APPENDIX 11-2

CARBON CALCULATIONS

Scottish Government Windfarm Carbon Assessment Tool

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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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	15		15		15	
Lifetime of windfarm (years)	35	Fixed	35		35	
Performance						
Power rating of turbines (turbine capacity) (MW)	6		5.9		6.1	
Capacity factor	Direct input of capacity fac		Direct input of capacity fac		Direct input of capacity fac	
Enter estimated capacity factor (percentage efficiency)	0.35		0.35		0.35	
Backup						
Extra capacity required for backup (%)	5		5		5	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10		10		10	
Carbon dioxide emissions from turbine life - (eg. manufacture, construction, decommissioning)	Calculate wrt installed cap		Calculate wrt installed cap		Calculate wrt installed cap	
Characteristics of peatland before windfarm development						
Type of peatland	Acid b		Acid b		Acid b	
Average annual air temperature at site (^oC)	9.8		5.1		15.6	
Average depth of peat at site (m)	2.00		2.00		2.00	
C Content of dry peat (% by weight)	53.23		19.57		64.28	
Average extent of drainage around drainage features at site (m)	15.00		15.00		15.00	
Average water table depth at site (m)	0.50		0.10		1.00	
Dry soil bulk density (g cm^{-3})	0.13		0.01		0.29	
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	10		5		15	
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25		0.2		0.3	
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)	1.26		1.26		1.26	
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	3.45		3.50		3.55	
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})	1.046		1.046		1.046	
Grid-mix emission factor (t CO_2 MWh^{-1})	0.20705		0.20705		0.20705	
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.437		0.437		0.437	
Borrow pits						
Number of borrow pits	4		4		4	
Average length of pits (m)	155.5		155.5		155.5	
Average width of pits (m)	88.5		88.5		88.5	
Average depth of peat removed from pit (m)	2.00		2		2	
Foundations and hard-standing area associated with each turbine						
Method used to calculate CO_2 loss from foundations and hard-standing	Enter detailed information 2		Enter detailed information 2		Enter detailed information 2	
Please enter construction data in sheet: Construction input data	28		28		28	
	28		28		28	
Average depth of peat removed from turbine foundations (m)	2.00		2.00		2.00	
	75		75		75	
	48		48		48	
Average depth of peat removed from hard-standing (m)	2.00		2.00		2.00	
Access tracks						
Total length of access track (m)	23200		22800		22800	
Existing track length (m)	4300		4300		4300	
Length of access track that is floating road (m)	12100		12100		12100	
Floating road width (m)	5		5		5	
Floating road depth (m)						
Length of floating road that is drained (m)						
Average depth of drains associated with floating roads (m)						
Length of access track that is excavated road (m)	6800		6800		6800	
Excavated road width (m)	5		5		5	
Average depth of peat excavated for road (m)	2.00		2.00		2.00	
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)						
Average depth of peat cut for cable trenches (m)	1.20		1.20		1.20	
Additional peat excavated (not already accounted for above)						
Volume of additional peat excavated (m^3)	27281		27281		27281	
Area of additional peat excavated (m^2)	78998.0		78998.0		78998.0	
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)	25		25		25	
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)	25		25		25	
Restoration of peat removed from borrow pits						
Area of borrow pits to be restored (ha)						
Depth of water table in borrow pit before restoration with respect to the restored surface (m)						
Depth of water table in borrow pit after restoration with respect to the restored surface (m)						
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)						
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	25		25		25	
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)	15		10		5	
Restoration of site after decomissioning						
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?	No		No		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?	No		No		No	
Will you manage areas to favour reintroduction of species	No		No		No	

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

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

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

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

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

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

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

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

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

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

Note: Coal-fired plant emission factor (EF) from electricity supplied in 2023 = 1.046 t CO_2 MWh^{-1}; Digest of UK Energy Statistics (DUKES): electricity - GOV.UK (2024)
Grid Mix EF for 2024 = 0.20705 t CO_2 MWh^{-1}. Greenhouse gas reporting: conversion factors 2024 - GOV.UK

Note: Fossil Fuel-Mix Emission Factor. The emission factor from electricity supplied in 2024 from all non renewable fuels = 0.437 t CO_2 MWh^{-1} Digest of UK Energy Statistics (DUKES): electricity - GOV.UK

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

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

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

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

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

Note: Peat Landslide Hazard. It is assumed that measures have been taken to limit damage (Scottish Executive, 2006, Peat Landslide Hazard and Risk Assessments. Best Practice Guide for Proposed Electricity Generation Developments. Scottish Executive, Edinburgh. pp. 34-35) so that C losses due to peat landslide can be assumed to be negligible. Link: http://www.scotland.gov.uk/Publications/2006/12/21162303/1.

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

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

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

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

Core input data

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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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Results

PAYBACK TIME AND CO_2 EMISSIONS

Note: The carbon payback time of the windfarm is calculated by comparing the loss of C from the site due to windfarm development with the carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or grid-mix. **Please note that carbon payback for the Lemanaghan Wind Farm has been calculated separately and is contained in Section 11.4.3.2 of Chapter 11 Climate.**

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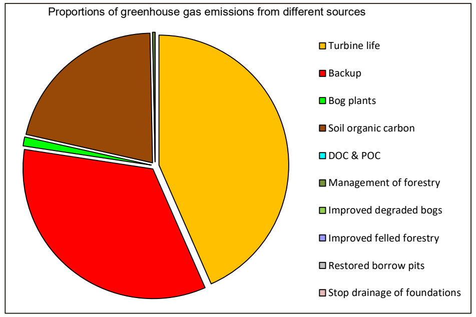
	Exp.	*Min.*	*Max.*
1. Windfarm CO_2 emission saving over…			
…coal-fired electricity generation ($tCO_2\ yr^{-1}$)	2886	2838	2934
…grid-mix of electricity generation ($tCO_2\ yr^{-1}$)	571	562	581
…fossil fuel - mix of electricity generation ($tCO_2\ yr^{-1}$)	1206	1186	1226
Energy output from windfarm over lifetime (MWh)	96579	94969	98189
Total CO_2 losses due to wind farm (t CO_2 eq.)			
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	77078	75677	78480
3. Losses due to backup	60293	59288	61298
4. Losses due to reduced carbon fixing potential	1985	1411	2646
5. Losses from soil organic matter	37622	-19135	173231
6. Losses due to DOC & POC leaching	0	0	0
7. Losses due to felling forestry	558	566	574
Total losses of carbon dioxide	177536	117807	316229
8. Total CO_2 gains due to improvement of site (t CO_2 eq.)			
8a. Change in emissions due to improvement of degraded bogs	0	0	0
8b. Change in emissions due to improvement of felled forestry	0	0	0
8c. Change in emissions due to restoration of peat from borrow pits	0	0	0
8d. Change in emissions due to removal of drainage from foundations & hardstanding	0	0	0
Total change in emissions due to improvements	0	0	0

RESULTS*	*Exp.*	*Min.*	*Max.*
Net emissions of carbon dioxide (t $CO_{2\ eq.}$)	177536	117807	316229
Carbon Payback Time			
…coal-fired electricity generation (years)	61.5	40.1	111.4
…grid-mix of electricity generation (years)	310.7	202.8	562.9
…fossil fuel - mix of electricity generation (years)	147.2	96.1	266.7
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	No gains!	No gains!	No gains!
Ratio of CO_2 eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	1838	1200	3330

***Carbon payback for Lemanaghan Wind Farm has been calculated separately and is contained in Section 11.4.3.2 of Chapter 11 of the EIAR**



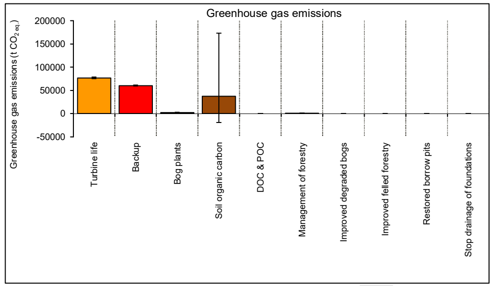
Data used in barchart of carbon payback time using fossil-fuel mix as counterfactual

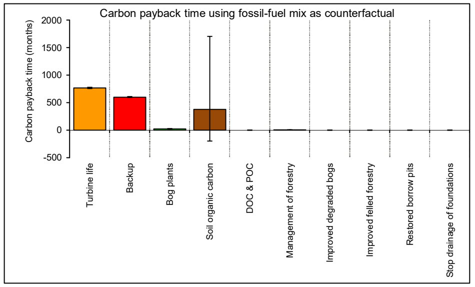
Greenhouse gas emissions

	Exp.	*Min*	*Max*
Turbine life	77078	1402	1402
Backup	60293	1005	1005
Bog plants	1985	573	662
Soil organic carbon	37622	56758	135609
DOC & POC	0	0	0
Management of forestry	558	0	16
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				Carbon payback time (months)		
	Exp.	*Min.*	*Max.*	*Exp.*	*Min.*	*Max.*
Turbine life	77078	1402	1402	767	14	14
Backup	60293	1005	1005	600	10	10
Bog plants	1985	573	662	20	6	6
Soil organic carbon	37622	56758	135609	374	574	1327
DOC & POC	0	0	0	0	0	0
Management of forestry	558	-8	16	6	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
	177536			1767		





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Results

PAYBACK TIME AND CO_2 EMISSIONS

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

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Windfarm CO_2 emission saving

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

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	15	15	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Power rating of turbines (turbine capacity) (MW)	6	5.9	6.1	6	5.9	6.1	6	5.9	6.1	6	5.9	6.1	6	5.9	6.1	6	5.9	6.1
Power of windfarm (MW)	90	88.5	91.5	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})	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046	1.046
Grid-mix emission factor (t CO_2 MWh^{-1})	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705	0.20705
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.437

Calculation of capacity factor	1	Direct input of capacity factor		
		Exp	Min	Max
Entered capacity factor (%)		0.35	0.35	0.35

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

Calculation of capacity factor from forestry management	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
	Exp	**Min**	**Max**	**Exp**	**Min**	**Max**	**Exp**	**Min**	**Max**	**Exp**	**Min**	**Max**	**Exp**	**Min**	**Max**	**Exp**	**Min**	**Max**
Wind speed ratio calculated in 7d				#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Average site windspeed (m s^{-1})	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual theoretical energy output from turbine (MW $turbine^{-1}$ yr^{-1})	52560	51684	53436	52560	51684	53436	52560	51684	53436	52560	51684	53436	52560	51684	53436	52560	51684	53436
Power curve				User-defined	User-defined	User-defined	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines	Partial power curves for different turbines
(Power curve code)				1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Slope (a)				0	0	0	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Intercept (b)				0	0	0	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
Annual power output from an individual turbine (MW $turbine^{-1}$ yr^{-1})				#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Calculated capacity factor (%)				#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######

Calculation of annual energy output from wind farm	Total			Forestry Area 1			Forestry Area 2			Forestry Area 3			Forestry Area 4			Forestry Area 5		
Direct input of capacity factor Capacity factor(%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual energy output from windfarm (MW yr^{-1})	**2759**	**2713**	**2805**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

RESULTS	**Total**			**Area 1**			**Area 2**			**Area 3**			**Area 4**			**Area 5**		
Windfarm CO_2 emission saving over…																		
…coal-fired electricity generation (tCO_2 yr^{-1})	**2886**	**2838.23**	**2934.44**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
…grid-mix of electricity generation (tCO_2 yr^{-1})	**571**	**561.812**	**580.856**	**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})	**1206**	**1185.76**	**1225.96**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Click here to move to Payback Time Click here

Windfarm CO_2 emission saving

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

Emissions due to turbine life

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

Method used to estimate CO_2 emissions from turbine life (eg. manufacture, construction, decommissioning)?	Calculate wrt installed capacity

	Exp	Min	Max
Direct input of emissions due to turbine life (t CO_2 windfarm^{-1})	**0**	**0**	**0**
Calculation of emissions due to turbine life from energy output			
CO_2 emissions due to turbine life (tCO_2 turbine^{-1})	5139	5045	5232
No. of turbines	15	15	15
Total calculated CO_2 emission of the wind farm due to turbine life (t CO_2 windfarm^{-1})	77078	75677	78480

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

RESULTS			
Losses due to turbine life (eg.	77078	75677	78480
Additional CO_2 payback time of windfarm due to turbine life (eg. manufacture, contruction, decomissioning)			
…coal-fired electricity generation (months)	320	320	321
…grid-mix of electricity generation (months)	1619	1616	1621
…fossil fuel - mix of electricity generation (months)	767	766	768

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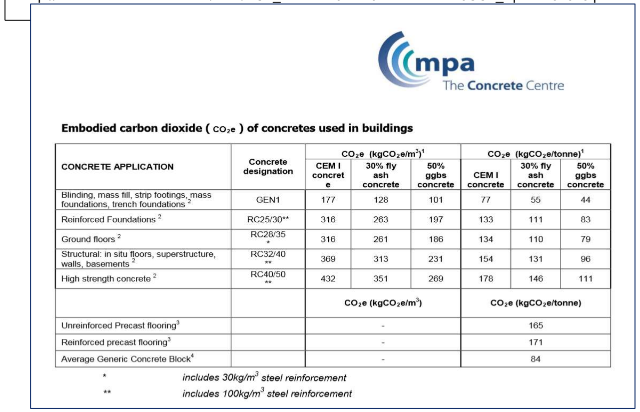
Emissions due to turbine life

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

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



mpa The Concrete Centre

Embodied carbon dioxide (CO_2e) of concretes used in buildings

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

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

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

Emissions due to backup power generation

Note: CO_2 loss due to back up is calculated from the extra capacity required for backup of the windfarm given in the input data.

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.

	Expected	**Minimum**	**Maximum**
Reserve capacity required for backup			
No. of turbines	15	15	15
Power rating of turbines (turbine capacity) (MW)	6	5.9	6.1
Power of wind farm (MW h^{-1})	90	88.5	91.5
Rated capacity (MW yr^{-1})	788400	775260	801540
Extra capacity required for backup (%)	5	5	5
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10
Reserve capacity (MWh yr^{-1})	3942	3876	4008
Carbon dioxide emissions due to backup power generation			
Coal-fired plant emission factor (t CO_2 MWh^{-1})	1.046	1.046	1.046
Grid-mix emission factor (t CO_2 MWh^{-1})	0.20705	0.20705	0.20705
Fossil fuel- mix emission factor (t CO_2 MWh^{-1})	0.437	0.437	0.437
Lifetime of windfarm (years)	35	35	35
Annual emissions due to backup from…			
…coal-fired electricity generation (tCO_2 yr^{-1})	4123	4055	4192
…grid-mix of electricity generation (tCO_2 yr^{-1})	816	803	830
…fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	1723	1694	1751
RESULTS			
Total emissions due to backup from…			
…coal-fired electricity generation (tCO_2)	144317	141911	146722
…grid-mix of electricity generation (tCO_2)	28567	28091	29043
…fossil fuel - mix of electricity generation (tCO_2)	**60293**	**59288**	**61298**
Additional CO_2 payback time of windfarm due to backup			
…coal-fired electricity generation (months)	600	600	600
…grid-mix of electricity generation (months)	600	600	600
…fossil fuel - mix of electricity generation (months)	600	600	600

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

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Emissions due to backup power generation

Note: CO_2 loss due to back up is calculated from the extra capacity required for backup of the windfarm given in the input data.

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)	228545	228545	228545
Total area affected by drainage due to windfarm construction (m^{-2})	252532	252532	252532
Total area where fixation by plants is lost (m^2)	481077	481077	481077

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.

	Expected	Minimum	Maximum
Total loss of carbon accumulation			
Carbon accumulation in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.2	0.3
Lifetime of windfarm (years)	35	35	35
Time required for regeneration of bog plants after restoration (years)	10	5	15
Carbon accumulation up to time of restoration (tCO$_2$ eq. ha^{-1})	41	29	55

	Expected	Minimum	Maximum
RESULTS			
Total loss of carbon accumulation by bog plants			
Total area where fixation by plants is lost (ha)	48	48	48
Carbon accumulation over lifetime of windfarm (tCO$_2$ eq. ha^{-1})	41	29	55
Total loss of carbon fixation by plants at the site (t CO$_2$)	**1985**	**1411**	**2646**
Additional CO$_2$ payback time of windfarm due to loss of CO2 fixing potential			
…coal-fired electricity generation (months)	8	6	11
…grid-mix of electricity generation (months)	42	30	55
…fossil fuel - mix of electricity generation (months)	20	14	26

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Emissions due to loss of bog plants

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

Emissions due to loss of soil organic carbon

Note: Loss of C stored in peatland is estimated from % site lost by peat removal (sheet 5a), CO$_2$ loss from removed peat (sheet 5b), % site affected by drainage (sheet 5c), and the CO2 loss from drained peat (sheet 5d).

		Expected result	Minimum result	Maximum result
	CO$_2$ loss due to windfarm construction			
Check	CO$_2$ loss from removed peat (t CO$_2$ equiv)	31167	-19135	121506
Check	CO$_2$ loss from drained peat (t CO$_2$ equiv)	6456	0	51725
	RESULTS **Total CO$_2$ loss from peat (removed + drained) (t CO$_2$ equiv)**	**37622**	**-19135**	**173231**
	Additional CO$_2$ payback time of windfarm due to loss of soil CO2			
	…coal-fired electricity generation (months)	156	-81	708
	…grid-mix of electricity generation (months)	790	-409	3579
	…fossil fuel - mix of electricity generation (months)	374	-194	1696

Click here to move to Payback Time Click here

Emissions due to loss of soil organic carbon

Note: Loss of C stored in peatland is estimated from % site lost by peat removal (sheet 5a), CO$_2$ loss from removed peat (sheet 5b), % site affected by drainage (sheet 5c), and the CO2 loss from drained peat (sheet 5d).

Volume of Peat Removed

Note: % site lost by peat removal is estimated from peat removed in borrow pits, turbine foundations, hard-standing and access tracks.
If peat is removed for any other reason, this must be added in as additional peat excavated in the core input sheet.

Peat removed from borrow pits	Total Exp	 Min	 Max
Number of borrow pits	4	4	4
Average length of pits (m)	155.5	155.5	155.5
Average width of pits (m)	88.5	88.5	88.5
Average depth of peat removed from pit (m)	2	2	2
Area of land lost in borrow pits (m^2)	55047	55047	55047
Volume of peat removed from borrow pits (m^3)	110094	110094	110094

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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diameter at surface (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diameter at bottom (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volume of peat removed from foundation area (m^3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Peat removed from hard-standing																		
Method used to calculate CO_2 loss from foundations	Enter detailed information																	
Calculation method code		2																
No. of turbines	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diameter at surface (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diameter at bottom (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depth of hardstanding (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)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volume of peat removed from hardstandingarea (m^3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Peat removed from access tracks	Total Exp	 Min	 Max
Floating roads			
Length of access track that is floating road (m)	12100	12100	12100

Floating road width (m)	5	5	5
Floating road depth (m)	0	0	0
Area of land lost in floating roads (m^2)	60500	60500	60500
Volume of peat removed for floating roads	0	0	0
Excavated roads			
Length of access track that is excavated road (m)	6800	6800	6800
Excavated road width (m)	5	5	5
Average depth of peat excavated for road (m)	2	2	2
Area of land lost in excavated roads (m^2)	34000	34000	34000
Volume of peat removed for excavated roads	68000	68000	68000
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)	94500	94500	94500
Total volume of peat removed due to access tracks (m^3)	68000	68000	68000

Additional peat excavated - (not already accounted for above)			
Volume of additional peat excavated (m^3)	27281	0	27281
Area of additional peat excavated (m^2)	78998	78998	78998

RESULTS	**Exp**	**Total** **Min**	**Max**
Total volume of peat removed (m^3) due to windfarm construction	**205375**	**178094**	**205375**
Total area of land lost due to windfarm construction (m^2)	**228545**	**228545**	**228545**

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

Volume of Peat Removed

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

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

CO_2 loss from removed peats

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

	Expected	Minimum	Maximum
CO_2 loss from removed peat			
C Content of dry peat (% by weight)	53.23	19.57	64.28
Dry soil bulk density (g cm^{-3})	0.13	0.01	0.29
% C contained in removed peat that is lost as CO_2	100	100	100
Total volume of peat removed (m^3) due to windfarm construction	205375	178094	205375
CO_2 loss from removed peat (t CO_2)	52916	920	141841

Check

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

	Expected	Minimum	Maximum
CO_2 loss from undrained peat left in situ			
Total area of land lost due to windfarm construction (ha)	23	23	23
CO_2 loss from undrained peat left in situ (t CO_2 ha^{-1})	952	878	890
CO_2 loss from undrained peat left in situ (t CO_2)	21749	20056	20335

	Expected	Minimum	Maximum
CO_2 loss attributable to peat removal only			
CO_2 loss from removed peat (t CO_2)	52916	920	141841
CO_2 loss from undrained peat left in situ (t CO_2)	21749	20056	20335
RESULTS **CO_2 loss attributable to peat removal only (t CO_2)**	**31167**	**-19135**	**121506**

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

Click here to move to Payback Time Click here

CO_2 loss from removed peats

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

Volume of peat drained

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

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

Peat affected by drainage around borrow pits		Total	
	Exp	Min	Max
Number of borrow pits	4	4	4
Average length of pits (m)	156	156	156
Average width of pits (m)	89	89	89
Average depth of peat removed from pit (m)	2.0	2.0	2.0
Area affected by drainage per borrow pit (m^2)	8220	8220	8220
Total area affected by drainage around borrowpits (m^2)	32880	32880	32880
Total volume affected by drainage around borrowpits (m^3)	32880	32880	32880

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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average length of turbine foundations at base (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average width of turbine foundations at base(m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average depth of peat removed from turbine foundations (m)				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average length of hard-standing at base (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average width of hard-standing at base (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average depth of peat removed from hard-standing (m)				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum depth of drains (m)				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total length of foundation and hardstanding (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total width of foundation and hardstanding (m)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area affected by drainage of foundation and hardstanding area (m^2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total area affected by drainage of foundation and hardstanding area (m^2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total volume affected by drainage of foundation and hardstanding area (m^3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Peat affected by drainage of access tracks	**Total**		
	Exp	**Min**	**Max**
Floating roads			
Length of floating road that is drained (m)	0	0	0
Floating road width (m)	5.0	5.0	5.0
Average depth of drains associated with floating roads (m)	0.00	0.00	0.00
Area affected by drainage of floating roads (m^2)	0	0	0
Volume affected by drainage of floating roads (m^3)	0	0	0
Excavated Road			
Length of access track that is excavated road (m)	6800	6800	6800
Excavated road width (m)	5	5	5
Average depth of peat excavated for road (m)	2.0	2.0	2.0
Area affected by drainage of excavated roads (m^2)	204000	204000	204000
Volume affected by drainage of excavated roads (m^3)	204000	204000	204000
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^2)	0	0	0
Total area affected by drainage of access track (m^2)	204000	204000	204000
Total volume affected by drainage of access track (m^3)	204000	204000	204000

Peat affected by drainage of cable trenches	**Total**		
	Exp	**Min**	**Max**
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0
Average depth of peat cut for cable trenches (m)	1.2	1.2	1.2
Total area affected by drainage of cable trenches (m^2)	0	0	0
Total volume affected by drainage of cable trenches (m^3)	0.00	0.00	0.00

Drainage around additional peat excavated	**Total** **Exp**	**Min**	**Max**
Volume of additional peat excavated (m^3)	27281.0	0.0	27281.0
Area of additional peat excavated (m^2)	78998.0	78998.0	78998.0
Average depth of excavated peat (m)	0	0	0
Radius of area excavated (m)	159	159	159
Radius of excavated and drained area (m)	174	174	174
Total area affected by drainage (m^2)	15652	15652	15652
Total volume affected by drainage (m^3)	5405.28	0.00	5405.28

Assumption: Area excavated is assumed to be a circle

RESULTS	**Total** **Exp**	**Min**	**Max**
Total area affected by drainage due to windfarm (m^2)	**252532**	**252532**	**252532**
Total volume affected by drainage due to windfarm (m^3)	**242285**	**236880**	**242285**

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

Click here to move to Payback Time Click here

Volume of peat drained

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

CO_2 loss due to drainage

Note: Note, CO_2 losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been derived directly from experimental data for acid bogs and fens (see Nayak et al, 2008 - Final report).

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

Drained Land	Expected	Minimum	Maximum
Total area affected by drainage due to wind farm construction (ha)	25	25	25
Will the hydrology of the site be restored on decommissioning?	No	No	No
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

		Expected	Minimum	Maximum
Check	Total volume affected by drainage due to wind farm (m^3)	242285	236880	242285
	C Content of dry peat (% by weight)	53	20	64
	Dry soil bulk density (g cm^{-3})	0.13	0.01	0.29
	Total GHG emissions from Drained Land (t CO_2 equiv.)	62426	1224	167333
	Total GHG Emissions from Undrained Land (t CO_2 equiv.)	55971	1224	115608

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

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

1. Losses if Land is Drained

		Expected	Minimum	Maximum
	Flooded period (days $year^{-1}$)	0	0	0
	Lifetime of windfarm (years)	35	35	35
	Time required for regeneration of bog plants after restoration (years)	10	5	15
	Methane Emissions from Drained Land			
Check	Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	-0.002	-0.019	0.018
	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.)	-73	-578	712
	Carbon Dioxide Emissions from Drained Land			
Check	Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	23.65	22.51	25.19
	CO_2 emissions from drained land (t CO_2)	26877	22739	31811
	Total GHG emissions from Drained Land (t CO_2 equiv.)	26804	22161	32523

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

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

2. Losses if Land is Undrained

		Expected	Minimum	Maximum
	Flooded period (days $year^{-1}$)	178	178	178
	Lifetime of windfarm (years)	35	35	35
	Time required for regeneration of bog plants after restoration (years)	10	5	15
	Methane Emissions from Undrained Land			
Check	Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.00	-0.02	0.16
	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.)	-55	-578	3461
	Carbon Dioxide Emissions from Undrained Land			
Check	Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	18.62	22.51	4.40
	CO_2 emissions from undrained land (t CO_2)	24087	22739	19009
	Total GHG Emissions from Undrained Land (t CO_2 equiv.)	24032	22161	22469

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

3. CO_2 Losses due to Drainage

	Expected	Minimum	Maximum
Total GHG emissions from drained land (t CO_2 equiv.)	62426	1224	167333
Total GHG emissions from undrained land (t CO_2 equiv.)	55971	1224	115608
RESULTS			
Total GHG emissions due to drainage (t CO_2 equiv.)	**6456**	**0**	**51725**

Click here to move to 5. Loss of soil CO_2 Click here
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CO_2 loss due to drainage

Note: Note, CO_2 losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been derived directly from experimental data for acid bogs and fens (see Nayak et al, 2008 - Final report).

Emission rates from soils

Note: Note, CO_2 losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been thoroughly tested against experimental data (see Nayak et al, 2008 - Final report).

Click here to move to 5d. Click here
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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

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

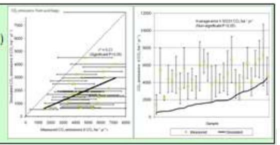
Assumption: The CH_4 emission rate provided for acid bogs is 11 (1-38) mg CH_4-C m^{-2} day^{-1} x 365 days; and for fens is 60 (21-162) mg CH_4-C m^{-2} day^{-1} x 365 days (Aselmann & Crutzen ,1989. J.Atm.Chem. 8, 307-358)

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

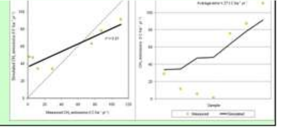
Calculations following ECOSSE based methodology			
Drained Land			
Total area affected by drainage due to wind farm construction (ha)	25	25	25
Total volume affected by drainage due to wind farm construction (m^3)	242285	236880	242285
Soil Characteristics that Determine Emission Rates			
Average annual air temperature at the site (°C)	9.8	5.1	15.6
Average water table depth at site (m)	0.50	1.00	0.10
Average water table depth of drained land (m)	0.96	1.00	0.96

Annual Emission Rates following site specific methodology			
Acid bogs			
Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	23.65	22.51	25.19
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	18.62	22.51	4.40
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	-0.002	-0.019	0.018
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.00	-0.02	0.16
Fens			
Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	64.72	62.17	67.97
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	55.46	62.17	10.91
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	-0.003	-0.007	0.000
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.00	-0.01	0.21

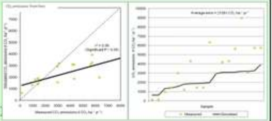
Note: Carbon dioxide emissions from acid bogs. Equation derived by regression analysis against 60 measurements (Nayak et al, 2009). The equation derived was
R_{CO2} = (3.667/1000) x ((6700 x exp(-0.26 x exp(-0.0515 × ((Wx100)-50)))) + ((72.54 × T) - 800))
where R_{CO2} is the annual rate of CO_2 emissions (t CO_2 (ha)$^{-1}$ yr^{-1}),
T = average annual peat temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 =0.53 P > 0.05).
Evaluation against 29 independent experiments shows a significant association (r^2 = 0.21; P>0.05) and an average error of 3023 t CO_2 ha^{-1} yr^{-1} which is non-significant (P<0.05) (Smith et al, 1997).



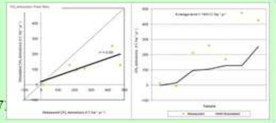
measurements (Nayak et al, 2009). The equation derived was
R_{CH4} = (1/1000) x (500 × exp(-0.1234 × (Wx100)) + ((3.529 × T) - 36.67))
where R_{CH4} is the annual rate of CH_4 emissions (t CH_4-C (ha)$^{-1}$ yr^{-1}),
T = average annual air temperature (°C) and
W is the water table depth (m).
The equation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



Note: Carbon dioxide emissions from fens. Equation derived by regression analysis against 44 measurements (Nayak et al, 2009). The equation derived was
R_{CO2} = (3.667/1000) x (16244 x exp(-0.175 x exp(-0.073 x ((Wx100)-50)))+(153.23 x T))
where R_{CO2} is the annual rate of CO_2 emissions (t CO_2 (ha)$^{-1}$ yr^{-1}),
T = average annual peat temperature (°C) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 = 0.42, P > 0.05).
Evaluation against 18 independent experiments shows a significant association (r^2 = 0.56; P>0.05) and an average error of 2108 t CO_2 ha^{-1} yr^{-1} (significance not defined due to lack of replicates-Smith et al, 1997)



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



Selected emission characteristics following site specific methodology			
Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	23.65	22.51	25.19
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	18.62	22.51	4.40
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	-0.002	-0.019	0.018
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.00	-0.02	0.16

RESULTS
Selected Emission Rates

Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	23.65	22.51	25.19
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	18.62	22.51	4.40
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	-0.002	-0.019	0.018
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.00	-0.02	0.16

Click here to move to 5d. CO2 loss from drained pe Click here
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Emission rates from soils

Note: Note, CO_2 losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been thoroughly tested against experimental data (see Nayak et al, 2008 - Final report).

Emissions due to loss of DOC and POC

Note: Note, CO_2 losses from DOC and POC are calculated using a simple approach derived from generic estimates of the percentage of the total CO2 loss that is due to DOC or POC leaching

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

	Expected	Minimum	Maximum
Total C loss			
Gross CO_2 loss from restored drained land (t CO_2)	0	0	0
Gross CH_4 loss from restored drained land (t CO_2 equiv.)	0	0	0
Gross CO_2 loss from improved land (t CO_2)			
Degraded Bog	0	0	0
Felled Forestry	0	0	0
Borrow Pits	0	0	0
Foundations & Hardstanding	0	0	0
Gross CH_4 loss from improved land (t CO_2 equiv.)			
Degraded Bog	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

Assumption: DOC loss ranges between 7 - 40% of the total gaseous loss if calculated from the reported (minimum and maximum) values in Worrall 2009 and is **26%** of the total gaseous loss if calculated from the mean of reported maximum and minimum value in Worrall 2009. These DOC values are flux based on soil water concentration (i.e. 12.5 - 85.9 MgC/KM^2/yr)
and not on flux at catchment outlet (i.e. 10.3 - 21.8 MgC/KM^2/yr)

Worrall, F. et al., 2009. The multi-annual carbon budget of a peat-covered catchment. *Science of The*

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

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

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

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 CO_2 loss due to DOC & POC leaching (t CO_2)	**0**	**0**	**0**
Additional CO_2 payback time of windfarm due to DOC & POC			
…coal-fired electricity generation (months)	0	0	0
…grid-mix of electricity generation (months)	0	0	0
…fossil fuel - mix of electricity generation (months)	0	0	0

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Emissions due to loss of DOC and POC

Note: Note, CO_2 losses from DOC and POC are calculated using a simple approach derived from generic estimates of the percentage of the total CO2 loss that is due to DOC or POC leaching

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

Emissions due to forest felling - calculation using simple management data

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

	Expected	Minimum	Maximum
Emissions due to forestry felling			
Area of forestry plantation to be felled (ha)	1.26	1.26	1.26
Carbon sequestered (tC ha^{-1} yr^{-1})	3.45	3.5	3.55
Lifetime of windfarm (years)	35	35	35
Carbon sequestered over the lifetime of the windfarm (t C ha^{-1})	120.75	122.5	124.25
RESULTS			
Total carbon loss due to felling of forestry (t CO$_2$)	**558**	**566**	**574**
Additional CO$_2$ payback time of windfarm due to management of forestry			
…coal-fired electricity generation (months)	2	2	2
…grid-mix of electricity generation (months)	12	12	12
…fossil fuel - mix of electricity generation (months)	6	6	6

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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.

Gains due to site improvement

Note: Note, CO_2 losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been thoroughly tested against experimental data (see Nayak et al, 2008 - Final report).

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

Reduction in GHG emissions due to improvement of site	**Expected result**				**Minimum result**				**Maximum result**			
Improvement of…	**Degraded Bog**	**Felled Forestry**	**Borrow Pits**	**Foundations & Hardstanding**	**Degraded Bog**	**Felled Forestry**	**Borrow Pits**	**Foundations & Hardstanding**	**Degraded Bog**	**Felled Forestry**	**Borrow Pits**	**Foundations & Hardstanding**
1. Description of site												
Period of time when effectiveness of the improvement can be guaranteed (years)	25	25	25	35	25	25	25	35	25	25	25	35
Area to be improved (ha)	0	0	0	0	0	0	0	0	0	0	0	0
Average air temperature at site (^oC)	9.8	9.8	9.8	9.8	5.1	5.1	5.1	5.1	15.6	15.6	15.6	15.6
Depth of peat drained (m)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Depth of peat above water table before improvement (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Depth of peat above water table after improvement (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Losses with improvement												
Flooded period (days $year^{-1}$)	178	178	178	178	178	178	178	178	178	178	178	178
Time required for hydrology and habitat to return to its previous state on restoration (years)	0	0	0	15	0	0	0	10	0	0	0	5
Improved period (years)	25	25	25	20	25	25	25	25	25	25	25	30
Methane emissions from improved land												
Site specific methane emission from improved soil on acid bogs (t CH_4-C ha^{-1} yr^{-1})	0.498	0.498	0.498	0.498	0.481	0.481	0.481	0.481	0.518	0.518	0.518	0.518
Site specific methane emission from improved soil on fens (t CH_4-C ha^{-1} yr^{-1})	0.560	0.560	0.560	0.560	0.557	0.557	0.557	0.557	0.564	0.564	0.564	0.564
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})	0.498	0.498	0.498	0.498	0.481	0.481	0.481	0.481	0.518	0.518	0.518	0.518
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})	0.48	0.48	0.48	0.48	-0.77	-0.77	-0.77	-0.77	2.02	2.02	2.02	2.02
Site specific CO_2 emissions from improved soil on fens (t CO_2 ha^{-1} yr^{-1})	5.57	5.57	5.57	5.57	2.92	2.92	2.92	2.92	8.82	8.82	8.82	8.82
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})	0.48	0.48	0.48	0.48	-0.77	-0.77	-0.77	-0.77	2.02	2.02	2.02	2.02
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 CO_2 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	0	15	0	0	0	10	0	0	0	5
Improved period (years)	25	25	25	20	25	25	25	25	25	25	25	30
Methane emissions from unimproved land												
Site specific methane emission from unimproved soil on acid bogs (t CH_4-C ha^{-1} yr^{-1})	0.498	0.498	0.498	0.498	0.481	0.481	0.481	0.481	0.518	0.518	0.518	0.518
Site specific methane emission from unimproved soil on fens (t CH_4-C ha^{-1} yr^{-1})	0.560	0.560	0.560	0.560	0.557	0.557	0.557	0.557	0.564	0.564	0.564	0.564
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})	0.498	0.498	0.498	0.498	0.481	0.481	0.481	0.481	0.518	0.518	0.518	0.518
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})	0.48	0.48	0.48	0.48	-0.77	-0.77	-0.77	-0.77	2.02	2.02	2.02	2.02
Site specific CO_2 emissions from unimproved soil on fens (t CO_2 ha^{-1} yr^{-1})	5.57	5.57	5.57	5.57	2.92	2.92	2.92	2.92	8.82	8.82	8.82	8.82
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})	0.48	0.48	0.48	0.48	-0.77	-0.77	-0.77	-0.77	2.02	2.02	2.02	2.02
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 CO_2 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 CO_2 equiv.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Additional CO_2 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**

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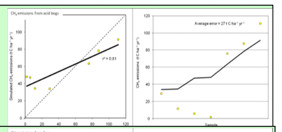
Gains due to site improvement

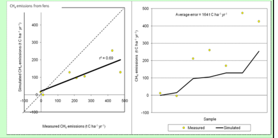
Note: Note, CO_2 losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been thoroughly tested against experimental data (see Nayak et al, 2008 - Final report).

Note: Methane emissions from acid bogs. Equation derived by regression analysis against 57 measurements (Nayak et al, 2009). The equation derived was

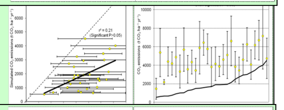
R_{CH4} = (1/1000) x (500 × exp(-0.1234 × (Wx100)) + ((3.529 × T) - 36.67))
where R_{CH4} is the annual rate of CH_4 emissions (t CH_4-C $(ha)^{-1}$ yr^{-1}),
T = average annual air temperature (^oC) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2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



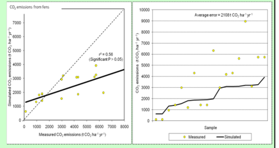
Note: Methane emissions from fens. Equation derived by regression analysis against experimental data from 35 measurements (Nayak et al, 2009). The equation derived was
R_{CH4} = (1/1000) x (-10+563.62 x exp(-0.097 x (W x 100))+(0.662 x T))
where R_{CH4} is the annual rate of CH_4 emissions (t CH_4-C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



R_{CO2} = (3.667/1000) x ((6700 x exp(-0.26 x exp(-0.0515 × ((Wx100)-50)))) + ((72.54 × T) - 800))
where R_{CO2} is the annual rate of CO_2 emissions (t CO_2 $(ha)^{-1}$ yr^{-1}),
T = average annual peat temperature (^oC) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 =0.53 $P > 0.05$).
Evaluation against 29 independent experiments shows a significant association (r^2 = 0.21; P>0.05) and an average error of 3023 t CO_2 ha^{-1} yr^{-1} which is non-significant (P<0.05) (Smith et al, 1997).



Note: Carbon dioxide emissions from fens. Equation derived by regression analysis against 44 measurements (Nayak et al, 2009). The equation derived was
R_{CO2} = (3.667/1000) x (16244 x exp(-0.175 x exp(-0.073 x ((Wx100)-50)))+(153.23 x T))
where R_{CO2} is the annual rate of CO_2 emissions (t CO_2 $(ha)^{-1}$ yr^{-1}),
T = average annual peat temperature (^oC) and
W is the water table depth (m).
The equation shows a significant correlation with measurements (r^2 = 0.42, $P > 0.05$).
Evaluation against 18 independent experiments shows a significant association (r^2 = 0.56; P>0.05) and an average error of 2108 t CO_2 ha^{-1} yr^{-1} (significance not defined due to lack of replicates-Smith et al, 1997)



Note: Methane emissions from acid bogs. As above

Note: Methane emissions from fens. As above

Note: CO_2 emissions from acid bogs. As above

Note: CO_2 emissions from fens. As above

TII CARBON TOOL

Ch 15: Material Assets, Table 15-9					Distance Assumptions	TII Embodied Carbon Tool Inputs (https://web.tii.ie/index.html)						TII Transport Inputs (https://web.tii.ie/index.html)		
Material	Total no. Truck Loads	Truck Types	TII Embodied Carbon	TII Traffic	Distance (km)	Category	Sub-Category	Material	Quantity	Unit	Embodied tCO2e	Transport Type	Distance (km)	Transport TCO2e
Concrete	1200	Trucks	✓	✓	23.27	Series number 1700 - Structural Concrete	In Situ Concrete - General	In-Situ Concrete, General	21,532,800.00	kg	2225.63	HGV - Rigid - Average	27920	28.689
Delivery of plant	66	Large artic		✓	238.45							HGV- All - Average	15737.7	17.068
Fencing & gates	6	Large artic	✓	✓	23.27	Series 300 - Fencing and Environmental Noise Barriers	Gate	Steel Double Field Gates 4m Width	5	no units	1.635	HGV- All - Average	139.6	0.151
Compound setup	60	Large artic		✓	238.45							HGV- All - Average	14307	15.516
Steel	41	Large artic	✓	✓	23.27	Other	Structural Steelwork	Anchorages and holding down bolt assemblies	820	tonnes	1,470.34	HGV- All - Average	953.93	1.035
Sand / binding / stone / pile foundation	328	Trucks	✓	✓	23.27	Series 600 - Earthwork	Backfill/Fill	Aggregates and sand, general UK, mixture of land won, marine, secondary and recycled, bulk, loose	3500000	kg	26.145	HGV - Articulated - Average	7631.47	8.584
Ducting and cabling (internal)	441	Large artic		✓	23.27							HGV - All - Average	10260.6	11.128
Crane (to lift steel)	2	Large artic		✓	238.45							HGV - All - Average	476.9	0.517
Crane (for turbines)	23	Large artic		✓	238.45							HGV - All - Average	5484.35	5.948
Refuelling for plant	354	Large artic		✓	23.27							HGV - Articulated - Average	8236.4	9.264
Stone for the Proposed Project	10000	Truck	✓	✓	23.27	Series 2400 - Brickwork, Blockwork and Stonework	Brickwork and Blockwork	General Stone	1002640	tonnes	79209	HGV - Articulated - Average	1,158,657	1,303.246
Materials for Proposed Grid Connection	120	Large artic		✓	23.27							HGV - All - Average	2792	3.028
Substation	1000	Truck		✓	23.27							HGV - Articulated - Average	23266.67	26.17
Stone for Temporary Construction Compound*	333	Truck		✓	23.27							HGV - All - Average	7747.8	8.402
Site maintenance	257	Large artic		✓	23.27							HGV - All - Average	5979.53	6.485
Miscellaneous	171	Large artic		✓	23.27							HGV - All - Average	3978.6	4.315
Total											82,932.752			1449.546

** Please note the Stone for the Temporary Construction Compounds has been fully encompassed within the line-item Stone for the Proposed Project i.e. embodied carbon and transport emissions*

List of Assumptions

Embodied Carbon Assumptions		
Item	Description	Assumption
Volume of Concrete Mixer	Calculation completed based on the average concrete mixer holding 8m3 of concrete	8
Volume of Average Artic Truck	Calculation completed based on the average artic truck having a carrying capacity of 20 tonnes	20
Ducting and cabling (internal)	Embodied carbon of electrical equipment not included as an option in TII Carbon Tool	-
Grid connection cable laying	Embodied carbon of electrical equipment not included as an option in TII Carbon Tool	-
Tree Felling	Embodied carbon of tree felling is included in the Macauley Institute Carbon Calculator for Wind Farms on Peatland	-
Turbine Lifecycle	Embodied carbon of the overall turbine lifecycle is included in the Macauley Institute Carbon Calculator for Wind Farms on Peatland	-
Volume of Concrete Material	There will be approximately 9,600m3 of concrete required for the Proposed Project., The TII Carbon Tool require this material to be in kg. The density of concrete to be used at the Proposed Wind Farm is assumed to have average density of approximately 2,243m3/kg. Based on an assumed 9,600m3 of concrete being required (based on 1200 truckloads of concrete with a 8m3 carrying capacity) this would result in approximately 21,532,800kg being used for the Proposed Project	21532800.00
Volume of Steel	An assumed 820 tonnes of steel is required (based on 41 truckloads of steel with a 20 tonne carrying capacity) for the Proposed Project	820
Volume of Sand/Binding Stone	There will be approximately 6,560 tonnes of sand/binding stone required for the Proposed Wind Farm., The TII Carbon Tool require this material to be in kg. Based on an assumed 6,560 tonnes of sand/binding stone being required (based on 328 truckloads of material with a 20 tonnes carrying capacity) this would result in approximately 6,560,000kg being used for the Proposed Project	6560000.00
Volume of Stone for the Proposed Project	An assumed total of 1,002,640 tonnes of stone is required (based on 49,799 truckloads of stone with a 20 tonne carrying capacity) for the Proposed Wind Farm, Proposed Grid Connection, Proposed Onsite 220kV Substation, and all other infrastructure including the temporary construction compounds.	1002640
Immature Woodland	The Macauley carbon Calculator uses the carbon sequestration rate for timber as a standard setting within the tool; on the Proposed Wind Farm there will only be the removal of immature woodland. Due to a lack of national emission factors for immature woodland, the carbon sequestration rate for timber was applied.	3.45

Please note that the assumptions for the embodied carbon and traffic assumptions are made based on best estimates of material sources. In reality the location of material sources will be dependent on what is available at the time of construction. The implications of distance variations on the estimation for carbon calculations is of a very low magnitude within the context of the overall carbon calculations and considered appropriate for the purposes of assessment in the EIAR.

Traffic Assumptions		
Item	Description	Assumption
Import (P) Distance	The average distance to the site from the two identified Port Locations for delivery of abnormal loads in Section 4.7.3 of the EIAR	238.45
Quarry (Q) Distance	Identified Quarries in Section 4.7.2 in the EIAR for Stone and Ready-Mix Concrete	23.27

Concrete Mixer Emission factor	Calculated from an HGV - Rigid - All emission factor as provided in the TII Carbon Tool. Source: 2024 DEZNZ emission factors - 'Delivery vehicles' tab, All Rigids HGVs and used Average laden weight. 2024 DEZNZ emission factors - 'WTT - delivery vehs & freight' tab, all Rigids HGVs and used Average laden weight.	1.03
Large Artic Emission Factor	Calculated from an HGV - All - Average emission factor as provided in the TII Carbon Tool. Source: 2024 DEZNZ emission factors - 'Delivery vehicles' tab, All artics HGVs and used Average laden weight. 2024 DEZNZ emission factors - 'WTT - delivery vehs & freight' tab, all artics HGVs and used Average laden weight.	1.08
Truck Emissions Factor	Calculated from an HGV - Articulated - Average emission factor as provided in the TII Carbon Tool. Source: 2024 DESNZ emission factors - 'Delivery vehicles' tab, All artics HGVs and used Average laden weight. 2024 DESNZ emission factors - 'WTT - delivery vehs & freight' tab, all artics HGVs and used Average laden weight.	1.12

Please note that the assumptions for the embodied carbon and traffic assumptions are made based on best estimates of material sources. In reality the location of material sources will be dependent on what is available at the time of construction. The implications of distance variations on the estimation for carbon calculations is of a very low magnitude within the context of the overall carbon calculations and considered appropriate for the purposes of assessment in the EIAR.

Carbon Fixing Vegetation Assumptions

Item	Description	Assumption
Calculation of Carbon Storage Potential in Enhancement Measures	The carbon storage capacity of restored habitats will vary over time as vegetation matures and land use and the baseline environment change. Therefore, while it can be assumed that native woodland replanting on the site will result in an increased capacity of carbon storage due to the carbon storage potential that exists within these habitats, to ensure the assessment below is identified under a theoretical precautionary scenario the quantification of these potential carbon savings (via an increase in carbon storage potential) associated with these measures has not been included in the carbon savings assessment.	Not considered in assessment or quantified
Calculation of Carbon Loss from removal of carbon fixing vegetation	Carbon losses associated with the removal of other carbon-fixing vegetation will result in additional carbon losses. These have not been quantified as the lack of consistent national-level field data and methodologies limits the ability to make accurate projections on carbon sequestration potential for other carbon fixing habitat types, i.e., hedgerow, grassland, etc., and therefore carbon loss associated with removal. While it can be assumed that loss of carbon fixing vegetation will occur as part of the Proposed Project due to the removal of these habitat types, the exact carbon loss is not quantifiable.	Not considered in assessment or quantified