APPENDIX 10-1

CARBON CALCULATIONS

Cover

CARBON CALCULATOR TOOL v . .

Help About...

Scottish Government and SEPA users only:

The Scottish Government
Application Status Control
Enter password
Sign in
Start Carbon Calculator

This tool calculates payback time for windfarm sited on peatlands using methods given in Nayak et al, 2008 (http://www.gov.scot/Publications/2008/06/25114657/0) and revised equations for GHG emissions (Nayak, D.R., Miller, D., Nolan, A., Smith, P. and Smith, J.U., 2010, Calculating carbon budgets of wind farms on Scottish peatland. Mires and Peat 4: Art. 9. Online: http://mires-and-peat.net/pages/volumes/map04/map0409.php

Admin

CARBON CALCULATOR TOOL v . . - APPLICATION STATUS CONTROL

Help

Reference Code: Search

Windfarm Name	Version	Methodology used for calculating emission factors	Status Date	Status
No data available in table				

PreviousNext

Selected:

Saved Signed-off Received Consented Refused Withdrawn
Revert to original status

Start

CARBON CALCULATOR TOOL v . .

- Will the site be drained on construction of the windfarm?
- Is the soil at the site highly organic?
- Does windfarm construction require a significant amount of deforestation?
  i.e. is removal in excess of keyholing the turbines within the forest boundary?

If you already have an Application Reference, type it here (or paste it in the first box):

Search

New application

CoreInput

Save ☐ Signed off for submission

Note: Results are only available once ALL data are correct and complete, and a new version will be created.

New app...

Ref: 2BUH-Q0PE-SEWW v

MENU≡

Help

Core input data | Forestry input data | Construction input data

Windfarm characteristics Page 1 of 12

Expected values	**Minimum**	**Maximum**
Dimensions		
Number of Turbines: 8		
Ch 4 Description	8	8
Duration of consent (years): 30		
Ch 4 Descriptions	25	30
Performance		
Power rating of 1 turbine (MW): 4.2		
Ch 4 Description	4.2	4.2
Capacity factor: Direct input (% estimated capacity factor) ▼		

Payback Time

Payback Time
Payback Time - ChartsInput Data

1. Windfarm CO2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	94,776	92,068	97,484
...grid-mix of electricity generation (t CO2 / yr)	26,123	25,377	26,870
...fossil fuel-mix of electricity generation (t CO2 / yr)	46,358	45,033	47,682
Energy output from windfarm over lifetime (MWh)	3,090,528	2,501,856	3,178,829

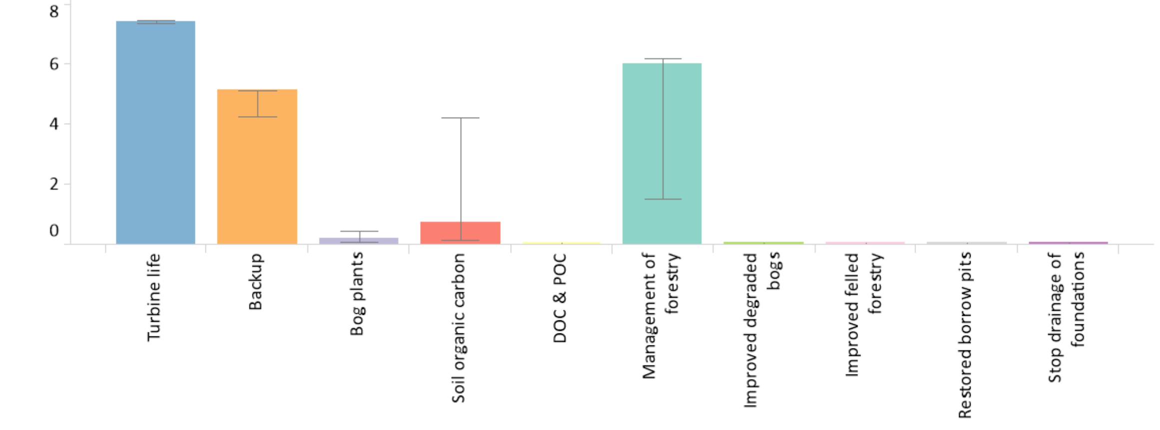
Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	28,665	28,602	28,918
3. Losses due to backup	19,868	16,556	19,868
4. Lossess due to reduced carbon fixing potential	812	238	1,643
5. Losses from soil organic matter	2,800	577	16,709
6. Losses due to DOC & POC leaching	0	0	0
7. Losses due to felling forestry	23,162	6,417	24,013
Total losses of carbon dioxide	75,307	52,390	91,150

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	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

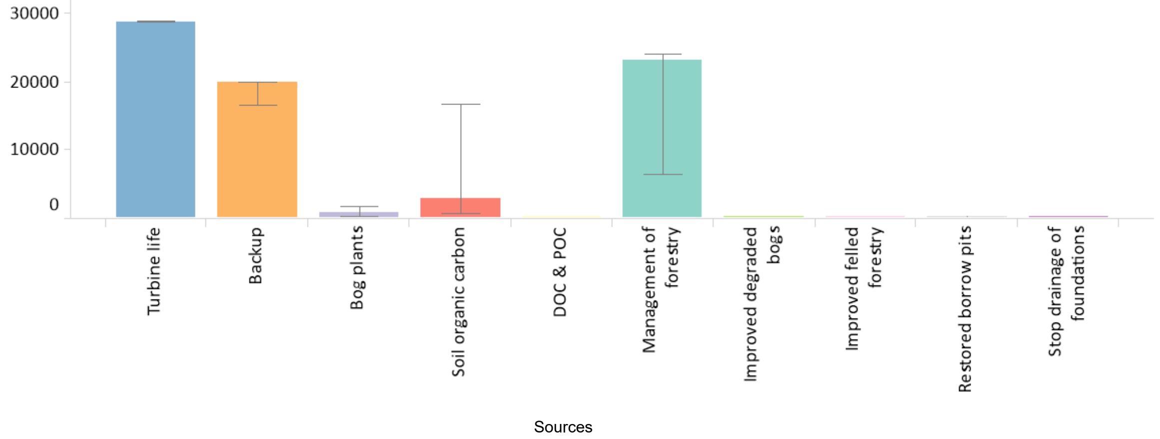
RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	75,307	52,390	91,150
Carbon Payback Time			
...coal-fired electricity generation (years)	0.8	0.5	1.0
...grid-mix of electricity generation (years)	2.9	1.9	3.6
...fossil fuel-mix of electricity generation (years)	1.6	1.1	2.0
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	No gains!	No gains!	No gains!
Ratio of CO2 eq. emissions to power generation (g/kWh) (for info. only)	24.37	16.48	36.43

Payback Time - Charts

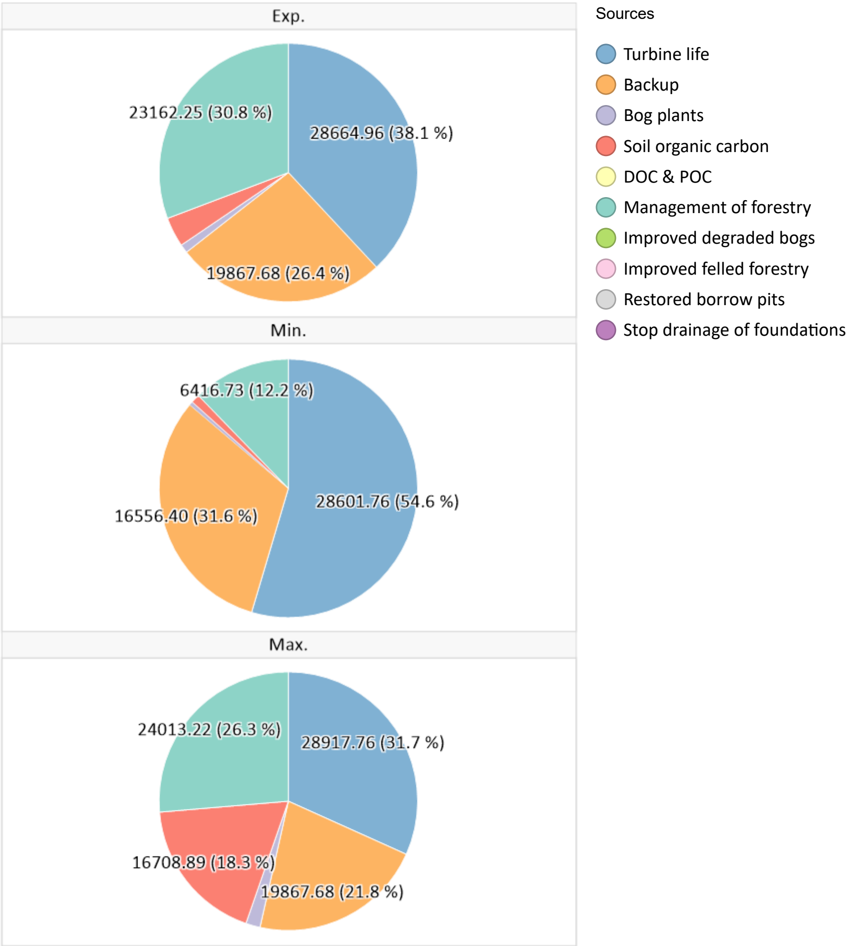
Carbon payback time (months) using fossil-fuel mix as conterfactual



Greenhouse gas emissions (t CO2 eq.)



Proportions of greenhouse gas emissions from different sources



View

Payback Time
Payback Time - ChartsInput Data

Print this page

Carbon Calculator v1.6.1

Slieveacurry Renewable Energy Development Location: 52.865687 -9.306766

Slieveacurry Ltd

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	8	8	8	Ch 4 Description
Duration of consent (years)	30	25	30	Ch 4 Descriptions
Performance				
Power rating of 1 turbine (MW)	4.2	4.2	4.2	Ch 4 Description
Capacity factor	35	34	36	SEAI Report
Backup				
Fraction of output to backup (%)	5	5	5	SNH Carbon Calculator Guidance
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO_2 emission from turbine life (tCO_2 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	Ch 11 Air & Climate
Average annual air temperature at site (°C)	10.7	6	15	Ch 11 Air and Climate
Average depth of peat at site (m)	0.6	0.4	0.7	Geotechnical & Peat Stability Assessment
C Content of dry peat (% by weight)	55	50	60	Default value used
Average extent of drainage around drainage features at site (m)	10	5	15	Ch 10 Water
Average water table depth at site (m)	0.5	0.1	1	Site specific
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)	10	5	15	Best Practice in Raised Bog Restoration in Ireland
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.2	0.3	SNH Guidance default value
Forestry Plantation Characteristics				

Input data **Expected value** **Minimum value** **Maximum value** **Source of data**

5. Loss of soil CO2 (a, b)

Emissions due to loss of soil organic carbon
Loss of C stored in peatland is estimated from % site lost by peat removal (table 5a), CO2 loss from removed peat (table 5b), % site affected by drainage (table 5c), and the CO2 loss from drained peat (table 5d).

5. Loss of soil C02

	Exp.	Min.	Max.
CO2 loss from removed peat (t CO2 equiv.)	2799.91	577.15	10221.97
CO2 loss from drained peat (t CO2 equiv.)	0	0	6486.92
RESULTS			
Total CO2 loss from peat (removed + drained) (t CO2 equiv.)	2799.91	577.15	16708.89
Additional CO2 payback time of windfarm due to loss of soil C...			
...coal-fired electricity generation (months)	0.35	0.08	2.06
...grid-mix of electricity generation (months)	1.29	0.27	7.46
...fossil fuel - mix of electricity generation (months)	0.72	0.15	4.21

CO_2 loss from removed peats
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.

5b. CO2 loss from removed peat

	Exp.	Min.	Max.
CO2 loss from removed peat (t CO2)	7985.79	3498.03	15801.49
CO2 loss from undrained peat left in situ (t CO2)	5185.88	2920.88	5579.51
RESULTS			
CO2 loss atributable to peat removal only (t CO2)	2799.91	577.15	10221.97

Volume of Peat Removed
% 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 data entry.

5a. Volume of peat removed

	Exp.	Min.	Max.
Peat removed from borrow pits			
Area of land lost in borrow pits (m2)	20010	2500	33600
Volume of peat removed from borrow pits (m3)	10005	750	16800
Peat removed from turbine foundations			
Area of land lost in foundation (m2)	5832	5000	6272
Volume of peat removed from foundation area (m3)	4665.6	3200	5644.8
Peat removed from hard-standing			
Area of land lost in hard-standing (m2)	12500	12500	12500
Volume of peat removed from hard-standing area (m3)	10000	8000	11250
Peat removed from access tracks			
Area of land lost in floating roads (m2)	0	0	0
Volume of peat removed from floating roads (m3)	0	0	0
Area of land lost in excavated roads (m2)	23880	17500	28000
Volume of peat removed from excavated roads (m3)	14328	8750	30800
Area of land lost in rock-filled roads (m2)	0	0	0
Volume of peat removed from rock-filled roads (m3)	0	0	0
Total area of land lost in access tracks (m2)	23880	17500	28000
Total volume of peat removed due to access tracks (m3)	14328	8750	30800
RESULTS			
Total area of land lost due to windfarm construction (m2)	68522	43714	87586
Total volume of peat removed due to windfarm construction (m3)	39598.6	21200	65294.8

5. Loss of soil CO2 (c,d,e)

Payback Time
Payback Time - ChartsInput Data

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

CO_2 loss due to drainage
Note, 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)

5c. Volume of peat drained

	Exp.	Min.	Max.
Total area affected by drainage around borrow pits (m2)	9360	1350	23400
Total volume affected by drainage around borrow pits (m3)	2340	202.5	5850
Peat affected by drainage around turbine foundation and hardstanding			
Total area affected by drainage of foundation and hardstanding area (m2)	25840	11800	41640
Total volume affected by drainage of foundation and hardstanding area (m3)	10336	3776	18738
Peat affected by drainage of access tracks			
Total area affected by drainage of access track(m2)	79600	35000	120000
Total volume affected by drainage of access track(m3)	23880	8750	66000
Peat affected by drainage of cable trenches			
Total area affected by drainage of cable trenches(m2)	35040	15000	54000
Total volume affected by drainage of cable trneches(m3)	8760	750	16200
Drainage around additional peat excavated			
Total area affected by drainage (m2)	3127.84	1475.75	5223.17
Total volume affected by drainage (m3)	297.89	102.28	672.44
RESULTS			
Total area affected by drainage due to windfarm (m2)	152967.84	64625.75	244263.17
Total volume affected by drainage due to windfarm (m3)	45613.89	13580.78	107460.44

5d. CO2 loss from drained peat

	Exp.	Min.	Max.
Calculations of C Loss from Drained Land if Site is NOT Restored after Decomissioning			
Total GHG emissions from Drained Land (t CO2 equiv.)	9198.88	2240.85	26005.66
Total GHG emissions from Undrained Land (t CO2 equiv.)	9198.88	2240.85	19518.74
Calculations of C Loss from Drained Land if Site IS Restored after Decomissioning			
Losses if Land is Drained			
CH4 emissions from drained land (t CO2 equiv.)	40.08	-92.12	622.23
CO2 emissions from drained land (t CO2)	11536.83	4410.28	20109.51
Total GHG emissions from Drained Land (t CO2 equiv.)	9198.88	2240.85	26005.66
Losses if Land is Undrained			
CH4 emissions from undrained land (t CO2 equiv.)	40.08	-92.12	2979.01
CO2 emissions from undrained land (t CO2)	11536.83	4410.28	12581.35
Total GHG emissions from Undrained Land (t CO2 equiv.)	9198.88	2240.85	19518.74
RESULTS			
Total GHG emissions due to drainage (t CO2 equiv.)	0	0	6486.92

Emission rates from soils
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)

5e. Emission rates from soils

	Exp.	Min.	Max.
Calculations following IPCC default methodology			
Flooded period (days/year)	178	178	178
Annual rate of methane emission (t CH4-C/ha year)	0.04	0.04	0.04
Annual rate of carbon dioxide emission (t CO2/ha year)	35.2	35.2	35.2

7. Forestry CO2 loss

Payback Time
Payback Time - ChartsInput Data

CO_2 loss from forests - calculation using detailed management information
Forest carbon calculator (Perks et al, 2009)

Total potential carbon squestration loss due to felling of forestry for the wind farm (t CO2)
Total emissions due to cleared land (t CO2)
Emissions due to harvesting operations (t CO2)
Fossil fuel equivalent saving from use of felled forestry as biofuel (t CO2)
Fossil fuel equivalent saving from use of replanted forestry as biofuel (t CO2)
RESULTS
Total carbon loss associated with forest management(t CO2)

Emissions due to forest felling - calculation using simple management data
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.

	Exp.	Min.	Max.
Area of forestry plantation to be felled (ha)	58.49	20	59
Carbon sequestered (t C ha-1 yr-1)	3.6	3.5	3.7
Lifetime of windfarm (years)	30	25	30
Carbon sequestered over the lifetime of the windfarm (t C ha-1)	108	87.5	111
RESULTS			
Total carbon loss due to felling of forestry (t CO2)	23162.25	6416.73	24013.22
Additional CO2 payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	2.93	0.84	2.96
...grid-mix of electricity generation (months)	10.64	3.03	10.72
...fossil fuel - mix of electricity generation (months)	6	1.71	6.04

8. CO2 gain - site improvement

Payback Time
Payback Time - ChartsInput Data

Gains due to site improvement
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).

Degraded Bog

	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.501	0.485	0.516
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0.721	-0.529	1.865
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 eqiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0

Felled Forestry

	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.501	0.485	0.516
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0.721	-0.529	1.865
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 eqiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0

Borrow Pits

	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.501	0.485	0.516
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0.721	-0.529	1.865
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 eqiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0

Foundations & Hardstanding

	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	30	25	30
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.501	0.485	0.516
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbone dioxide emissions (t CO2 ha-1 yr-1)	0.721	-0.529	1.865
CO2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO2 eqiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	30	25	30

3. CO2 loss backup

Payback Time
Payback Time - ChartsInput Data

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

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.

	Exp.	Min.	Max.
Reserve energy (MWh/yr)	14,717	14,717	14,717
Annual emissions due to backup from fossil fuel-mix of electricity generation (tCO2/yr)	662	662	662
RESULTS			
Total emissions due to backup from fossil fuel-mix of electricity generation (tCO2)	19,868	16,556	19,868

1. CO2 emission saving

Payback Time
Payback Time - ChartsInput Data

Emissions due to turbine life

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

Capacity factor calculated from forestry data

Area name	Value type	Capacity factor (%)	Wind speed ratio	Average site windspeed (m/s)	Annual theoretical energy output (MW / turbine yr)

Capacity factor - Direct input

	Exp.	Min.	Max.
Capacity factor (%)	35.0	34.0	36.0

	Exp.	Min.	Max.
Annual energy output from windfarm (MW/yr)			
RESULTS			
Emissions saving over coal-fired electricity generatio...	94,776	92,068	97,484
Emissions saving over grid-mix of electricity generati...	26,123	25,377	26,870
Emissions saving over fossil fuel - mix of electricity g...	46,358	45,033	47,682

2. CO2 loss turbine life

Payback Time
Payback Time - ChartsInput Data

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

Calculation of emissions with relation to installed capacity

	Exp.	Min.	Max.
Emissions due to turbine frome energy output (t CO2)	3457	3457	3457
Emissions due to cement used in construction (t CO2)	1011	948	1264

Direct input of emissions due to turbine life

	Exp.	Min.	Max.
Emissions due to turbine life (tCO2/windfarm)			

RESULTS

	Exp.	Min.	Max.
Losses due to turbine life (manufacture, construction, etc.) (t CO2)	28665	28602	28918
Additional CO2 payback time of windfarm due to turbine life			
...coal-fired electricity generation (months)	4	4	4
...grid-mix of electricity generation (months)	13	14	13
...fossil fuel - mix of electricity generation (months)	7	8	7

4. Loss CO2 fixing pot.

Payback Time
Payback Time - ChartsInput Data

Emissions due to loss of bog plants

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

	Exp.	Min.	Max.
Area where carbon accumulation by bog plants is lost (ha)	22.15	10.83	33.18
Total loss of carbon accumulation up to time of restoration (tCO2 eq./ha)	37	22	50
RESULTS			
Total loss of carbon fixation by plants at the site (t CO2)	812	238	1643
Additional CO2 payback time of windfarm due to loss of CO2 fixing potential			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	1
...fossil fuel - mix of electricity generation (months)	0	0	0

6. CO_2 loss DOC & POC

Payback Time
Payback Time - ChartsInput Data

Emissions due to loss of DOC and POC
Note, CO_2 losses from DOC and POC are calculated using a simple approach derived from generic estimates of the percentage of the total CO_2 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)

	Exp.	Min.	Max.
Gross CO2 loss from restored drained land (t CO2)	0.00	0.00	0.00
Gross CH4 loss from restored drained land (t CO2 equiv.)	0.00	0.00	0.00
Gross CO2 loss from improved land (t CO2)	0.00	0.00	0.00
Gross CH4 loss from improved land (t CO2 equiv.)	0.00	0.00	0.00
Total gaseous loss of C (t C)	0.00	0.00	0.00
Total C loss as DOC (t C)	0.00	0.00	0.00
Total C loss as POC (t C)	0.00	0.00	0.00
RESULTS			
Total CO2 loss due to DOC leaching (t CO2)	0.00	0.00	0.00
Total CO2 loss due to POC leaching (t CO2)	0.00	0.00	0.00
Total CO2 loss due to DOC & POC leaching (t CO2)	0.00	0.00	0.00
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