Carbon Calculator Payback Time and CO2 emissions UO8O-64K6-LFGB Higher Turbine Range

Higher Turbine Range 6 MW

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	13	13	13	Chapter 2 - Project Description
Duration of consent (years)	40	40	40	Chapter 2 - Project Description
Performance				
Power rating of 1 turbine (MW)	6	5	6	Chapter 2 - Project Description
Capacity factor	35	34	36	Chapter 2 - Project Description
Backup				
Fraction of output to backup (%)	5	5	5	SNH Calculator Guidance
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO2 emission from turbine life ($tCO2\ MW^{-1}$) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	
Characteristics of peatland before windfarm development				

Input data	Expected value	Minimum value	Maximum value	Source of data
Type of peatland	Acid bog	Acid bog	Acid bog	Chapter 5 - Terrestrial Ecology
Average annual air temperature at site (°C)	10.3	10.2	10.4	Chapter 10 Air and Climate
Average depth of peat at site (m)	1.38	0	4.4	Chapter 8 Soils & Geology
C Content of dry peat (% by weight)	55	50	60	Default Value
Average extent of drainage around drainage features at site (m)	15	10	20	Chapter 9 Hydrology and Hydrogeology
Average water table depth at site (m)	0.5	0.1	1	Chapter 9 Hydrology & Hydrogeology
Dry soil bulk density (g cm^{-3})	0.1	0.09	0.11	Default Value Used
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	2	2	3	Default Value Used
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.24	0.26	Default Value Used
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	5.83	5.82	5.84	Chapter 2 Project Description
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	3.6	3.5	3.7	Cannell, 1999
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh^{-1})	1.002	1.002	1.002	
Grid-mix emission factor (t CO2 MWh^{-1})	0.19338	0.19338	0.19338	

Input data	Expected value	Minimum value	Maximum value	Source of data
Fossil fuel-mix emission factor (t CO2 MWh^{-1})	0.432	0.432	0.432	
Borrow pits				
Number of borrow pits	0	0	0	Chapter 2 Project Description
Average length of pits (m)	0	0	0	Chapter 2 Project Description
Average width of pits (m)	0	0	0	Chapter 2 Project Description
Average depth of peat removed from pit (m)	0	0	0	Chapter 2 Project Description
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	25.55	25	26	Chapter 2 -Project Description
Average width of turbine foundations (m)	20	19	21	Peat and Spoil Management Plan
Average depth of peat removed from turbine foundations(m)	1.6	0.4	3	Peat and Spoil Management Plan
Average length of hard-standing (m)	72	70	73	Peat and Spoil Management Plan
Average width of hard-standing (m)	50	49	51	Peat and Spoil Management Plan
Average depth of peat removed from hard-standing (m)	1.6	0.4	3	Peat and Spoil Management Plan
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m^3)	13136	13135	13137	Chapter 15 - Traffic and Transport
Access tracks				
Total length of access track (m)	11330	11310	11350	Chapter 2 - Project Description
Existing track length (m)	9650	9640	9660	Chapter 2 - Project Description

Input data	Expected value	Minimum value	Maximum value	Source of data
Length of access track that is floating road (m)	0	0	0	Chapter 2 - Project Description
Floating road width (m)	5	5	5	Chapter 2 - Project Description
Floating road depth (m)	0	0	0	Chapter 2 - Project Description
Length of floating road that is drained (m)	0	0	0	Chapter 2 - Project Description
Average depth of drains associated with floating roads (m)	0	0	0	Chapter 2 - Project Description
Length of access track that is excavated road (m)	1680	1670	1690	Chapter 2 - Project Description
Excavated road width (m)	5	5	5	Chapter 2 - Project Description
Average depth of peat excavated for road (m)	1.9	0.83	3	Chapter 2 - Project Description
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	
Length of rock filled road that is drained (m)	0	0	0	
Average depth of drains associated with rock filled roads (m)	0	0	0	
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0	
Average depth of peat cut for cable trenches (m)	0	0	0	
Additional peat excavated (not already accounted for above)				

Input data	Expected value	Minimum value	Maximum value	Source of data
Volume of additional peat excavated (m^3)	8247	8246	8248	Drainage, Wind Farm Substation, Hydrogen Plant, Internal Cabling
Area of additional peat excavated (m^2)	0	0	0	Peat and Spoil Management Plan
Peat Landslide Hazard				
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)	15.23	15.23	15.23	Chapter 5 Terrestrial Ecology
Water table depth in degraded bog before improvement (m)	0.16	0	0.25	Chapter 5 Terrestrial Ecology
Water table depth in degraded bog after improvement (m)	0.1	0	0.15	Chapter 5 Terrestrial Ecology
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	15	5	20	Chapter 5 Terrestrial Ecology
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	40	40	40	Chapter 5 Terrestrial Ecology
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	0
Water table depth in felled area before improvement (m)	0	0	0	
Water table depth in felled area after improvement (m)	0	0	0	

Input data	Expected value	Minimum value	Maximum value	Source of data
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	0	0	0	
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	0	0	0	
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	0	0	0	0
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0	0	0	
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	0	0	0	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	0	0	0	
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	0	0	0	0
Water table depth around foundations and hardstanding after restoration (m)	0	0	0	
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0	0	0	
Restoration of site after decomissioning				

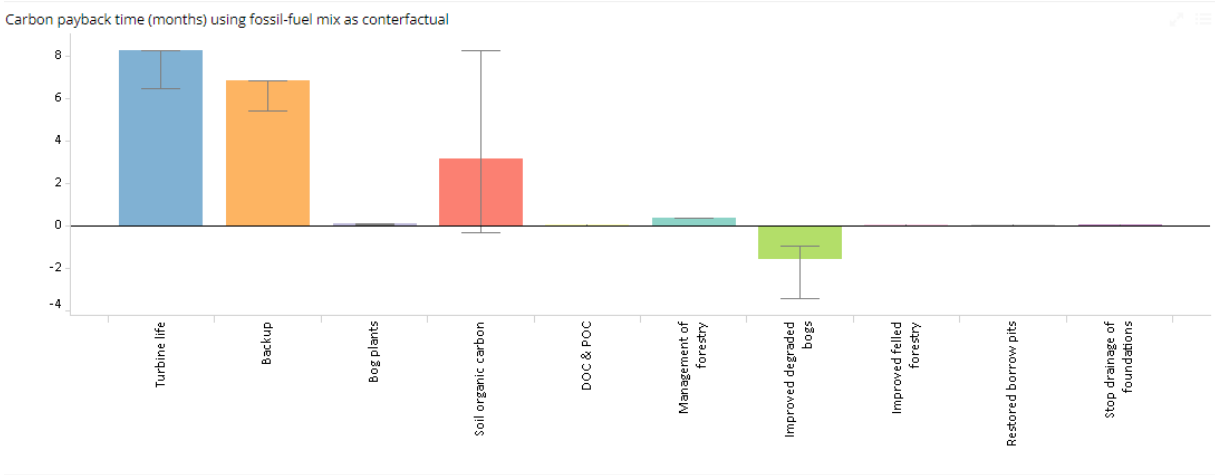
Input data	Expected value	Minimum value	Maximum value	Source of data
Will the hydrology of the site be restored on decommissioning?	No	No	No	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	0
Will you attempt to block all artificial ditches and facilitate rewetting?	No	No	No	0
Will the habitat of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you control grazing on degraded areas?	Yes	Yes	Yes	0
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	0
Methodology				
Choice of methodology for calculating emission factors	IPCC default			

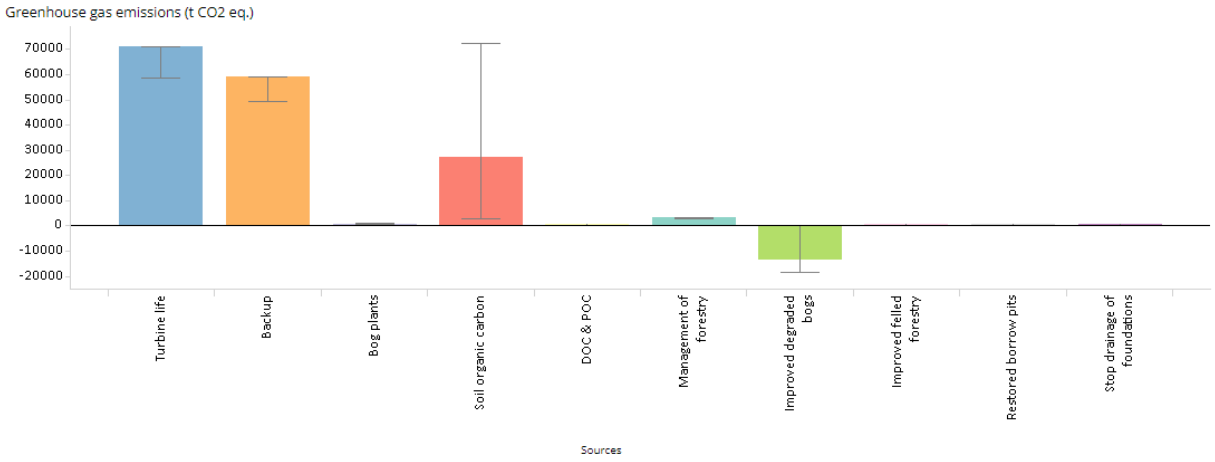
1. Windfarm CO2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	239,626	193,983	246,473
...grid-mix of electricity generation (t CO2 / yr)	46,246	37,438	47,568
...fossil fuel-mix of electricity generation (t CO2 / yr)	103,312	83,633	106,264
Energy output from windfarm over lifetime (MWh)	9,565,920	7,743,840	9,839,232

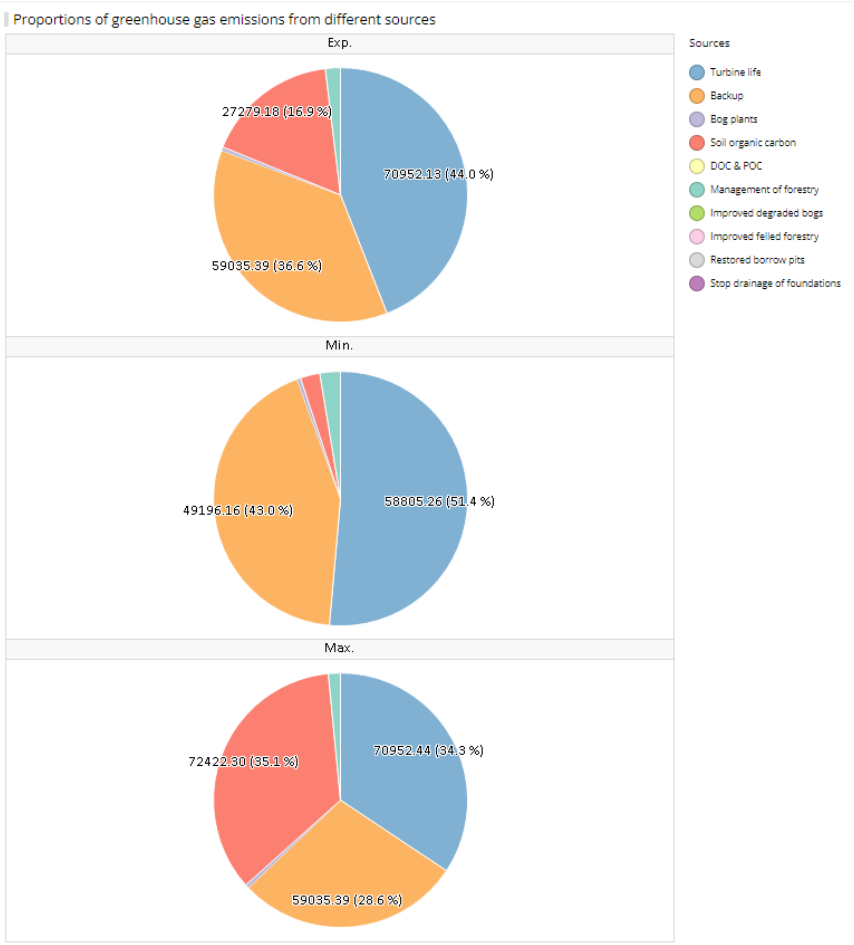
Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	70,952	58,805	70,952
3. Losses due to backup	59,035	49,196	59,035
4. Lossess due to reduced carbon fixing potential	729	518	989
5. Losses from soil organic matter	27,680	3,043	73,590
6. Losses due to DOC & POC leaching	7	0	14
7. Losses due to felling forestry	3,078	2,988	3,169
Total losses of carbon dioxide	161,482	114,550	207,751

8. Total CO2 gains due to improvement of site (t CO2 eq.)	Exp.	Min.	Max.
8a. Change in emissions due to improvement of degraded bogs	-13,174	0	-18,443
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	-13,174	0	-18,443

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	148,308	96,107	207,751
Carbon Payback Time			
...coal-fired electricity generation (years)	0.6	0.4	1.1
...grid-mix of electricity generation (years)	3.2	2.0	5.5
...fossil fuel-mix of electricity generation (years)	1.4	0.9	2.5
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	2.10	0.17	No gains!


Carbon payback time (months) using fossil-fuel mix as conterfactual
8
6
4
2
0
-2
-4
Turbine life
Backup
Bog plants
Soil organic carbon
DOC & POC
Management of forestry
Improved degraded bogs
Improved felled forestry
Restored borrow pits
Stop drainage of foundations


Greenhouse gas emissions (t CO2 eq.)
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
Turbine life
Backup
Bog plants
Soil organic carbon
DOC & POC
Management of forestry
Improved degraded bogs
Improved felled forestry
Restored borrow pits
Stop drainage of foundations
Sources


Proportions of greenhouse gas emissions from different sources
Exp.
27279.18 (16.9 %)
70952.13 (44.0 %)
59035.39 (36.6 %)
Min.
49196.16 (43.0 %)
58805.26 (51.4 %)
Max.
72422.30 (35.1 %)
70952.44 (34.3 %)
59035.39 (28.6 %)
Sources
Turbine life
Backup
Bog plants
Soil organic carbon
DOC & POC
Management of forestry
Improved degraded bogs
Improved felled forestry
Restored borrow pits
Stop drainage of foundations

Lower Turbine Range 5 MW

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	13	13	13	Chapter 2 - Project Description
Duration of consent (years)	40	40	40	Chapter 2 - Project Description
Performance				
Power rating of 1 turbine (MW)	5	5	6	Chapter 2 - Project Description
Capacity factor	35	34	36	Chapter 2 - Project Description
Backup				
Fraction of output to backup (%)	5	5	5	SNH Calculator Guidance
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO2 emission from turbine life ($tCO2\ MW^{-1}$) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	Chapter 5 - Terrestrial Ecology
Average annual air temperature at site (°C)	10.3	10.2	10.4	Chapter 10 Air and Climate
Average depth of peat at site (m)	1.38	0	4.4	Chapter 8 Soils & Geology

Input data	Expected value	Minimum value	Maximum value	Source of data
C Content of dry peat (% by weight)	55	50	60	Default Value
Average extent of drainage around drainage features at site (m)	15	10	20	Chapter 9 Hydrology and Hydrogeology
Average water table depth at site (m)	0.5	0.1	1	Chapter 9 Hydrology & Hydrogeology
Dry soil bulk density (g cm^{-3})	0.1	0.09	0.11	Default Value Used
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	2	2	3	Default Value Used
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.24	0.26	Default Value Used
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	5.83	5.82	5.84	Chapter 2 Project Description
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	3.6	3.5	3.7	Cannell, 1999
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh^{-1})	1.002	1.002	1.002	
Grid-mix emission factor (t CO2 MWh^{-1})	0.19338	0.19338	0.19338	
Fossil fuel-mix emission factor (t CO2 MWh^{-1})	0.432	0.432	0.432	
Borrow pits				
Number of borrow pits	0	0	0	Chapter 2 Project Description

Input data	Expected value	Minimum value	Maximum value	Source of data
Average length of pits (m)	0	0	0	Chapter 2 Project Description
Average width of pits (m)	0	0	0	Chapter 2 Project Description
Average depth of peat removed from pit (m)	0	0	0	Chapter 2 Project Description
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	25.55	25	26	Chapter 2 -Project Description
Average width of turbine foundations (m)	20	19	21	Peat and Spoil Management Plan
Average depth of peat removed from turbine foundations(m)	1.6	0.4	3	Peat and Spoil Management Plan
Average length of hard-standing (m)	72	70	73	Peat and Spoil Management Plan
Average width of hard-standing (m)	50	49	51	Peat and Spoil Management Plan
Average depth of peat removed from hard-standing (m)	1.6	0.4	3	Peat and Spoil Management Plan
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m^3)	13136	13135	13137	Chapter 15 - Traffic and Transport
Access tracks				
Total length of access track (m)	11330	11310	11350	Chapter 2 - Project Description
Existing track length (m)	9650	9640	9660	Chapter 2 - Project Description
Length of access track that is floating road (m)	0	0	0	Chapter 2 - Project Description
Floating road width (m)	5	5	5	Chapter 2 - Project Description
Floating road depth (m)	0	0	0	Chapter 2 - Project Description

Input data	Expected value	Minimum value	Maximum value	Source of data
Length of floating road that is drained (m)	0	0	0	Chapter 2 - Project Description
Average depth of drains associated with floating roads (m)	0	0	0	Chapter 2 - Project Description
Length of access track that is excavated road (m)	1680	1670	1690	Chapter 2 - Project Description
Excavated road width (m)	5	5	5	Chapter 2 - Project Description
Average depth of peat excavated for road (m)	1.9	0.83	3	Chapter 2 - Project Description
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	
Length of rock filled road that is drained (m)	0	0	0	
Average depth of drains associated with rock filled roads (m)	0	0	0	
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0	
Average depth of peat cut for cable trenches (m)	0	0	0	
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	8247	8246	8248	Drainage, Wind Farm Substation, Hydrogen Plant, Internal Cabling
Area of additional peat excavated (m^2)	0	0	0	Peat and Spoil Management Plan

Input data	Expected value	Minimum value	Maximum value	Source of data
Peat Landslide Hazard				
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)	15.23	15.23	15.23	Chapter 5 Terrestrial Ecology
Water table depth in degraded bog before improvement (m)	0.16	0	0.25	Chapter 5 Terrestrial Ecology
Water table depth in degraded bog after improvement (m)	0.1	0	0.15	Chapter 5 Terrestrial Ecology
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	15	5	20	Chapter 5 Terrestrial Ecology
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	40	40	40	Chapter 5 Terrestrial Ecology
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	0
Water table depth in felled area before improvement (m)	0	0	0	
Water table depth in felled area after improvement (m)	0	0	0	
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	0	0	0	
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	0	0	0	

Input data	Expected value	Minimum value	Maximum value	Source of data
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	0	0	0	0
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0	0	0	
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	0	0	0	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	0	0	0	
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	0	0	0	0
Water table depth around foundations and hardstanding after restoration (m)	0	0	0	
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0	0	0	
Restoration of site after decomissioning				
Will the hydrology of the site be restored on decommissioning?	No	No	No	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	0

Input data	Expected value	Minimum value	Maximum value	Source of data
Will you attempt to block all artificial ditches and facilitate rewetting?	No	No	No	0
Will the habitat of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you control grazing on degraded areas?	Yes	Yes	Yes	0
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	0
Methodology				
Choice of methodology for calculating emission factors	IPCC default			

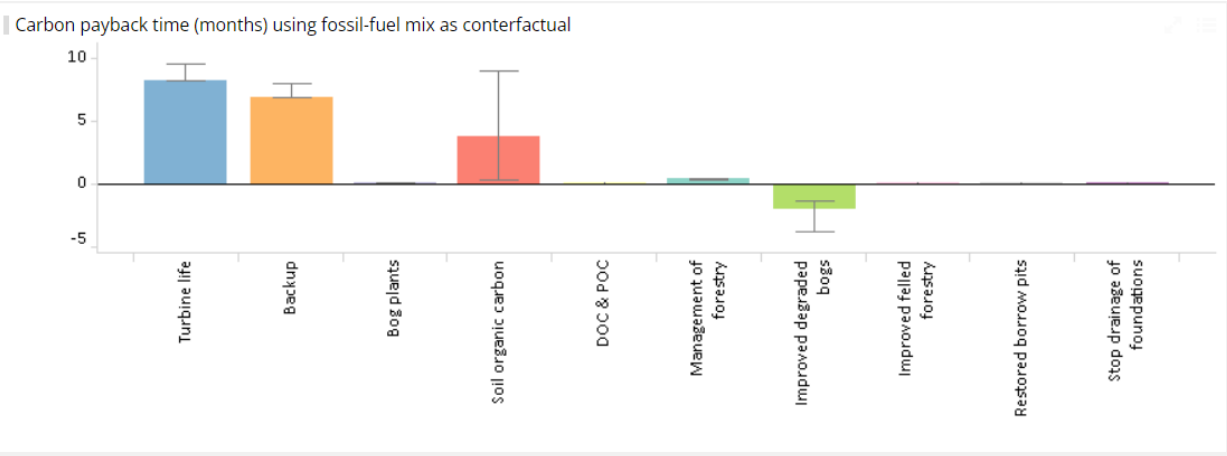
Carbon Losses

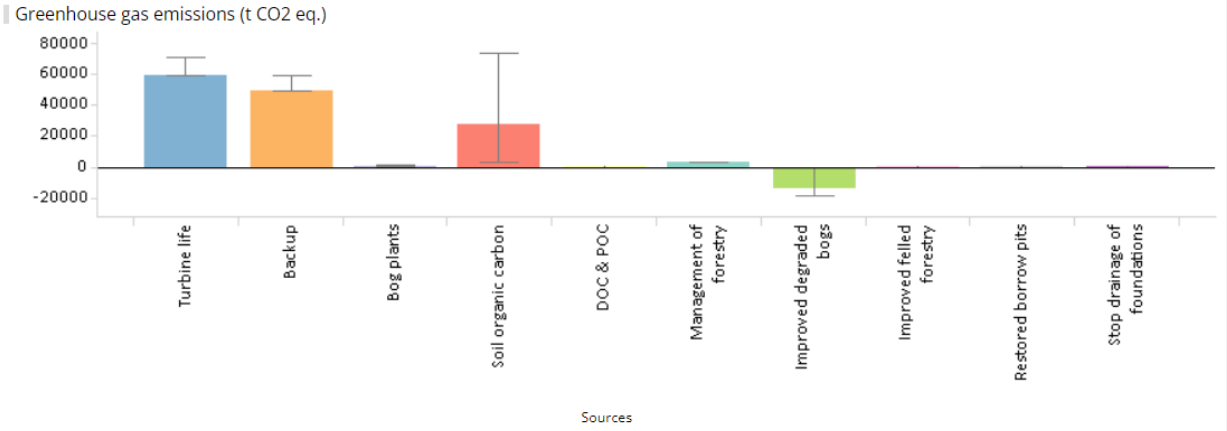
1. Windfarm CO2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	199,689	193,983	246,473
...grid-mix of electricity generation (t CO2 / yr)	38,539	37,438	47,568
...fossil fuel-mix of electricity generation (t CO2 / yr)	86,093	83,633	106,264
Energy output from windfarm over lifetime (MWh)	7,971,600	7,743,840	9,839,232

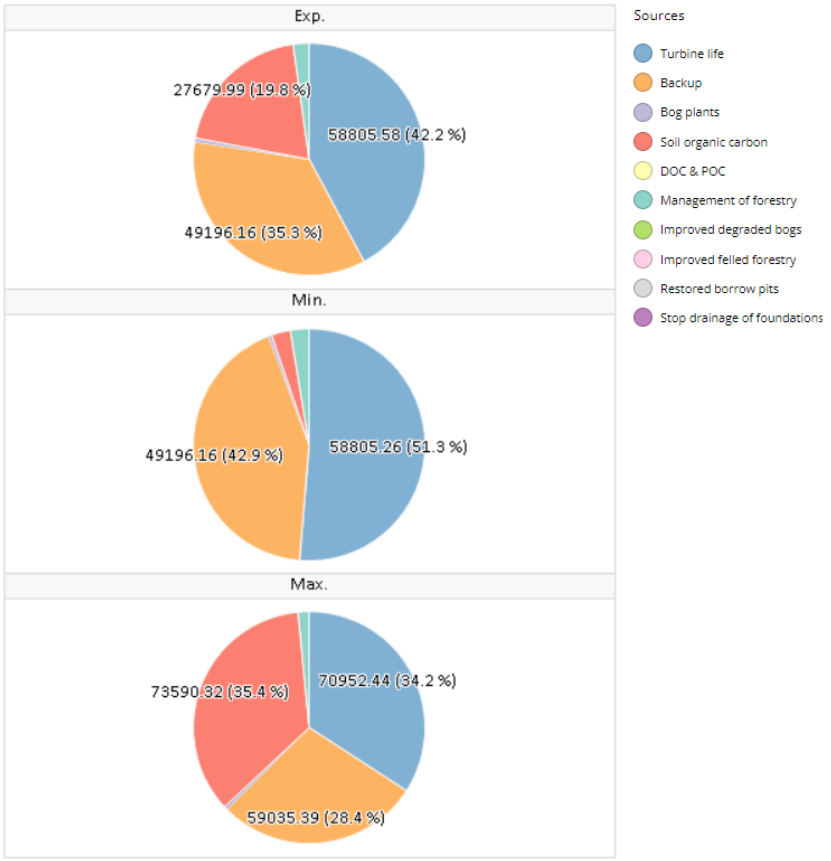
Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	58,806	58,805	70,952
3. Losses due to backup	49,196	49,196	59,035
4. Lossess due to reduced carbon fixing potential	729	518	989
5. Losses from soil organic matter	27,680	3,043	73,590
6. Losses due to DOC & POC leaching	7	0	14
7. Losses due to felling forestry	3,078	2,988	3,169
Total losses of carbon dioxide	139,496	114,550	207,751

8. Total CO2 gains due to improvement of site (t CO2 eq.)	Exp.	Min.	Max.
8a. Change in emissions due to improvement of degraded bogs	-13,174	0	-18,443
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	-13,174	0	-18,443

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	126,322	96,107	207,751
Carbon Payback Time			
...coal-fired electricity generation (years)	0.6	0.4	1.1
...grid-mix of electricity generation (years)	3.3	2.0	5.5
...fossil fuel-mix of electricity generation (years)	1.5	0.9	2.5
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	2.10	0.17	No gains!


Carbon payback time (months) using fossil-fuel mix as conterfactual
10
5
0
-5
Turbine life
Backup
Bog plants
Soil organic carbon
DOC & POC
Management of forestry
Improved degraded bogs
Improved felled forestry
Restored borrow pits
Stop drainage of foundations


Greenhouse gas emissions (t CO2 eq.)
80000
60000
40000
20000
0
-20000
Turbine life
Backup
Bog plants
Soil organic carbon
DOC & POC
Management of forestry
Improved degraded bogs
Improved felled forestry
Restored borrow pits
Stop drainage of foundations
Sources


Proportions of greenhouse gas emissions from different sources
Exp.
27679.99 (19.8 %)
58805.58 (42.2 %)
49196.16 (35.3 %)
Min.
49196.16 (42.9 %)
58805.26 (51.3 %)
Max.
73590.32 (35.4 %)
70952.44 (34.2 %)
59035.39 (28.4 %)
Sources
Turbine life
Backup
Bog plants
Soil organic carbon
DOC & POC
Management of forestry
Improved degraded bogs
Improved felled forestry
Restored borrow pits
Stop drainage of foundations