



APPENDIX 11-2

CARBON CALCULATIONS

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		Record source of data
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	
Windfarm characteristics					
Dimensions					
No. of turbines	14	Fixed	14		14
Lifetime of windfarm (years)	35		35		35
Performance	4.8		4.7		4.9
Capacity factor	Direct input of capacity fac		Direct input of capacity fac		Direct input of capacity fac
Capacity factor	0.37		0.37		0.37
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 - (eo. 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 (°C)	10		5.7		15.2
Average depth of peat at site (m)	0.60		0.60		0.60
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		10.00		20.00
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)	44		43.95		44.05
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		Click here		Click here
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)	144.25		144.25		144.25
Average width of pits (m)	81.7		81.7		81.7
Average depth of peat removed from pit (m)	0.60		0.6		0.6
Foundations and hard-standing areas 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					
Existing track length (m)	25		25		25
Length of access track that is floating road (m)	25		25		25
Average depth of peat removed from turbine foundations (m)	0.60		0.60		0.60
	80		80		80
	35		35		35
Average depth of peat removed from hard-standing (m)	0.60		0.60		0.60
Access tracks					
Total length of access track (m)	14400		14400		14400
Existing track length (m)	2300		2300		2300
Length of access track that is floating road (m)	85		85		85
Floating road width (m)	5		5		5
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)	12015		12015		12015
Excavated road width (m)	5		5		5
Average depth of peat excavated for road (m)	0.60		0.60		0.60
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 (eo. 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)	28620		28620		28620
Area of additional peat excavated (m ²)	18775.0		18775.0		18775.0
Peat Landslide Hazard					
WebLink: Peat Landslide Hazard and Risk Assessment: 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 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?	No		No		No
Will you attempt to block all artificial ditches and facilitate rewilding?	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 been blowing continuously and at maximum output (DECC 2004). See also www.bmwi.com/en/capacity-factors.html

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 (5%). The House of Lords Economic Affairs Committee report on the Economics of Renewable Energy (Parliamentary Business, 2006) notes that to cover peak demand a 20% margin of extra capacity has been sufficient to keep the rest of a power cut due to insufficient generation at a very low level. The estimate provided by BEF0 has an average 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 turbines etc: If total emissions for the windfarm are unknown, emissions should be calculated according to turbine capacity. The normal range of CO₂ emissions is 304 to 1847 tCO₂ MW (White & Kulicinski, 2000; White, 2007).

Note: Type of peatland: An acid bog is fed primarily by rainwater and often inhibited by sphagnum moss, that makes it acidic (Stewart & Brooks, 1997). A fen is a type of wetland fed by surface and/or groundwater (Madrine 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 refuge for peat-forming vegetation, the removal of structures, or an assessment of the impact of leaving them in situ. Methods used to renatinate 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

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 sequestration for yield class 16 m³ ha⁻¹ yr⁻¹ = 3.4 tC ha⁻¹ yr⁻¹ (Garnett, 1999).

Note: Coal-fired plant emission factor (ECF) from electricity supplied in 2023 = 1.046 tCO₂ MWh⁻¹ based on UK Energy Statistics (DUKES) electricity - GOV.UK (2024). Grid Mix ECF for 2024 = 0.20705 tCO₂ 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 tCO₂ MWh⁻¹ based on UK Energy Statistics (DUKES) electricity - GOV.UK

Note: Total length of access track: If areas of access track overlap with contouring data, 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 (Southey-Excuse, 2006; Peat Landslide Hazard and Risk Assessment: Best Practice Guide for Proposed Electricity Generation Developments: Scottish Executive, Edinburgh, 2006) so that C losses due to peat landslides can be assumed to be negligible. Link: <http://www.scotland.gov.uk/Publications/2006/12/16120201>

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 - Degradation and Emissions: Final Report, ECOSSE Report, 1006: 37/03/1003: 1492 - 1495).

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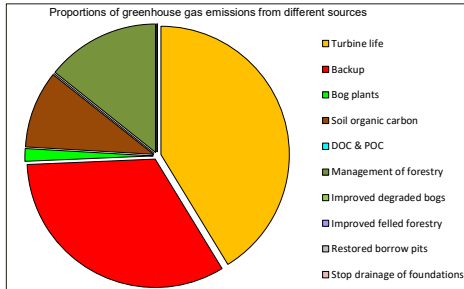
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Results
 PAYBACK TIME AND CO₂ EMISSIONS
 Note: The carbon payback time of the windfarm is calculated by comparing the loss of C from the site due to windfarm development with the carbon-savings achieved by the windfarm while displacing electricity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

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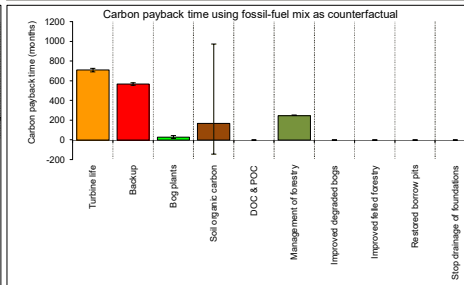
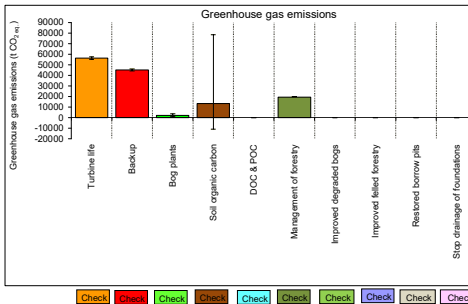
	Exp.	Min.	Max.
1. Windfarm CO₂ emission saving over...			
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	2278	2231	2326
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	451	442	460
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	952	932	972
Energy output from windfarm over lifetime (MWh)	76233	74645	77821
Total CO₂ losses due to wind farm (t CO₂ eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decommissioning)	56243	54935	57551
3. Losses due to backup	45019	44081	45957
4. Losses due to reduced carbon fixing potential	2168	1149	3633
5. Losses from soil organic matter	13334	-10875	78484
6. Losses due to DOC & POC leaching	0	0	0
7. Losses due to felling forestry	19483	19743	20070
Total losses of carbon dioxide	136246	109032	205695
8. Total CO₂ gains due to improvement of site (t CO₂ 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 CO₂ eq.)	136246	109032	205695
Carbon Payback Time			
...coal-fired electricity generation (years)	59.8	46.9	92.2
...grid-mix of electricity generation (years)	302.1	236.8	465.8
...fossil fuel - mix of electricity generation (years)	143.1	112.2	220.7
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	No gain!	No gain!	No gain!
Ratio of CO₂ eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g / kWh)	1787	1401	2756



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

Greenhouse gas emissions	Exp.	Min.	Max.
Turbine life	56243	1308	1308
Backup	45019	938	938
Bog plants	2168	1019	1465
Soil organic carbon	13334	24208	65150
DOC & POC	0	0	0
Management of forestry	19483	0	587
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.	Exp.	Min.	Max.
Turbine life	56243	1308	1308	709	17	16
Backup	45019	938	938	568	12	12
Bog plants	2168	1019	1465	27	13	18
Soil organic carbon	13334	24208	65150	168	312	805
DOC & POC	0	0	0	0	0	0
Management of forestry	19483	-260	587	246	-3	7
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
	136246			1718		

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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RESULTS Windfarm CO ₂ emission saving over...	Total			Area 1			Area 2			Area 3			Area 4			Area 5		
...coal-fired electricity generation (tCO ₂ yr ⁻¹)	2278	2230.8	2325.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	451	441.58	460.37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	952	931.99	971.65	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,
 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)	4017	3924	4111
No. of turbines	14	14	14
Total calculated CO ₂ emission of the wind farm due to turbine life (t CO ₂ windfarm ⁻¹)	56243	54935	57551

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

RESULTS

Losses due to turbine life (eg. manufacture, construction, decommissioning)	56243	54935	57551
Additional CO ₂ payback time of windfarm due to turbine life (eg. manufacture, construction, decommissioning)			
...coal-fired electricity generation (months)	296	296	297
...grid-mix of electricity generation (months)	1497	1493	1500
...fossil fuel - mix of electricity generation (months)	709	707	711

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

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



Embodied carbon dioxide (CO₂e) of concretes used in buildings

CONCRETE APPLICATION	Concrete designation	CO ₂ e (kgCO ₂ e/m ³) ¹			CO ₂ e (kgCO ₂ e/tonne) ¹		
		CEM I concrete	30% fly ash concrete	60% ggbfs concrete	CEM I concrete	30% fly ash concrete	60% ggbfs 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	188	134	110	79
Structural in situ floors, superstructure, walls, basements ²	RC32/40**	369	313	231	154	131	96
High strength concrete ²	RC40/50**	432	351	269	178	146	111
		CO ₂ e (kgCO ₂ e/m ³)			CO ₂ e (kgCO ₂ e/tonne)		
Unreinforced Precast flooring ³		-	-	-	-	165	-
Reinforced precast flooring ³		-	-	-	-	171	-
Average Generic Concrete Block ⁴		-	-	-	-	84	-

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

Emissions due to backup power generation

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

	Expected	Minimum	Maximum
Reserve capacity required for backup			
No. of turbines	14	14	14
Power rating of turbines (turbine capacity) (MW)	4.8	4.7	4.9
Power of wind farm (MW h ⁻¹)	67.2	65.8	68.6
Rated capacity (MW yr ⁻¹)	588672	576408	600936
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)	2943	2882	3005

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)	3079	3015	3143
...grid-mix of electricity generation (tCO ₂ yr ⁻¹)	609	597	622
...fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)	1286	1259	1313

RESULTS

Total emissions due to backup from...			
...coal-fired electricity generation (tCO ₂)	107756	105511	110001
...grid-mix of electricity generation (tCO ₂)	21330	20885	21774
...fossil fuel - mix of electricity generation (tCO ₂)	45019	44081	45957
Additional CO₂ payback time of windfarm due to backup			
...coal-fired electricity generation (months)	568	568	568
...grid-mix of electricity generation (months)	568	568	568
...fossil fuel - mix of electricity generation (months)	568	568	568

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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)	126416	126416	126416
Total area affected by drainage due to windfarm construction (m ²)	399157	265147	534123
Total area where fixation by plants is lost (m ²)	525573	391563	660539
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
RESULTS			
Total loss of carbon accumulation by bog plants			
Total area where fixation by plants is lost (ha)	53	39	66
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 CO₂)	2168	1149	3633
Additional CO₂ payback time of windfarm due to loss of CO₂ fixing potential			
...coal-fired electricity generation (months)	11	6	19
...grid-mix of electricity generation (months)	58	31	95
...fossil fuel - mix of electricity generation (months)	27	15	45

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

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Emissions due to loss of bog plants

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

Emissions due to loss of soil organic carbon

Note: Loss of C stored in peatland is estimated from % site lost by peat removal (sheet 5a), 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)	13334	-10875	56522
<input type="checkbox"/> CO ₂ loss from drained peat (t CO ₂ equiv)	0	0	21962
RESULTS			
Total CO₂ loss from peat (removed + drained) (t CO₂ equiv)	13334	-10875	78484
Additional CO₂ payback time of windfarm due to loss of soil CO₂			
...coal-fired electricity generation (months)	70	-58	405
...grid-mix of electricity generation (months)	355	-296	2046
...fossil fuel - mix of electricity generation (months)	168	-140	969

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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	Total		
	Exp	Min	Max
Number of borrow pits	4	4	4
Average length of pits (m)	144.25	144.25	144.25
Average width of pits (m)	81.7	81.7	81.7
Average depth of peat removed from pit (m)	0.6	0.6	0.6
Area of land lost in borrow pits (m ²)	47141	47141	47141
Volume of peat removed from borrow pits (m ³)	28285	28285	28285

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
Diameter at bottom (m)				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	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
Diameter at bottom (m)				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 hardstanding area (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
<u>Floating roads</u>			
Length of access track that is floating road (m)	85	85	85

Floating road width (m)	5	5	5
Floating road depth (m)	0	0	0
Area of land lost in floating roads (m ²)	425	425	425
Volume of peat removed for floating roads	0	0	0
Excavated roads			
Length of access track that is excavated road (m)	12015	12015	12015
Excavated road width (m)	5	5	5
Average depth of peat excavated for road (m)	0.6	0.6	0.6
Area of land lost in excavated roads (m ²)	60075	60075	60075
Volume of peat removed for excavated roads	36045	36045	36045
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)	60500	60500	60500
Total volume of peat removed due to access tracks (m ³)	36045	36045	36045

Additional peat excavated - (not already accounted for above)			
Volume of additional peat excavated (m ³)	28620	0	28620
Area of additional peat excavated (m ²)	18775	18775	18775

	RESULTS		
	Exp	Total Min	Max
Total volume of peat removed (m³) due to windfarm construction	92950	64330	92950
Total area of land lost due to windfarm construction (m²)	126416	126416	126416

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

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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)	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	92950	64330	92950
CO ₂ loss from removed peat (t CO ₂)	23949	332	64195

Check

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

CO₂ loss from undrained peat left in situ			
Total area of land lost due to windfarm construction (ha)	13	13	13
CO ₂ loss from undrained peat left in situ (t CO ₂ ha ⁻¹)	840	887	607
CO ₂ loss from undrained peat left in situ (t CO ₂)	10615	11207	7673

CO₂ loss attributable to peat removal only			
CO ₂ loss from removed peat (t CO ₂)	23949	332	64195
CO ₂ loss from undrained peat left in situ (t CO ₂)	10615	11207	7673
RESULTS			
CO₂ loss attributable to peat removal only (t CO₂)	13334	-10875	56522

Click here to move to 5. Loss of soil CO₂

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CO₂ loss from removed peats

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

Volume of peat drained

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

Extent of drainage around each metre of drainage ditch	Total		
	Exp	Min	Max
Average extent of drainage around drainage features at site (m)	15	10	20

Peat affected by drainage around borrow pits	Total		
	Exp	Min	Max
Number of borrow pits	4	4	4
Average length of pits (m)	144	144	144
Average width of pits (m)	82	82	82
Average depth of peat removed from pit (m)	0.6	0.6	0.6
Area affected by drainage per borrow pit (m ²)	7679	4919	10638
Total area affected by drainage around borrowpits (m ²)	30714	19676	42552
Total volume affected by drainage around borrowpits (m ³)	9214	5903	12766

Peat affected by drainage around turbine foundation and hardstanding	Exp	Total Min	Max	Construction Area 1			Construction Area 2			Construction Area 3			Construction Area 4			Construction Area 5		
				Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max	Exp	Min	Max
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	Exp	Total 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)	12015	12015	12015
Excavated road width (m)	5	5	5
Average depth of peat excavated for road (m)	0.6	0.6	0.6
Area affected by drainage of excavated roads (m ²)	360450	240300	480600
Volume affected by drainage of excavated roads (m ³)	108135	72090	144180
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)	360450	240300	480600
Total volume affected by drainage of access track (m ³)	108135	72090	144180

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)	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	Exp	Total	
		Min	Max
Volume of additional peat excavated (m ³)	28620.0	0.0	28620.0
Area of additional peat excavated (m ²)	18775.0	18775.0	18775.0
Average depth of excavated peat (m)	2	0	2
Radius of area excavated (m)	77	77	77
Radius of excavated and drained area (m)	92	87	97
Total area affected by drainage (m ²)	7993	5171	10971
Total volume affected by drainage (m ³)	12183.98	0.00	16724.20

Assumption: Area excavated is assumed to be a circle

RESULTS	Exp	Total	
		Min	Max
Total area affected by drainage due to windfarm (m²)	399157	265147	534123
Total volume affected by drainage due to windfarm (m³)	129533	77992.8	173670

Click here to move to 5d. CO2 loss from drained peat [Click here](#)

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

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)	40	27	53
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

Check	Total volume affected by drainage due to wind farm (m ³)	129533	77993	173670
	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 CO₂ equiv.)	33375	403	119944
	Total GHG Emissions from Undrained Land (t CO₂ equiv.)	33375	403	97982

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)	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)	0.000	-0.017	0.026
	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.)	-18	-538	2131
	Carbon Dioxide Emissions from Drained Land			
Check	Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	18.67	22.67	14.06
	CO ₂ emissions from drained land (t CO ₂)	33536	24044	37556
	Total GHG emissions from Drained Land (t CO₂ equiv.)	33517	23506	39687

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)	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.)	-18	-538	7583
	Carbon Dioxide Emissions from Undrained Land			
Check	Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	18.67	22.67	4.30
	CO ₂ emissions from undrained land (t CO ₂)	33536	24044	24837
	Total GHG Emissions from Undrained Land (t CO₂ equiv.)	33517	23506	32420

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.)	33375	403	119944
	Total GHG emissions from undrained land (t CO ₂ equiv.)	33375	403	97982
	RESULTS			
	Total GHG emissions due to drainage (t CO₂ equiv.)	0	0	21962

Click here to move to 5. Loss of soil CO₂ [Click here](#)
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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

Emission characteristics of acid bogs (IPCC, 1997)

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

Emission characteristics of fens (IPCC, 1997)

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

Selected emission characteristics (IPCC, 1997)

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

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 (Asefmann & 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 (Amendano and Menges, 1986, J. Ecol. 74, 755-774).

Calculations following ECOSSE based methodology

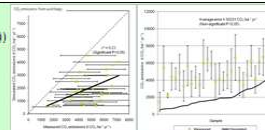
Drained Land

Total area affected by drainage due to wind farm construction (ha)	40	27	53
Total volume affected by drainage due to wind farm construction (m ³)	129533	77993	173670

Soil Characteristics that Determine Emission Rates

Average annual air temperature at the site (°C)	10	5.7	15.2
Average water table depth at site (m)	0.50	1.00	0.10
Average water table depth of drained land (m)	0.50	1.00	0.33

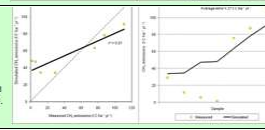
Note: Carbon dioxide emissions from acid bogs. Equation derived by regression analysis against 60 measurements (Nayak et al, 2009). The equation derived was $R_{CO_2} = (3.667/1000) \times ((6700 \times \exp(-0.26 \times \exp(-0.0515 \times ((W \times 100) - 50)))) + ((72.54 \times T) - 800))$ where 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).



Annual Emission Rates following site specific methodology

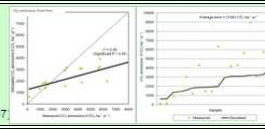
Acid bogs			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	18.67	22.67	14.06
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	18.67	22.67	4.30
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.000	-0.017	0.026
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	-0.02	0.16

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).



Fens			
Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	55.58	62.50	40.09
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	55.58	62.50	10.69
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.001	-0.006	0.024
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	-0.01	0.21

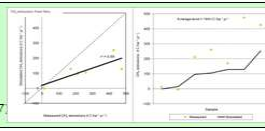
Note: Carbon dioxide emissions from fens. Equation derived by regression analysis against 44 measurements (Nayak et al, 2009). The equation derived was $R_{CO_2} = (3.667/1000) \times (16244 \times \exp(-0.175 \times \exp(-0.073 \times ((W \times 100) - 50)))) + (153.23 \times T)$ where R_{CO_2} is the 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 = 0.68; 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).



Selected emission characteristics following site specific methodology

Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	18.67	22.67	14.06
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	18.67	22.67	4.30
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.000	-0.017	0.026
Rate of methane emission in undrained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.00	-0.02	0.16

Note: Methane emissions from fens. Equation derived by regression analysis against experimental data from 35 measurements (Nayak et al, 2009). The equation derived was $R_{CH_4} = (1/1000) \times (-10-863.62 \times \exp(-0.097 \times (W \times 100)) - (0.662 \times T))$ 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 = 0.68; 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).



RESULTS

Selected Emission Rates

Rate of carbon dioxide emission in drained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	18.67	22.67	14.06
Rate of carbon dioxide emission in undrained soil (t CO ₂ ha ⁻¹ yr ⁻¹)	18.67	22.67	4.30
Rate of methane emission in drained soil ((t CH ₄ -C) ha ⁻¹ yr ⁻¹)	0.000	-0.017	0.026
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 peat [Click here](#)

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Emission rates from soils

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

Emissions due to loss of DOC and POC

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

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

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

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

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

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

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

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

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

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Emissions due to loss of DOC and POC

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

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

Emissions due to forest felling - calculation using simple management data

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

	Expected	Minimum	Maximum
Emissions due to forestry felling			
Area of forestry plantation to be felled (ha)	44	43.95	44.05
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 CO₂)	19483	19743	20070
Additional CO₂ payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	103	106	104
...grid-mix of electricity generation (months)	518	537	523
...fossil fuel - mix of electricity generation (months)	246	254	248

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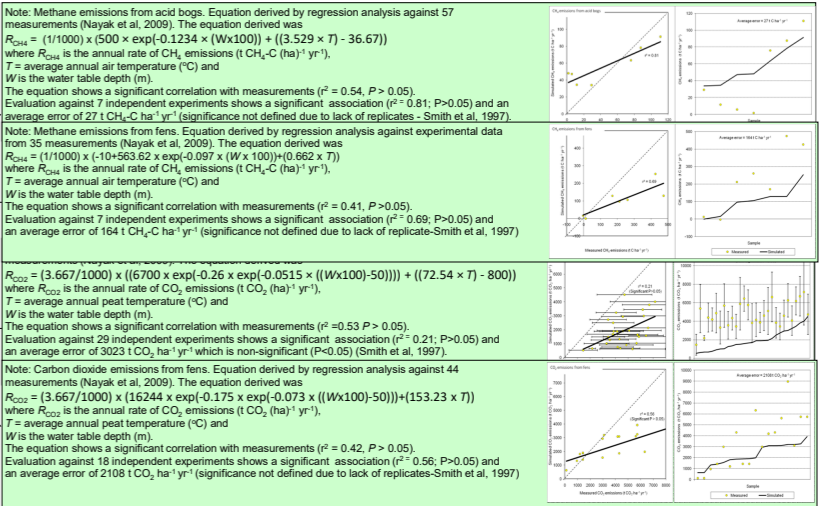
Emissions due to forest felling - calculation using simple management data

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, 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

Improvement of...	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)	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 (°C)	10	10	10	10	5.7	5.7	5.7	5.7	15.2	15.2	15.2	15.2
Depth of peat drained (m)	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
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)	0.499	0.499	0.499	0.499	0.483	0.483	0.483	0.483	0.517	0.517	0.517	0.517
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)	0.499	0.499	0.499	0.499	0.483	0.483	0.483	0.483	0.517	0.517	0.517	0.517
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)	0.53	0.53	0.53	0.53	-0.61	-0.61	-0.61	-0.61	1.91	1.91	1.91	1.91
Site specific CO ₂ emissions from improved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	5.68	5.68	5.68	5.68	3.26	3.26	3.26	3.26	8.60	8.60	8.60	8.60
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)	0.53	0.53	0.53	0.53	-0.61	-0.61	-0.61	-0.61	1.91	1.91	1.91	1.91
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	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)	0.499	0.499	0.499	0.499	0.483	0.483	0.483	0.483	0.517	0.517	0.517	0.517
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)	0.499	0.499	0.499	0.499	0.483	0.483	0.483	0.483	0.517	0.517	0.517	0.517
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)	0.53	0.53	0.53	0.53	-0.61	-0.61	-0.61	-0.61	1.91	1.91	1.91	1.91
Site specific CO ₂ emissions from unimproved soil on fens (t CO ₂ ha ⁻¹ yr ⁻¹)	5.68	5.68	5.68	5.68	3.26	3.26	3.26	3.26	8.60	8.60	8.60	8.60
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)	0.53	0.53	0.53	0.53	-0.61	-0.61	-0.61	-0.61	1.91	1.91	1.91	1.91
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).

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	1498	Trucks	✓	✓	19.45	Series number 1700 - Structural Concrete	In Situ Concrete - General	In-Situ Concrete, General	26,880,112.00	kg	2778.328	HGV - Rigid - Average	29136.1	29.939
Delivery of plant	62	Large artic		✓	144.60							HGV- All - Average	8965.2	9.723
Fencing & gates	6	Large artic	✓	✓	19.45	Series 300 - Fencing and Environmental Noise Barriers	Gate	Steel Double Field Gates 4m Width	6	no units	1.963	HGV- All - Average	116.7	0.127
Compound setup	56	Large artic		✓	144.60							HGV- All - Average	8097.6	8.782
Steel	38	Large artic	✓	✓	19.45	Other	Structural Steelwork	Anchorage and holding down bolt assemblies	620	tonnes	1,111.72	HGV- All - Average	739.10	0.802
Sand / binding / stone / pile foundation	306	Trucks	✓	✓	19.45	Series 600 - Earthwork	Backfill/Fill	Aggregates and sand, general UK, mixture of land won, marine, secondary and recycled, bulk, loose	6120000.00	kg	45.716	HGV - Articulated - Average	5951.70	6.694
Ducting and cabling (internal)	412	Large artic		✓	19.45							HGV - All - Average	8013.4	8.691
Crane (to lift steel)	2	Large artic		✓	144.60							HGV - All - Average	289.2	0.314
Crane (for turbines)	21	Large artic		✓	144.60							HGV - All - Average	3036.6	3.293
Refuelling for plant	330	Large artic		✓	19.45							HGV - Articulated - Average	6418.5	7.219
Stone for the Proposed Project	5704	Truck	✓	✓	19.45	Series 2400 - Brickwork, Blockwork and Stonework	Brickwork and Blockwork	General Stone	114080	tonnes	9,012.32	HGV - Articulated - Average	114891.15	124.788
Materials for Proposed Grid Connection	2384	Large artic		✓	19.45							HGV - All - Average	46368.8	50.287
Tree Felling	432	Truck		✓	19.45							HGV - Articulated - Average	4454.05	9.451
Site maintenance	240	Large artic		✓	19.45							HGV - All - Average	4668.00	5.062
Miscellaneous	91	Large artic		✓	19.45							HGV - All - Average	1769.95	1.92
Total											12950.049		267.092	

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 11,984m3 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 11,984m3 of concrete being required (based on 1498 truckloads of concrete with a 8m3 carrying capacity) this would result in approximately 21,532,800kg being used for the Proposed Project	26880112.00
Volume of Steel	An assumed 620 tonnes of steel is required (based on 38 truckloads of steel with a 20 tonne carrying capacity) for the Proposed Project	620
Volume of Sand/Binding Stone	There will be approximately 6,120 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 6,120 tonnes of sand/binding stone being required (based on 306 truckloads of material with a 20 tonnes carrying capacity) this would result in approximately 6,120,000kg being used for the Proposed Project	6120000.00
Volume of Stone for the Proposed Project	An assumed total of 114080 tonnes of stone is required (based on 5704 truckloads of stone with a 20 tonne carrying capacity) for the Proposed Project.	114080

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	For modelling purposes, the average distance to the site from the two identified Port Locations for delivery of abnormal loads (Shannon Foynes and Port of Cork (Ringaskiddy))	144.60
Quarry (Q) Distance	For modelling purposes, the average distance from Kealkill, Co. Cork, Dunmanway, Co. Cork, Macroom, Co. Cork and Bantry, Co. Cork was used to determine the distance of transportation of all materials for the Proposed Project	19.45
Concrete Mixer Emission factor	Calculated from an HGV - Rigid - All emission factor as provided in the TII Carbon Tool. Source: 2024 DEZLNZ emission factors - 'Delivery vehicles' tab, All Rigid HGVs and used Average laden weight. 2024 DEZLNZ emission factors - 'WTT - delivery vehs & freight' tab, all Rigid 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 DEZLNZ emission factors - 'Delivery vehicles' tab, All artics HGVs and used Average laden weight. 2024 DEZLNZ 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. Please note, the carbon sequestration potential associated with the replanting of native woodland will be able to be determined in the future via the Teagasc Forest Carbon Tool; currently this is not able to be completed due to Teagasc carrying out further analysis and validation on current data and the sequestration potential not being available in the public domain.	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