

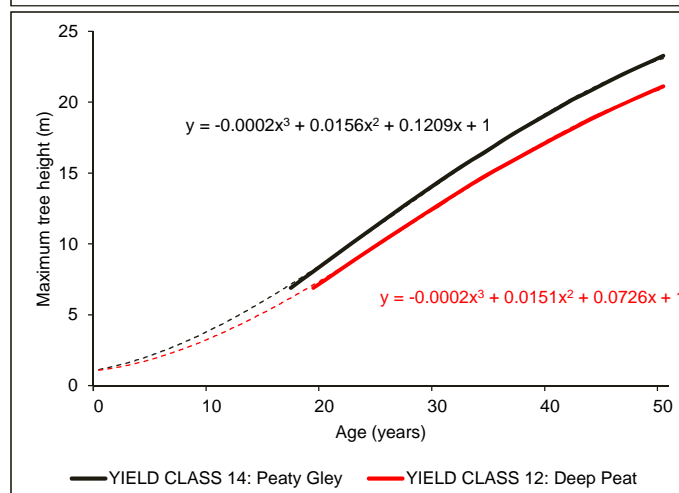
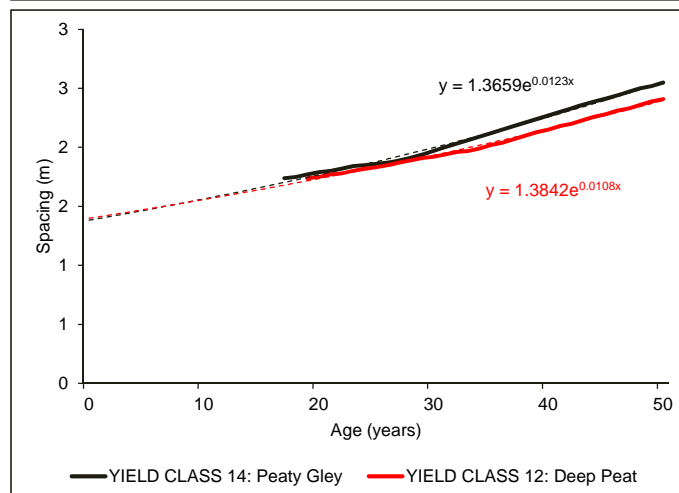
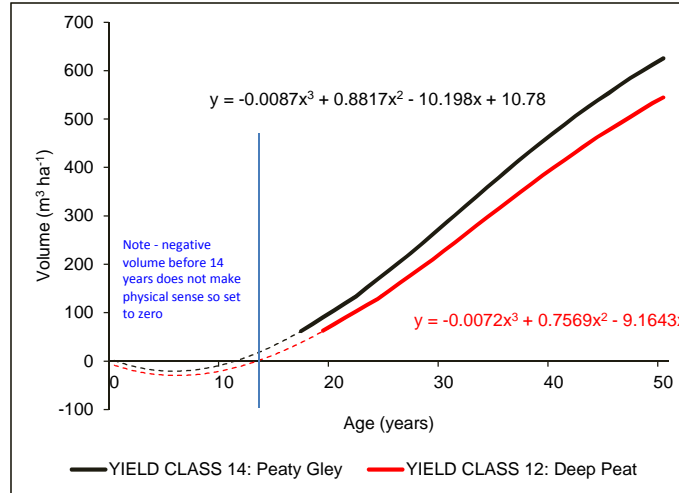
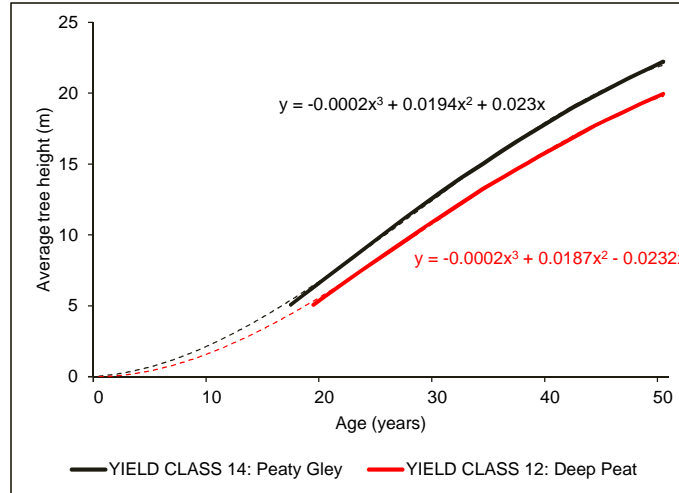
Average stand data

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

STAND_ID ForestGALES
SPECIES Sitka Spruce

YIELD CLASS 14: Peaty Gley

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



YIELD CLASS 12: Deep Peat

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

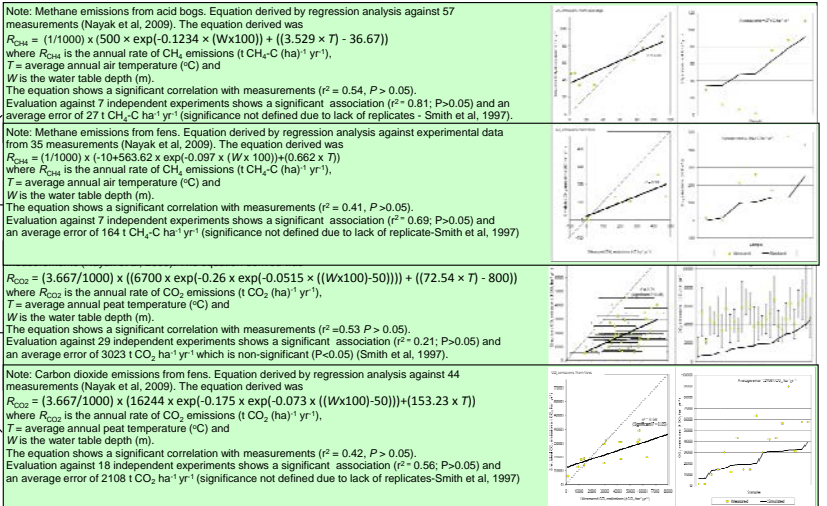
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Gains due to site improvement
 Note: Note, CO₂ losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, 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 = Site specific (required for planning applications)
 Type of peatland = Acid Bog

Reduction in GHG emissions due to improvement of site	Expected result				Minimum result				Maximum result			
	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Hardstanding	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Hardstanding	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Hardstanding
1. Description of site												
Period of time when effectiveness of the improvement can be guaranteed (years)	0	0	22	25	0	0	21	25	0	0	23	25
Area to be improved (ha)	0	0	0	0	0	0	0	0	0	0	0	0
Average air temperature at site (°C)	7.5	7.5	7.5	7.5	3.9	3.9	3.9	3.9	11.2	11.2	11.2	11.2
Depth of peat drained (m)	0.68	0.68	1.05	0.68	0.50	0.50	1.00	0.50	1.00	1.00	1.10	1.00
Depth of peat above water table before improvement (m)	0.00	0.00	0.20	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.30	0.00
Depth of peat above water table after improvement (m)	0.00	0.00	0.30	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.20	0.00
2. Losses with improvement												
Flooded period (days year ⁻¹)	178	178	178	178	178	178	178	178	178	178	178	178
Time required for hydrology and habitat to return to its previous state on restoration (years)	0	0	3	0	0	0	2	0	0	0	4	0
Improved period (years)	0	0	19	25	0	0	19	25	0	0	19	25
Methane emissions from improved land												
Site specific methane emission from improved soil on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.490	0.490	0.002	0.490	0.477	0.477	-0.019	0.477	0.503	0.503	0.045	0.503
Site specific methane emission from improved soil on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.559	0.559	0.026	0.559	0.556	0.556	0.004	0.556	0.561	0.561	0.078	0.561
IPCC annual rate of methane emission on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
IPCC annual rate of methane emission on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219
Selected annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.490	0.490	0.002	0.490	0.477	0.477	-0.019	0.477	0.503	0.503	0.045	0.503
CH ₄ emissions from improved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Carbon dioxide emissions from improved land												
Site specific CO ₂ emission from improved soil on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	-0.13	-0.13	10.92	-0.13	-1.09	-1.09	14.00	-1.09	0.85	0.85	7.30	0.85
Site specific CO ₂ emissions from improved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	4.27	4.27	31.94	4.27	2.25	2.25	43.47	2.25	6.35	6.35	18.39	6.35
IPCC annual rate of carbon dioxide emission on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IPCC annual rate of carbon dioxide emission on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Selected annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	-0.13	-0.13	10.92	-0.13	-1.09	-1.09	14.00	-1.09	0.85	0.85	7.30	0.85
CO ₂ emissions from improved land (t CO ₂)	0	0	0	0	0	0	0	0	0	0	0	0
Total GHG emissions from improved land (t CO₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
3. Losses without improvement												
Flooded period (days year ⁻¹)	0	0	0	0	0	0	0	0	0	0	0	0
Time required for hydrology and habitat to return to its previous state on restoration (years)	0	0	3	0	0	0	2	0	0	0	4	0
Improved period (years)	0	0	19	25	0	0	19	25	0	0	19	25
Methane emissions from unimproved land												
Site specific methane emission from unimproved soil on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.490	0.490	0.032	0.490	0.477	0.477	0.123	0.477	0.503	0.503	0.015	0.503
Site specific methane emission from unimproved soil on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.559	0.559	0.076	0.559	0.556	0.556	0.206	0.556	0.561	0.561	0.028	0.561
IPCC annual rate of methane emission on acid bogs (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IPCC annual rate of methane emission on fens (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Selected annual rate of methane emission (t CH ₄ -C ha ⁻¹ yr ⁻¹)	0.490	0.490	0.032	0.490	0.477	0.477	0.123	0.477	0.503	0.503	0.015	0.503
CH ₄ emissions from unimproved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Carbon dioxide emissions from unimproved land												
Site specific CO ₂ emission from unimproved soil on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	-0.13	-0.13	6.32	-0.13	-1.09	-1.09	1.29	-1.09	0.85	0.85	11.90	0.85
Site specific CO ₂ emissions from unimproved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	4.27	4.27	16.31	4.27	2.25	2.25	4.34	2.25	6.35	6.35	34.02	6.35
IPCC annual rate of carbon dioxide emission on acid bogs (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20
IPCC annual rate of carbon dioxide emission on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20	35.20
Selected annual rate of carbon dioxide emission (t CO ₂ ha ⁻¹ yr ⁻¹)	-0.13	-0.13	6.32	-0.13	-1.09	-1.09	1.29	-1.09	0.85	0.85	11.90	0.85
CO ₂ emissions from unimproved land (t CO ₂)	0	0	0	0	0	0	0	0	0	0	0	0
Total GHG emissions from unimproved land (t CO₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
RESULTS												
4. Reduction in GHG emissions due to improvement of site												
Total GHG emissions from improved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Total GHG emissions from unimproved land (t CO ₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Reduction in GHG emissions due to improvement (t CO₂ equiv.)	0	0	0	0	0	0	0	0	0	0	0	0
Additional CO₂ payback time of windfarm due to site improvement												
...coal-fired electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0
...grid-mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0	0	0	0	0	0	0	0	0	0



Note: Methane emissions from acid bogs. As above

Note: Methane emissions from fens. As above

Note: CO₂ emissions from acid bogs. As above

Note: CO₂ emissions from fens. As above

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

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Frequently Asked Questions

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GENERAL

Syin Yi Phoon (Senior Hydrologist, EnviroCentre Ltd)

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

Response: Protection of sheets removed

Syin Yi Phoon (Senior Hydrologist, EnviroCentre Ltd)

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

Response: This feature has been replaced

CORE INPUT DATA

Cameron McIver (Cameron Ecology Ltd)

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

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

Stephen Lockett (AECOM)

Question:

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

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

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

Possible approach:

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

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

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

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

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

Tanya Ogilvy (SEPA)

Question:

Response:

5c. Volume of peat drained

Stephen Lockett (AECOM)

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

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

5e. Emission rates from soils

Stephen Lockett (AECOM)

Question: Rate of carbon dioxide emission

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

Response:

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

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

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

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

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

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

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

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

CHANGES IN VERSION 2.2.0			
Worksheet	Cells	Change	Thanks to...
Construction input data	C28, C29...	"Volume cement..." changed to "Volume concrete..."	Marianne Brownlee, Arcus Renewable Energy Consulting
1. Windfarm CO2 emission saving	F49	=IF(F19=1,365*24*F11*F10*G21/100,SUM(I49,L49,O49,R49,U49)) changed to =IF(D19=1,365*24*F11*F10*G21/100,SUM(I49,L49,O49,R49,U49))	Cameron McIver, Cameron Ecology Ltd

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

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

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

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

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

CHANGES IN VERSION 2.7.2

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

CHANGES IN VERSION 2.8.0

Worksheet	Cells	Change	Comment	Thanks to...
5c. Volume of peat drained	Rows 67 - 76	Inserted rows to include additional excavated peat in volume of peat drained	Include additional excavated peat in volume of peat drained	Susana Sebastian, SEPA
	C67-C68; D67-D68; E67-E68	Title lines		
	C69	=Core input data!C74		
	D69,E69	Similar to above		
	C70	=Core input data!C75		
	D70,E70	Similar to above		
	C71	=IF(C70>0,C69/C70,0)		
	D71,E71	Similar to above		
	C72	=SQRT(C70/PI())		
	D72,E72	Similar to above		
	C73	=C72+C9		
	D73,E73	Similar to above		
	C74	=PI()*C73*C73-C70		
	D74,E74	Similar to above		
	C75	=C74*C71		
	D75,E75	Similar to above		
	C79	=C18+C34+C57+C64 changed to =C18+C34+C57+C64+C74		
	D79,E79	Similar to above		
	C80	=C19+C35+C58+C65 changed to =C19+C35+C58+C65+C75		
	D80,E80	Similar to above		
7ii. Forestry CO2 loss - detail	F62	=F60*F61 changed to =F60*F61*F55	Calculation of emissions associated to the transport of wood to biomass plant should account for number of trips to plant	Susana Sebastian, SEPA
Forestry input data	G62-T62	Similar to above		
Core input data	C23	Units changed from g CO2 km ⁻¹ to g CO2 km ⁻¹ t ⁻¹		
8. CO2 gain - site improvement	Row 15	Insert input for average depth of peat at site	Limit improvements following restoration to the depth of the peat	Susana Sebastian, SEPA
	C15	=Core input data!C25		
	D15-N15 (excl. E15, I15 & M15)	Similar to above		
	E15	=Core input data!C46		
	I15,M15	Similar to above		
	C16	Core input data!C82 changed to =IF('Core input data!C82<C15,'Core input data!C82,C15)		
	D16-N16	Similar to above		
	C17	=Core input data!C83 changed to =IF('Core input data!C83<C15,'Core input data!C83,C15)		
	D17-N17	Similar to above		
	C21	C12-C20 changed to =IF(C12-C20>0,C12-C20,0)		
	D21-N21	Similar to above		
Core input data	Rows 85, 91, 97	Insert period of time when the improvement can be guaranteed to work (years)	Improvements in C sequestration should continue for as long as the improvement can be guaranteed.	Rob McCall, NRW
8. CO2 gain - site improvement	C12	=Core input data!C12 changed to =Core input data!C85		
	D12-N12 (excl. E12, I12 & M12)	Similar to above		
Payback Time and CO2 emissions	Row 37	Insert ratio of soil carbon loss to gain by restoration	Include calculation of ratio of soil losses to gains	Rob McCall, NRW
	C37	=IF(C26<0,-(C17+C18)/C26,0)		
	D637,E37	Similar to above		
Payback Time and CO2 emissions	Row 38	Insert ratio of C emissions to power generation	Include calculation of C emissions to power generation	Susana Sebastian, SEPA
	C38	=((C20+C26)*1000000)/(C12*1000)		
	D637,E37	Similar to above		
5. Loss of soil CO2	D11	=D8+D9 changed to =MIN(D8+D9,E8+E9)	Correct use of minimum and maximum wrt water table depth at very low depths	Peter Batten
	E11	=E8+E9 changed to =MAX(D8+D9,E8+E9)		
5e. Emission rates from soils	D31	=Core input data!E24 changed to =Core input data!G24		
	E31	=Core input data!G24 changed to =Core input data!E24		
	D33	=Core input data!E28 changed to =Core input data!G28		
	E33	=Core input data!G28 changed to =Core input data!E28		
8. CO2 gain - site improvement	G17	=IF('Core input data!E83<G15,'Core input data!E83,G15) changed to =IF('Core input data!G83<G15,'Core input data!G83,G15)	Correct use of minimum and maximum depth of water table after restoration	Jo Smith, University of Aberdeen
	H17-J17 K17	Similar to above =IF('Core input data!G83<K15,'Core input data!G83,K15) changed to =IF('Core input data!E83<K15,'Core input data!E83,K15)		
	L17-N17	Similar to above		
8. CO2 gain - site improvement	G12	=Core input data!E85 changed to =Core input data!G85	Correct use of min/max period when restoration can be restored	Jo Smith, University of Aberdeen
	H12-J12 K12 L12-N12	Similar to above =Core input data!G85 changed to =Core input data!E85 Similar to above		
8. CO2 gain - site improvement	C34	=IF('Core input data!\$C\$112=2,'8. CO2 gain - site improvement!C30,'8. CO2 gain - site improvement!C32) changed to =IF('Core input data!\$C\$112=2,IF('Core input data!\$C\$23=1,C30,C31),IF('Core input data!\$C\$23=1,C32,C31))	Correct selection of emission factor when soil type is fen	Elizabeth Keen, Peter Brett Associates LLP
	D34-N34 C53	Similar to above =IF('Core input data!\$C\$112=2,'8. CO2 gain - site improvement!C49,'8. CO2 gain - site improvement!C51) changed to =IF('Core input data!\$C\$112=2,IF('Core input data!\$C\$23=1,C49,C50),IF('Core input data!\$C\$23=1,C51,C52))		
	D53-N53	Similar to above		

CHANGES IN VERSION 2.9.0

Worksheet	Cells	Change	Comment	Thanks to...
Core input data	B94	"Water table depth in borrow pit before restoration (m)" changed to "Depth of water table in borrow pit before restoration with respect to the restored surface (m)"	Confusing wording as water table depth may always be entered as zero.	Clare Wharmby - Carbon Forecast
	B95	"Water table depth in borrow pit after restoration (m)" changed to "Depth of water table in borrow pit after restoration with respect to the restored surface (m)"		
8. CO2 gain - site improvement	C47	=(23*16/12)*C\$13*C\$40*C46*(C\$19/365) changed to =(23*16/12)*C\$13*C\$40*C46*(C\$38/365)	Error in formula using the improved flooded period instead of the unflooded period	Elizabeth Keen - Peter Brett Associates
	D47-N47	Similar to above		
7c. Average stand data	Rows 13-29	Stand data extended from 17 year to 0 years	If forest stand is less than 17 years old, the calculations fail	Brenda Park - AMEC
	Rows 168-86	Similar to above		
7ii. Forestry CO2 loss - detail	F31	=IF(F29>0,IF(F27="Deep Peat",VLOOKUP(F29,'7c. Average stand data!\$D\$87:\$G\$118,3)),VLOOKUP(F29,'7c. Average stand data!\$D\$30:\$G\$63,3)),0) changed to =IF(F29>0,IF(F27="Deep Peat",VLOOKUP(F29,'7c. Average stand data!\$D\$68:\$G\$118,2)),VLOOKUP(F29,'7c. Average stand data!\$D\$12:\$G\$62,2)),0)		
	G31-T31	Similar to above		
7ii. Forestry CO2 loss - detail	G35	=IF('Forestry input data!\$F\$33=1,"Yes", "No") changed to =IF('Forestry input data!\$D\$33=1,"Yes", "No")	Use of felled wood as biofuel not correctly read in min and max calculations	Jo Smith - University of Aberdeen
	H35,J35,K35,M35,N35,P35,Q35 S35,T35	Similar to above		
7ii. Forestry CO2 loss - detail	F16	=7a. C sequest. in trees (3PG)!\$F\$24 changed to =IF(F12>0,7a. C sequest. in trees (3PG)!\$F\$24,0)	Avoid #NA	Claire Frost - AECOM
	G16-T16	Similar to above		
Forestry input data	Note: Emissions from felling and timber removal.	"the emissions are 6657 g CO ₂ m ^{-3m} changed to "the emissions are 6675 g CO ₂ m ^{-3m} "		Jonathon Davison - Mott MacDonald
Forestry input data	Note: Emissions associated with transportation	"3933000 g CO ₂ km ⁻¹ (range 3850000 - 4015000 g CO ₂ km ⁻¹ - average = 39.33 g CO ₂ km ⁻¹ t ⁻¹)" changed to "39.33 g CO ₂ km ⁻¹ t ⁻¹ (range 38.5 - 40.15 g CO ₂ km ⁻¹ t ⁻¹ - average = 39.33 g CO ₂ km ⁻¹ t ⁻¹)"		Jonathon Davison - Mott MacDonald
Payback Time and CO2 emissions	C37	=IF(C26<0,-(C17+C18)/C26,"No gains!")	Ensure no restoration is highlighted as no gains rather than appearing	Sarah Lister, Natural Power
	D637,E37	Similar to above		
Payback Time and CO2 emissions	C38	=((12/44)*(C20+C26)*1000000)/(C12*1000)	Express ratio as CO2 rather than C emissions to power generation	Sarah Lister, Natural Power
	D637,E37	Similar to above		

Appendix 6.E

Carbon Calculator - Justification for Values Used

Appendix 6.E – Enoch Hill Wind Farm - Justification for Values Used in Carbon Calculator

Input data	Enoch Hill Wind Farm			Comments/Assumptions
	Expected	Minimum	Maximum	
Wind Farm Characteristics				
Dimensions				
No. of turbines	19	19	19	Number of turbines included in Proposed Development.
Lifetime of wind farm	25	25	25	Standard lifetime used by Nayak <i>et al.</i>
Power rating of turbines	3.3MW	3.3MW	3.3MW	3.3MW is the candidate turbine in the ES as outlined in Chapter 4 .
Capacity factor	27%	21.7%	33.6%	Average capacity factor in Scotland between 2009-2014 ¹ is 27%. Minimum and maximum values inserted as a range.
Extra capacity required for back up	5	0	5	Following the guidance provided by Nayak <i>et al</i> , UK Energy in brief 2013 ² confirms that wind energy accounts for less than 20% of total national electricity generation therefore 0% could be used however 5% has been used to reflect a worst case scenario 0% is entered as a minimum value.
Additional emissions due to thermal inefficiency of back up generation (%)	10	10	10	Default used by Nayak <i>et al.</i>
Carbon dioxide emissions from turbines life	Calculate w.r.t installed capacity			Total CO ₂ emission calculated using installed capacity (default equation provided in spreadsheet).
Peatland Characteristics before wind development				
Average annual air temperature at site (°C)	7.5	3.9	11.2	Average annual temperature taken for Eskdalemuir Met Office station 1981-2010 ³ . Expected value calculated using average of minimum and maximum average temperatures. Maximum and minimum chosen as a range.

¹ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/437811/et6_1.xls Renewable electricity capacity and generation (ET 6.1) Last accessed 03/07/2015

² https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224130/uk_energy_in_brief_2013.PDF Last accessed 13/12/13

³ <http://www.metoffice.gov.uk/climate/uk/averages/19812010/sites/eskdalemuir.html> Last accessed 06/10/2014

Input data	Enoch Hill Wind Farm			Comments/Assumptions
	Expected	Minimum	Maximum	
Average peat depth at site	0.68	0.5	1.0	Expected value calculated as average value of all 1,581 peat depth measurements taken at site. Minimum and maximum values chosen as a range. See Peat Management Plan (PMP) ES Appendix 6.A for calculations.
Content of dry peat % by weight	55	49	62	Calculated using typical values provided in carbon balance spreadsheet.
Average extent of drainage around drainage features at site (m)	7.5	5	10	No site specific measurements available, precautionary values used.
Average water table depth at site (m)	0.3	0.2	0.4	Expected value is average across all 1,581 measurements taken at site where water table depth is estimated to be equivalent to catotelm thickness. Detailed water table depth measurements were not taken.
Dry soil bulk density (gcm ⁻³)	0.25	0.20	0.45	Due to lack of site specific information, indicative figures from National Soil Inventory of Scotland have been used.
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	3	2	5	Estimated values, based on condition of the current vegetation.
Carbon accumulation due to C fixation by bog plants in undrained peat (tC ha ⁻¹ yr ⁻¹)	0.25	0.12	0.31	Default values provided by Nayak <i>et al.</i>
Forestry Plantation Characteristics				
Enter simple data				
Area of forestry plantation to be felled (ha)	0	0	0	No forestry felling is expected.
Average rate of carbon sequestration in timber	n/a	n/a	n/a	
Counterfactual emission factors				
Coal-fired plant emission factor tCO ₂ MWh ⁻¹	0.907	0.907	0.907	Provisional values for 2013 published in Chapter 5 of DUKES 2014 ⁴ .
Grid mix emission factor tCO ₂ MWh ⁻¹	0.454	0.454	0.454	Provisional values for 2013 published in Chapter 5 of DUKES 2014.
Fossil fuel mix emission factor tCO ₂ MWh ⁻¹	0.701	0.701	0.701	Provisional values for 2013 published in Chapter 5 of DUKES 2014.
Borrow Pits				
Number of Areas	1	1	1	Three potential borrow pit search areas have been identified as described in Chapter 4 of the ES. However only one area is on true peat (>0.5m in depth).

⁴ <https://www.gov.uk/government/statistics/digest-of-united-kingdom-energy-statistics-dukes-2014-printed-version> Last accessed 06/06/2014

Input data	Enoch Hill Wind Farm			Comments/Assumptions
	Expected	Minimum	Maximum	
Average length of area (m)	100	50	150	
Average width of areas (m)	100	50	150	
Average depth of peat removed from area (m)	1.05	1.00	1.10	Average peat depth in borrow pit - see PMP (ES Appendix 6.A).
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	27.5	25	27.5	An excavation area of 27.5m square is expected (and worst case).
Average width of turbine foundations (m)	27.5	25	27.5	As above.
Average depth of peat removed from turbine foundations (m)	0.95	0.75	1.25	Average peat depth values taken from peat excavation calculations across all 19 turbine locations. See PMP, ES Appendix 6.A for calculations. Minimum and maximum entered as a range.
Average length of hard standing	50	50	50	Hardstandings are 50 x 25m. Additional area not required for excavation as not deep.
Average width of hard standing	25	25	25	As above.
Average depth of peat removed from hardstanding (m)	0.69	0.5	1.0	Average peat depth values taken from peat excavation calculations done for the PMP for turbine and hardstanding locations. See PMP, ES Appendix 6.A for calculations. Minimum and maximum entered as a range.
Access tracks				
Total length of access tracks (m)	12,900	12,900	12,900	As outlined in ES Chapter 4 , the total value includes new cut and floating track length as outlined in Chapter 4 of ES.
Existing tracks length (m)	n/a	n/a	n/a	No upgrading of existing track on this site.
<u>Length of access tracks that is floating road (m)</u>	1,900	1,800	2,000	Expected value is taken from PMP (ES Appendix 6.A). Minimum and maximum entered as a range to allow for variations following detailed site investigation.
Floating road width (m)	6	6	6	As per Figure 4.3 in ES.
Floating road depth (m)	0.5	0.5	0.5	As per Figure 4.3 in ES.
Length of floating road that is drained (m)	1,900	1,800	2,000	Assume the full length of floating road is drained, will be confirmed following detailed ground investigation.
Average depth of drains associated with floating roads (m)	0.5	0.5	0.5	Assume drain depth of 0.5m.

Input data	Enoch Hill Wind Farm			Comments/Assumptions
	Expected	Minimum	Maximum	
<u>Length of access track that is excavated road (m)</u>	11,000	10,500	11,500	Total new track length as outlined in ES Chapter 4 allowing for 1.9km of floating road. Minimum and maximum entered as a range to allow for variations following detailed site investigation.
Excavated road width (m)	6	6	6	As per Figure 4.3 in ES.
Average depth of peat excavated from road (m)	0.58	0.50	0.70	Average peat depth value calculated from peat depth measurements along new track used. See PMP, ES Appendix 6.A for calculations. Minimum and maximum entered as a range.
<u>Length of access track that is rock filled road (m)</u>	0	0	0	All new track is expected to be excavated road.
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	0	0	
Cable Trenches				
Length of any cable trench on peat that does not follow access track and is lined with a permeable material (m)	0	0	0	Assume full length of cable route to follow access track.
Depth of cable trench	0	0	0	
Additional peat excavated (not accounted for above)				
Volume of additional peat excavated (m ³)	20,258	19,500	21,000	Total volume of excavated peat for primary and secondary compound, control building, met masts and passing places along access tracks.
Area of additional peat excavated (m ²)	34,400	33,050	35,595	Area of infrastructure as per site layout and described in ES Chapter 4 (minimum and maximum figures calculated assuming peat depth of 0.59m calculated from volume above). See PMP, ES Appendix 6.A for calculations.
Peat Landslide hazard				
Peat landslide hazard risk assessment				Measures have been taken to limit risk. See Peatslide Hazard and Risk Assessment (ES Appendix 6.B).
Improvement of C sequestration at site by blocking drains, restoration of habitat etc.				
<u>Improvement of degraded bog</u>				
Area of degraded bog to be improved (ha)	0	0	0	n/a



Input data	Enoch Hill Wind Farm			Comments/Assumptions	
	Expected	Minimum	Maximum		
Water table depth in degraded bog before improvement (m)	n/a	n/a	n/a	n/a	
Water table depth in degraded bog after improvement (m)	n/a	n/a	n/a	n/a	
Time required for hydrology and habitat of bog to return to its previous state on restoration (years)	n/a	n/a	n/a	n/a	
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	n/a	n/a	n/a	n/a	
<u>Improvement of felled plantation</u>					
Area of felled plantation to be improved (ha)	0	0	0	There will be no felled plantation within the Development Site.	
Water table depth in felled area before improvement (m)	0	0	0		
Water table depth in felled area after improvement (m)	0	0	0		
Time required for hydrology and habitat of felled plantation to return to its previous state on restoration (years)	0	0	0		
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	0	0	0		
<u>Restoration of peat removed from borrow pits</u>					
Area of borrow pits to be restored (ha)	5	4	5		As outlined in the PMP provided in ES Appendix 6.A . Minimum and maximum entered as a range.
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.3	0.2	0.4	Estimated water table depth in borrow pit before restoration. Using average water table depth.	
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.3	0.2	0.4	Restored water table depth expected (estimated to be restored to previous value).	
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	3	2	4	Estimated time input for the expected case, minimum and maximum entered as a range.	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	22	23	21	The restoration measures are expected to last the lifetime of the wind farm (i.e. following restoration to previous state).	
<u>Removal of drainage from foundations and hardstanding</u>				Assume no removal of drainage.	



Input data	Enoch Hill Wind Farm			Comments/Assumptions
	Expected	Minimum	Maximum	
Water table depth around foundations and hardstanding before restoration	0	0	0	
Water table depth around foundations and hardstanding after restoration	0	0	0	
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 you attempt to block any gullies that have formed due to the wind farm?	Yes	Yes	No	Assumes that any gullies caused by construction of the wind farm would be blocked to maintain habitats except worst case scenario (maximum column).
Will you attempt to block all artificial ditches and facilitate rewetting?	No	No	No	
Will the habitat of the site be restored on decommissioning				
Will you control grazing on degraded areas?	Yes	Yes	Yes	If required.
Will you manage areas to favour reintroduction of species	No	No	No	

Construction Input Data

Number of turbines in this area	19	19	19	Number of turbines included in proposed development.
Turbine foundations				
Depth of hole dug when constructing foundations	0.3	0.3	0.3	Based on Figure 4.13 in the ES.
Approximate geometric shape of hole dug when constructing foundations	Rectangular	Rectangular	Rectangular	Circular or square geometry not available as an option.
Length at surface (m)	27.5	25	27.5	Based on Figure 4.13 in the ES, adjusted dimensions for a rectangular geometry.
Width at surface (m)	27.5	25	27.5	Based on Figure 4.13 in the ES, adjusted dimensions for a rectangular geometry.
Length at bottom (m)	25	25	25	Based on Figure 4.13 in the ES, adjusted dimensions for a rectangular geometry.
Width at bottom (m)	25	25	25	Based on Figure 4.13 in the ES, adjusted dimensions for a rectangular geometry.
Hardstanding				
Depth of hole dug when constructing hardstanding	0.6	0.6	0.6	Based on Figure 4.4 in the ES and details in Chapter 4.
Approximate geometric shape of hole dug when constructing hardstanding	Rectangular	Rectangular	Rectangular	
Length at surface (m)	50	50	50	Based on Figure 4.4 in the ES.
Width at surface (m)	25	25	25	Based on Figure 4.4 in the ES.
Length at bottom (m)	50	50	50	Based on Figure 4.4 in the ES.
Width at bottom (m)	25	25	25	Based on Figure 4.4 in the ES.
Is piling used?	No	No	No	Based on Figure 4.4 in the ES.
Volume of concrete used per turbine base (m ³)	750	500	750	Calculated from area of turbine foundations and depth of excavation. Range given to allow for a range of candidate turbines, with 750m ³ being the largest.