Appendix 5.1 Carbon Calculator Inputs and Outputs

Lochluichart Wind Farm S42

Supporting Environmental Information Report

Bluebell Wind Limited

SLR Project No.: 405.065579.00001

October 2025

Making Sustainability Happen

Core input data

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

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

Click here to move to Payback Time Click here

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Input data	Expected values: Enter expected value here	Expected values: Record source of data	Possible range of values: Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Windfarm characteristics						
Dimensions						
No. of turbines	5		5		5	EIA Chapter 3
Lifetime of windfarm (years)	40		40		40	
Performance						
Power rating of turbines (turbine capacity) (MW)	4.8		4.8		4.8	EIAR Chapter 3
Capacity factor	Direct input of capacity fa		Direct input of capacity fa		Direct input of capacity fa	
Enter estimated capacity factor (percentage efficiency)	26.2		26.2		26.2	Site-specific capacity factor
Backup						
Extra capacity required for backup (%)	5	Carbon Calculator Tool Guidance	5		5	SG recommends 5%
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	Dale et al (2004)	10		10	Fixed, SG recommends 10%
Carbon dioxide emissions from turbine life - (eg. manufacture, construction, decommissioning)	Calculate wrt installed ca		Calculate wrt installed ca		Calculate wrt installed ca	Fixed, SG recommends 10%
Characteristics of peatland before windfarm development						
Type of peatland	Acid b		Acid b		Acid b	EIA Chapter 7
Average annual air temperature at site (^oC)	8.22		5.1		11.35	from annual met data (Strathy East station 1991-2020)
Average depth of peat at site (m)	0.62		0.61		0.63	From 2019 EIAR - PSRA technical appendix
C Content of dry peat (% by weight)	50		49		51	From 2019 EIAR - Calculated from climate avaerages for area.
Average extent of drainage around drainage features at site (m)	3.10		3.00		3.20	From 2019 EIAR - Technical estimation - further refined after drainage installed.
Average water table depth at site (m)	0.30		0.10		0.50	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance".
Dry soil bulk density (g cm^{-3})	0.13		0.07		0.29	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance" for intact peat.
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	10		5		15	Values informed by Rochefort et al., (2003).
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25		0.12		0.31	Values informed by Carbon Tool Guidance Document. Apparent C accumulation rate in peatland is 0.12 to 0.31 tC ha-1 yr-1 (Turunen et al., 2001; Botch et al., 1995). The SNH guidance uses a value of 0.25 tC ha-1 yr-1.
Forestry Plantation Characteristics						
Method used to calculate CO_2 loss from forest felling	Enter simple data	No forestry to be felled	Enter simple data		Enter simple data	
Area of forestry plantation to be felled (ha)	4.09		4.08		4.1	Chapter 11
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	3.60		2.50		4.70	Standard value from NatureScot
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})	1.002	Fixed	1.002		1.002	
Grid-mix emission factor (t CO_2 MWh^{-1})	0.19338	Fixed	0.19338		0.19338	
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.432	Fixed	0.432		0.432	

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% (Dale et al 2004).

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 and Grid Mix Emission Factors. Coal fired plant emission factor (EF) from

Borrow pits				
Number of borrow pits	2	2	2	From 2019 EIAR - Borrow Pit Assessment Technical Appendix
Average length of pits (m)	300	300	300	From 2019 EIAR - Borrow Pit Assessment Technical Appendix
Average width of pits (m)	150	150	150	From 2019 EIAR - Borrow Pit Assessment Technical Appendix
Average depth of peat removed from pit (m)	0.6	0.6	0.6	From 2019 EIAR - PSRA Technical Appendix
Foundations and hard-standing area associated with each turbine				
Method used to calculate CO_2 loss from foundations and hard-standing	Rectangular with vertical	Rectangular with vertical	Rectangular with vertical	
Average length of turbine foundations (m)	23	23	23	From 2019 EIAR - Chapter 3
Average width of turbine foundations (m)	23	23	23	From 2019 EIAR - Chapter 3
Average depth of peat removed from turbine foundations (m)	0.50	0.50	0.50	From 2019 EIAR - PSRA Technical Appendix
Average length of hard-standing (m)	50	50	50	From 2019 EIAR - Chapter 3
Average width of hard-standing (m)	20	20	20	From 2019 EIAR - Chapter 3
Average depth of peat removed from hard-standing (m)	0.60	0.60	0.60	From 2019 EIAR - PSRA Technical Appendix
Access tracks				
Total length of access track (m)	9065	9064	9066	From 2019 EIAR - Chapter 3
Existing track length (m)	5065	5065	5065	From 2019 EIAR - Chapter 3
Length of access track that is floating road (m)	4000	3999	4001	From 2019 EIAR - Chapter 3
Floating road width (m)	5.5	5.5	5.5	From 2019 EIAR - EIA Chapter 3
Floating road depth (m)	0.50	0.40	0.60	From 2019 EIAR - Chapter 3
Length of floating road that is drained (m)	0.75	0.74	0.76	From 2019 EIAR - Chapter 3
Average depth of drains associated with floating roads (m)	0.50	0.50	0.50	From 2019 EIAR - Chapter3
Length of access track that is excavated road (m)	0	0	0	N/A
Excavated road width (m)	5	5	5	Not applicable
Average depth of peat excavated for road (m)	0.00	0.00	0.00	Not applicable
Length of access track that is rock filled road (m)	0	0	0	N/A
Rock filled road width (m)	5	5	5	N/A
Rock filled road depth (m)	0	0	0	N/A
Length of rock filled road that is drained (m)	0	0	0	N/A
Average depth of drains associated with rock filled roads (m)	0.00	0.00	0.00	N/A
Cable Trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0	N/A
Average depth of peat cut for cable trenches (m)	0.00	0.00	0.00	N/A
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	0	0	0	N/A
Area of additional peat excavated (m^2)	0.0	0.0	0.0	N/A
Peat Landslide Hazard				
[Weblink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments]	negligible	negligible	negligible	Fixed
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)	5	5	5	Draft HMP
Water table depth in degraded bog before improvement (m)	0.10	0.05	0.30	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance". Values for 'degraded peat'.
Water table depth in degraded bog after improvement (m)	0.09	0.04	0.29	Standard values from "Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance". Values for 'intact peat'.
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	10	5	15	Based on professional judgement of the project team
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	40	40	40	Total lifetime of windfarm
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	N/A
Water table depth in felled area before improvement (m)	0.00	0.00	0.00	N/A
Water table depth in felled area after improvement (m)	0.00	0.00	0.00	N/A
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2	2	2	N/A
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	20	20	20	N/A

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.

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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Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	5	5	5	From 2019 EIAR - Borrow Pit Assessment Technical Appendix
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	2.00	1.00	3.00	From 2019 EIAR - Technical average used.
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.10	0.00	0.11	From 2019 EIAR - Technical estimation - refined when restoration has taken place.
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	5	5	5	From 2019 EIAR - Technical average used.
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	20	20	20	From 2019 EIAR - Technical average used.
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	1.00	0.90	1.10	From 2019 EIAR - Technical estimation
Water table depth around foundations and hardstanding after restoration (m)	0.90	0.80	1.00	From 2019 EIAR - Technical estimation
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0.1	0.1	0.1	From 2019 EIAR - Technical estimation
Restoration of site after decomissioning				
Will the hydrology of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	From 2019 EIAR
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	From 2019 EIAR
Will the habitat of the site be restored on decommissioning?	No	No	No	
Will you control grazing on degraded areas?	Not appl	Not app	Not app	Not applicable to the development
Will you manage areas to favour reintroduction of species	No	No	No	Not applicable to the development

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

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

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

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

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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Click here to move to Payback Time 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.

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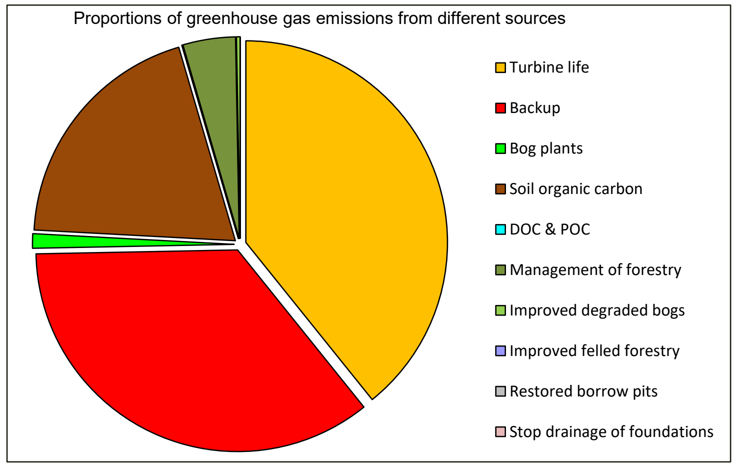
	Exp.	*Min.*	*Max.*
1. Windfarm CO_2 emission saving over…			
…coal-fired electricity generation (tCO_2 yr^{-1})	55193	55193	55193
…grid-mix of electricity generation (tCO_2 yr^{-1})	10652	10652	10652
…fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	23796	23796	23796
Energy output from windfarm over lifetime (MWh)	2203315	2203315	2203315
Total CO_2 losses due to wind farm (t CO_2 eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	20087	20087	20087
3. Losses due to backup	18165	18165	18165
4. Losses due to reduced carbon fixing potential	592	255	809
5. Losses from soil organic matter	10047	-375	32489
6. Losses due to DOC & POC leaching	15	1	59
7. Losses due to felling forestry	2160	1496	2827
Total losses of carbon dioxide	51064	39628	74435
8. Total CO_2 gains due to improvement of site (t CO_2 eq.)			
8a. Change in emissions due to improvement of degraded bogs	149	0	-1138
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	-1146	-1135	-887
8d. Change in emissions due to removal of drainage from foundations & hardstanding	-154	0	-164
Total change in emissions due to improvements	-1151	-1135	-2188

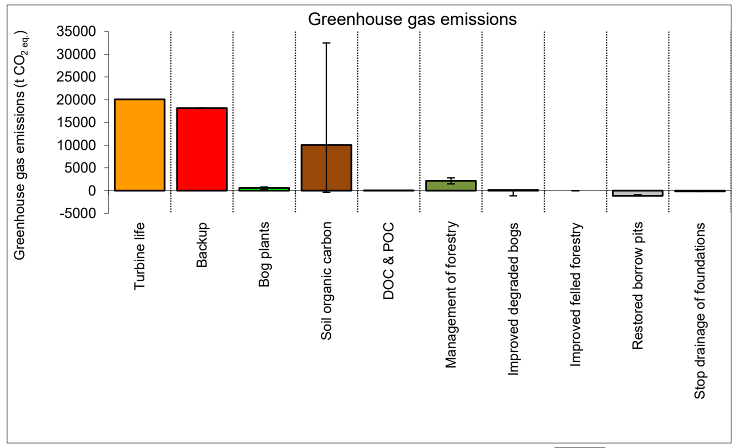
RESULTS	*Exp.*	*Min.*	*Max.*
Net emissions of carbon dioxide (t $CO_{2\ eq.}$)	**49914**	**37440**	**73301**
Carbon Payback Time			
…coal-fired electricity generation (years)	0.9	0.7	1.3
…grid-mix of electricity generation (years)	4.7	3.5	6.9
…fossil fuel - mix of electricity generation (years)	**2.1**	**1.6**	**3.1**
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)	**23**	**17**	**33**

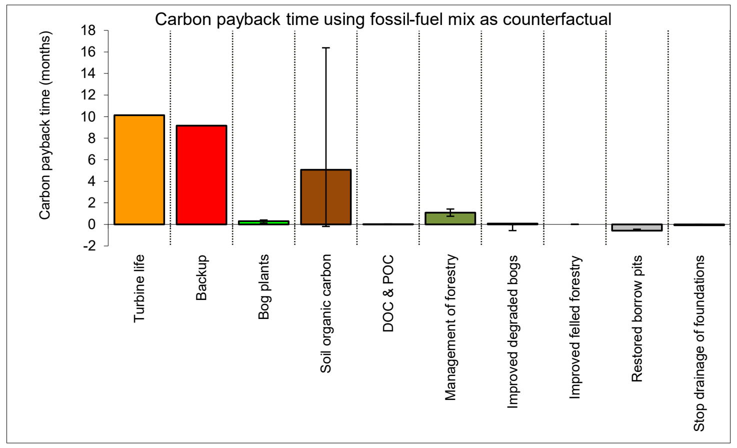


Data used in barchart of carbon payback time using fossil-fuel mix as counterfactual

Greenhouse gas emissions

	Exp.	*Min*	*Max*
Turbine life	20087	0	0
Backup	18165	0	0
Bog plants	592	337	217
Soil organic carbon	10047	10422	22443
DOC & POC	15	14	44
Management of forestry	2160	664	667
Improved degraded bogs	149	149	0
Improved felled forestry	0	0	0
Restored borrow pits	0	0	259
Stop drainage of foundations	0	0	0





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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	20087	0	0	10	0	0
Backup	18165	0	0	9	0	0
Bog plants	592	337	217	0	0	0
Soil organic carbon	10047	10422	22443	5	5	11
DOC & POC	15	14	44	0	0	0
Management of forestry	2160	664	667	1	0	0
Improved degraded bogs	149	149	-1287	0	0	-1
Improved felled forestry	0	0	0	0	0	0
Restored borrow pits	-1146	-11	259	-1	0	0
Stop drainage of foundations	-154	-154	-10	0	0	0
	49914			25		

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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