Appendix 14-2

Calculated Carbon Savings and Losses

Core input data

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

Note: The input parameters include some variables that can be specified by default values, but others that must be site specific. Variables that can be taken from defaults are marked with purple tags on left hand side.

Click here

Click here

Input data	Expected values: Enter expected value here	Expected values: Record source of data
Windfarm characteristics		
Dimensions		
No. of turbines	19	Planning Permission Request
Lifetime of windfarm (years)	30	Planning Permission Request
Performance		
Power rating of turbines (turbine capacity) (MW)	4.8	
Capacity factor	Direct input of capacity fac	
Enter estimated capacity factor (percentage efficiency)	30.0	Long term average capacity factor (IWEA)
Backup		
Extra capacity required for backup (%)	5	Value from SNH guidance
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	Value from SNH guidance. Over 20% of national electricity is fro renewables.
Carbon dioxide emissions from turbine life - (eg. manufacture, construction, decommissioning)	Calculate wrt installed cap	
Characteristics of peatland before windfarm development		
Type of peatland	Acid b	Site is predominantly covered in forestry and heavily modified and drained. Not an undisturbed bog.
Average annual air temperature at site (°C)	9	Met Eireann 30 Year Averages
Average depth of peat at site (m)	1.40	Site Investigations
C Content of dry peat (% by weight)	55	The carbon content of dry peat is assumed to be 55% (the carbon content of dry peat ranges fro 49 to 62% (MLURI et al., 1991 cited by Nayak et al, 2008)
Average extent of drainage around drainage features at site (m)	15.00	Assumption
Average water table depth at site (m)	0.20	Trial Pit Logs
Dry soil bulk density (g cm^{-3})	0.20	
Characteristics of bog plants		
Time required for regeneration of bog plants after restoration (years)	10	Assumption
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	Value from SNH guidance
Forestry Plantation Characteristics		
Method used to calculate CO_2 loss from forest felling	Enter simple data	
Area of forestry plantation to be felled (ha)	67	Provided
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	3.60	Value from SNH guidance
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})		
Grid-mix emission factor (t CO_2 MWh^{-1})	0.375	Energy Related Co2 emissions I Ireland 2005 to 2018. SEAI.
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})		
Borrow pits		
Number of borrow pits	11	Cells 3 BPs in total
Average length of pits (m)	70	per cell
Average width of pits (m)	15	per cell
Average depth of peat removed from pit (m)	0.80	per cell
Foundations and hard-standing area associated with each turbine		
Method used to calculate CO_2 loss from foundations and hard-standing	Rectangular with vertical w	
Average length of turbine foundations (m)	24	Circular hardstand
Average width of turbine foundations (m)	24	Circular hardstand
Average depth of peat removed from turbine foundations (m)	1.45	Site Investigations
Average length of hard-standing (m)	40	Engineering
Average width of hard-standing (m)	35	Engineering
Average depth of peat removed from hard-standing (m)	1.16	Site Investigations
Access tracks		
Total length of access track (m)	19800	Engineering
Existing track length (m)	8400	Engineering
Length of access track that is floating road (m)	3800	Engineering
Floating road width (m)	5	Engineering
Floating road depth (m)	0.60	Engineering
Length of floating road that is drained (m)	3800	Engineering
Average depth of drains associated with floating roads (m)	0.00	Engineering
Length of access track that is excavated road (m)	7600	Engineering
Excavated road width (m)	5	Engineering
Average depth of peat excavated for road (m)	1.31	Site Investigations
Length of access track that is rock filled road (m)	0	Engineering
Rock filled road width (m)	0	Engineering
Rock filled road depth (m)	0	Engineering
Length of rock filled road that is drained (m)	0	Engineering
Average depth of drains associated with rock filled roads (m)	0.00	Engineering
Cable Trenches		
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	All cable trenches will follow access tracks at the current time, however final route for connection has not been decided and may influence the final cable trench layout. Lined with a geotextile membrane.
Average depth of peat cut for cable trenches (m)	1.25	Cable trenches will have a depth of 1.25m
Additional peat excavated (not already accounted for above)		
Volume of additional peat excavated (m^3)	3780	Substation and Construction Conmpound and Met Mast
Area of additional peat excavated (m^2)	27875.0	Substation and Construction Conmpound and Met Mast
Peat Landslide Hazard		
Weblink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	0	Peat Stability Report
Improvement of C sequestration at site by blocking drains, restoration of habitat etc		
Improvement of degraded bog		Predominantly a forestry operation rather than bog. Site will continue to be managed as commercial forestry. No significat gains due to improvements assumed. Negligble compared to losses.
Area of degraded bog to be improved (ha)		
Water table depth in degraded bog before improvement (m)		
Water table depth in degraded bog after improvement (m)		
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)		
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)		
Improvement of felled plantation land		Predominantly a forestry operation rather than bog. Site will continue to be managed as commercial forestry. No significat gains due to improvements assumed. Negligble compared to losses.
Area of felled plantation to be improved (ha)		
Water table depth in felled area before improvement (m)		
Water table depth in felled area after improvement (m)		
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)		
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)		
Restoration of peat removed from borrow pits		
Area of borrow pits to be restored (ha)	2	Engineering
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.20	Trial Pit Logs
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.20	Trial Pit Logs
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	15	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	35	
Early removal of drainage from foundations and hardstanding		
Water table depth around foundations and hardstanding before restoration (m)	0.20	Trial Pit Logs
Water table depth around foundations and hardstanding after restoration (m)	0.20	Trial Pit Logs
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	35	
Restoration of site after decomissioning		
Will the hydrology of the site be restored on decommissioning?	Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	
Will the habitat of the site be restored on decommissioning?	Yes	
Will you control grazing on degraded areas?	Not appli	
Will you manage areas to favour reintroduction of species	Not appli	
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

... 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 ... proposing that the capacity credit of wind power should be 8%, and ...undation 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%

...issions from turbine life. If total emissions for the windfarm are unknown, emissions ...e 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.

...bog plants ...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} yr^{-1} = 3.6 tC ha^{-1} yr^{-1} (Cannell, 1999).

Note: Coal-Fired Plant and Grid Mix Emission Factors. Coal-fired plant emission factor (EF) from electricity supplied in 2014 = 0.093 t CO_2 MWh^{-1}. Grid-Mix EF for 2014 = 0.394 t CO_2 MWh^{-1}. Source = DUKES, 2015b.

Note: Fossil Fuel-Mix Emission Factor. The emission factor from electricity supplied in 2014 from all fossil fuels = 0.642 t CO_2 MWh^{-1}. Source = DUKES, 2015b.

Rectangular with vertical w

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

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

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

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

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

Note: Peat Landslide Hazard. It is assumed that measures have been taken to limit damage (Scottish Executive, 2006, Peat Landslide Hazard and Risk Assessments. Best Practice Guide for Proposed Electricity Generation Developments. Scottish Executive, Edinburgh. pp. 34-35) 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.

Click here

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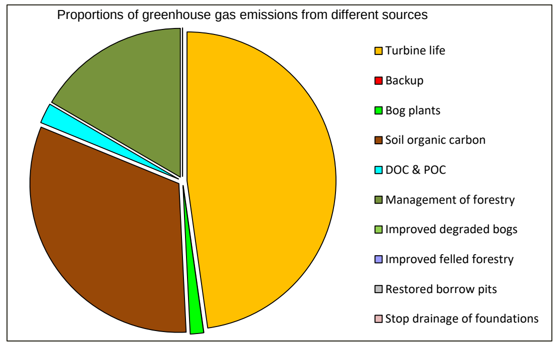
Results
PAYBACK TIME AND CO_2 EMISSIONS

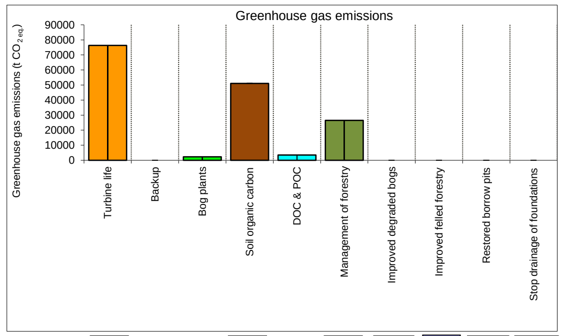
Note: The carbon payback time of the windfarm is calculated by comparing the loss of C from the site due to windfarm development with the carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or grid-mix.

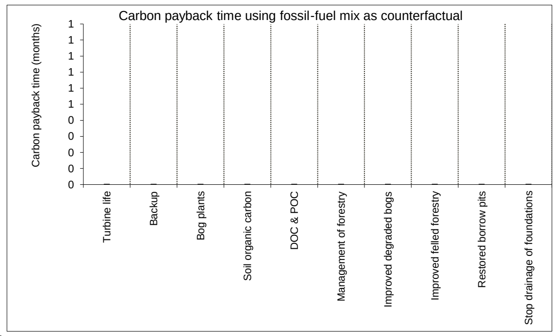
Click here to return to Input data — Click here
Click here to return to Instructions — Click here

	Exp.	*Min.*	*Max.*
1. Windfarm CO_2 emission saving over…			
…coal-fired electricity generation (tCO_2 yr^{-1})	0	0	0
…grid-mix of electricity generation (tCO_2 yr^{-1})	89878	0	0
…fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	0	0	0
Energy output from windfarm over lifetime (MWh)	7190208	0	0
Total CO_2 losses due to wind farm (t CO_2 eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	76329	0	0
3. Losses due to backup	0	0	0
4. Losses due to reduced carbon fixing potential	2309	0	0
5. Losses from soil organic matter	51078	#DIV/0!	#DIV/0!
6. Losses due to DOC & POC leaching	3503	0	0
7. Losses due to felling forestry	26534	0	0
Total losses of carbon dioxide	159754	#DIV/0!	#DIV/0!
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 $CO_{2\ eq.}$)	**159754**	**#DIV/0!**	**#DIV/0!**
Carbon Payback Time			
…coal-fired electricity generation (years)	#DIV/0!	#DIV/0!	#DIV/0!
…grid-mix of electricity generation (years)	1.8	#DIV/0!	#DIV/0!
…fossil fuel - mix of electricity generation (years)	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
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)	**22**	**#DIV/0!**	**#DIV/0!**







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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.

Click here to return to Input data — Click here
Click here to return to Instructions — Click here

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

Greenhouse gas emissions

	Exp.	*Min*	*Max*
Turbine life	76329	76329	0
Backup	0	0	0
Bog plants	2309	2309	0
Soil organic carbon	51078	#DIV/0!	#DIV/0!
DOC & POC	3503	3503	0
Management of forestry	26534	26534	0
Improved degraded bogs	0	0	0
Improved felled forestry	0	0	0
Restored borrow pits	0	0	0
Stop drainage of foundations	0	0	0

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

Greenhouse gas emissions				Carbon payback time (months)		
	Exp.	*Min.*	*Max.*	*Exp.*	*Min.*	*Max.*
Turbine life	76329	76329	-76329	#DIV/0!	#DIV/0!	#DIV/0!
Backup	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!
Bog plants	2309	2309	-2309	#DIV/0!	#DIV/0!	#DIV/0!
Soil organic carbon	51078	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
DOC & POC	3503	3503	-3503	#DIV/0!	#DIV/0!	#DIV/0!
Management of forestry	26534	26534	-26534	#DIV/0!	#DIV/0!	#DIV/0!
Improved degraded bogs	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!
Improved felled forestry	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!
Restored borrow pits	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!
Stop drainage of foundations	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!
	159754			#DIV/0!		