ARCUS

LOCHLUICHART WIND FARM EXTENSION II
APPENDIX 5.A

APRIL 2021

INFINERGY

TABLE OF CONTENTS

PAYBACK TIME AND CO_2 EMISSIONS

1. Windfarm CO2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	50,676	50,657	50,696
...grid-mix of electricity generation (t CO2 / yr)	13,968	13,963	13,973
...fossil fuel-mix of electricity generation (t CO2 / yr)	24,787	24,778	24,797
Energy output from windfarm over lifetime (MWh)	2,203,315	2,202,474	2,204,156

Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (e.g., manufacture, construction, decommissioning)	20,789	20,789	20,789
3. Losses due to backup	18,922	18,922	18,922
4. Losses due to reduced carbon fixing potential	208	194	222
5. Losses from soil organic matter	8,226	7,666	8,865
6. Losses due to DOC & POC leaching	3	1	21
7. Losses due to felling forestry	1,077	741	1,420
Total losses of carbon dioxide	49,225	48,312	50,238

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	-1,200	-1,200	-925
8d. Change in emissions due to removal of drainage from foundations & hardstanding	-145	0	-151
Total change in emissions due to improvements	-1,345	-1,200	-1,076

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	47,880	47,235	49,038
Carbon Payback Time			
...coal-fired electricity generation (years)	0.9	0.9	1
...grid-mix of electricity generation (years)	3.4	3.4	3.5
...fossil fuel-mix of electricity generation (years)	1.9	1.9	2
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	6.12	7.12	7.4
Ratio of CO2 eq. emissions to power generation (g/kWh) (for info. only)	21.73	21.43	22.26

PAYBACK TIME CHARTS

INPUT DATA

1 WINDFARM CO_2 EMISSION SAVING

Capacity Factor - Direct Input	Exp.	Min.	Max.
Capacity factor (%)	26.2	26.2	26.2

Annual energy output from windfarm (MW/yr)	Exp.	Min.	Max.
RESULTS			
Emissions saving over coal-fired electricity generation (tCO2/yr)	50,676	50,657	50,696
Emissions saving over grid-mix of electricity generation (tCO2/yr)	13,968	13,963	13,973
Emissions saving over fossil fuel - mix of electricity generation (tCO2/yr)	24,787	24,778	24,797

2 CO_2 LOSS DUE TO TURBINE LIFE

Calculation of emissions with relation to installed capacity	**Exp.**	**Min.**	**Max.**
Emissions due to turbine from energy output (t CO2)	4017	4017	4017
Emissions due to cement used in construction (t CO2)	702	702	702

RESULTS	**Exp.**	**Min.**	**Max.**
Losses due to turbine life (manufacture, construction, etc.) (t CO2)	20789	20789	20789
Additional CO2 payback time of windfarm due to turbine life			
...coal-fired electricity generation (months)	5	5	5
...grid-mix of electricity generation (months)	18	18	18
...fossil fuel - mix of electricity generation (months)	10	10	10

3 CO_2 LOSS DUE TO BACKUP

	Exp.	Min.	Max.
Reserve energy (MWh/yr)	10,512	10,512	10,512
Annual emissions due to backup from fossil fuel-mix of electricity generation (tCO2/yr)	473	473	493
RESULTS			
Total emissions due to backup from fossil fuel-mix of electricity generation (tCO2)	18,922	18,922	18,922

4 LOSS OF CO_2 FIXING POTENTIAL

	Exp.	Min.	Max.
Area where carbon accumulation by bog plants is lost (ha)	5.25	5.22	5.27
Total loss of carbon accumulation up to time of restoration (tCO2 eq./ha)	40	37	42
RESULTS			
Total loss of carbon fixation by plants at the site (t CO2)	208	194	222
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	0
...fossil fuel - mix of electricity generation (months)	0	0	0

5 LOSS OF SOIL CO_2

5. Loss of CO_2	**Exp.**	**Min.**	**Max.**
CO2 loss from removed peat (t CO2 equiv.)	7962.36	7428.73	8565.8
CO2 loss from drained peat (t CO2 equiv.)	263.84	236.97	298.71
RESULTS			
Total CO2 loss from peat (removed + drained) (t CO2 equiv.)	8226.2	7665.69	8864.52
Additional CO2 payback time of windfarm due to loss of soil CO2			
...coal-fired electricity generation (months)	1.95	1.82	2.1
...grid-mix of electricity generation (months)	7.07	6.59	7.61
...fossil fuel - mix of electricity generation (months)	3.89	3.71	4.29

5a. Volume of peat removed	**Exp.**	**Min.**	**Max.**
Peat removed from borrow pits			
Area of land lost in borrow pits (m2)	23560	23560	23560
Volume of peat removed from borrow pits (m3)	16492	16492	16492
Peat removed from turbine foundations			
Area of land lost in foundation (m2)	2645	2645	2645
Volume of peat removed from foundation area (m3)	1322.5	1322.5	1322.5
Peat removed from hard-standing			
Area of land lost in hard-standing (m2)	5000	5000	5000
Volume of peat removed from hard-standing area (m3)	3000	3000	3000
Peat removed from access tracks			
Area of land lost in floating roads (m2)	825	819.5	830.5
Volume of peat removed from floating roads (m3)	412.5	327.8	498.3
Area of land lost in excavated roads (m2)	0	0	0
Volume of peat removed from excavated roads (m3)	0	0	0
Area of land lost in rock-filled roads (m2)	13435	13430	13440
Volume of peat removed from rock-filled roads (m3)	0	0	0
Total area of land lost in access tracks (m2)	14260	14249.5	14270.5
Total volume of peat removed due to access tracks (m3)	412.5	327.8	498.3
RESULTS			
Total area of land lost due to windfarm construction (m2)	45465	45454.5	45475.5
Total volume of peat removed due to windfarm construction (m3)	21227	21142.3	21312.8

5b. CO_2 loss from removed peat	**Exp.**	**Min.**	**Max.**
CO2 loss from removed peat (t CO2)	9339.96	8736.78	9963.82
CO2 loss from undrained peat left in situ (t CO2)	1377.61	1308.06	1398.02
RESULTS			
CO2 loss attributable to peat removal only (t CO2)	7962.36	7428.73	8565.8

5c. Volume of peat drained	Exp.	Min.	Max.
Total area affected by drainage around borrow pits (m2)	2792.48	2700	2885.12
Total volume affected by drainage around borrow pits (m3)	977.37	945	1009.79
Peat affected by drainage around turbine foundation and hardstanding			
Total area affected by drainage of foundation and hardstanding area (m2)	3788.2	3660	3916.8
Total volume affected by drainage of foundation and hardstanding area (m3)	1136.46	1098	1175.04
Peat affected by drainage of access tracks			
Total area affected by drainage of access track(m2)	438.75	430.1	447.44
Total volume affected by drainage of access track(m3)	109.69	107.53	111.86
Peat affected by drainage of cable trenches			
Total area affected by drainage of cable trenches(m2)	0	0	0
Total volume affected by drainage of cable trenches(m3)	0	0	0
Drainage around additional peat excavated			
Total area affected by drainage (m2)	0	0	0
Total volume affected by drainage (m3)	0	0	0
RESULTS			
Total area affected by drainage due to windfarm (m2)	7019.43	6790.1	7249.36
Total volume affected by drainage due to windfarm (m3)	2223.52	2150.53	2296.69

5d. CO_2 loss from drained peat	Exp.	Min.	Max.
Calculations of C Loss from Drained Land if Site is NOT Restored after Decommissioning			
Total GHG emissions from Drained Land (t CO2 equiv.)	978.36	888.68	1073.71
Total GHG emissions from Undrained Land (t CO2 equiv.)	714.52	651.71	775
Calculations of C Loss from Drained Land if Site IS Restored after Decommissioning			
Losses if Land is Drained			
CH4 emissions from drained land (t CO2 equiv.)	-22.39	-23.75	-23.28
CO2 emissions from drained land (t CO2)	313.61	290.2	332.04
Total GHG emissions from Drained Land (t CO2 equiv.)	978.36	888.68	1073.71
Losses if Land is Undrained			
CH4 emissions from undrained land (t CO2 equiv.)	1.86	-4	6.34
CO2 emissions from undrained land (t CO2)	210.83	199.4	216.52
Total GHG emissions from Undrained Land (t CO2 equiv.)	714.52	651.71	775
RESULTS			
Total GHG emissions due to drainage (t CO2 equiv.)	263.84	236.97	298.71

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
Calculations following ECOSSE based methodology			
Total area affected by drainage due to wind farm construction (ha)	0.7	0.68	0.72
Average water table depth of drained land (m)	0.32	0.32	0.32
Selected emission characteristics following site specific methodology			
Rate of carbon dioxide emission in drained soil (t CO2/ha year)	9.93	9.71	9.96
Rate of carbon dioxide emission in undrained soil (t CO2/ha year)	3.26	3.48	2.85
Rate of methane emission in drained soil (t CH4-C/ha year)	-0.02	-0.03	-0.02
Rate of methane emission in undrained soil (t CH4-C/ha year)	0.03	0.02	0.04
RESULTS			
Selected rate of carbon dioxide emission in drained soil (t CO2/ha year)	9.93	9.71	9.96
Selected rate of carbon dioxide emission in undrained soil (t CO2/ha year)	3.26	3.48	2.85
Selected rate of methane emission in drained soil (t CH4-C/ha year)	-0.02	-0.03	-0.02
Selected rate of methane emission in undrained soil (t CH4-C/ha year)	0.03	0.02	0.04

6 CO_2 LOSS BY DOC AND POC LOSS

	Exp.	Min.	Max.
Gross CO2 loss from restored drained land (t CO2)	0	0	0
Gross CH4 loss from restored drained land (t CO2 equiv.)	0	0	0
Gross CO2 loss from improved land (t CO2)	0	0	0
Gross CH4 loss from improved land (t CO2 equiv.)	113.49	93.58	471.64
Total gaseous loss of C (t C)	2.78	2.29	11.53
Total C loss as DOC (t C)	0.72	0.16	4.61
Total C loss as POC (t C)	0.22	0.09	1.15
RESULTS			
Total CO2 loss due to DOC leaching (t CO2)	2.65	0.59	16.92
Total CO2 loss due to POC leaching (t CO2)	0.81	0.34	4.23
Total CO2 loss due to DOC & POC leaching (t CO2)	3.46	0.92	21.15
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

7 FORESTRY CO_2 LOSS

	Exp.	Min.	Max.
Area of forestry plantation to be felled (ha)	2.04	2.02	2.06
Carbon sequestered (t C ha-1 yr-1)	3.6	2.5	4.7
Lifetime of windfarm (years)	40	40	40
Carbon sequestered over the lifetime of the windfarm (t C ha-1)	144	100	188
RESULTS			
Total carbon loss due to felling of forestry (t CO2)	1077.13	740.67	1420.04
Additional CO2 payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	0.26	0.18	0.34
...grid-mix of electricity generation (months)	0.93	0.64	1.22
...fossil fuel - mix of electricity generation (months)	0.52	0.36	0.69

8 CO_2 GAIN – SITE IMPROVEMENT

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)	15	15	15
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.467	0.464	0.467
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO2 ha-1 yr-1)	-1.859	-2.072	-1.832
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)	15	15	15
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.467	0.464	0.467
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO2 ha-1 yr-1)	-1.859	-2.072	-1.832
CO2 emissions from unimproved land (t CO2 equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO2 eqiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO2 equiv.)	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)	18	18	18
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.467	0.464	0.467
CH4 emissions from improved land (t CO2 equiv.)	0	0	0

Selected annual rate of carbon dioxide emissions (t CO2 ha-1 yr-1)	-1.859	-2.072	-1.832
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)	18	18	18
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.467	0.464	0.467
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO2 ha-1 yr-1)	-1.859	-2.072	-1.832
CO2 emissions from unimproved land (t CO2 equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO2 eqiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO2 equiv.)	0	0	0

Borrow Pits	**Exp.**	**Min.**	**Max.**
1. Description of site			
Area to be improved (ha)	4.5	4.5	4.5
Depth of peat above water table before improvement (m)	0.7	0.7	0.7
Depth of peat above water table after improvement (m)	0.1	0.11	0
2. Losses with improvement			
Improved period (years)	15	15	15
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	0.112	0.093	0.467
CH4 emissions from improved land (t CO2 equiv.)	113.488	93.579	471.641
Selected annual rate of carbon dioxide emissions (t CO2 ha-1 yr-1)	0.527	0.659	-1.832
CO2 emissions from improved land (t CO2 equiv.)	18.231	22.784	-63.369
Total GHG emissions from improved land (t CO2 eqiv.)	131.719	116.363	408.272
3. Losses without improvement			
Improved period (years)	15	15	15
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	-0.033	-0.036	-0.033
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO2 ha-1 yr-1)	19.722	19.509	19.748
CO2 emissions from unimproved land (t CO2 equiv.)	1331.22	1316.86	1333.02

Total GHG emissions from unimproved land (t CO2 eqiv.)	1331.22	1316.86	1333.02
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO2 equiv.)	1199.5	1200.5	924.745

Foundations & Hardstanding	**Exp.**	**Min.**	**Max.**
1. Description of site			
Area to be improved (ha)	0.379	0	0.392
Depth of peat above water table before improvement (m)	0.62	0.61	0.63
Depth of peat above water table after improvement (m)	0.62	0.61	0.63
2. Losses with improvement			
Improved period (years)	39.9	39.9	39.9
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	-0.033	-0.036	-0.033
CH4 emissions from improved land (t CO2 equiv.)	-7.438	0	-7.614
Selected annual rate of carbon dioxide emissions (t CO2 ha-1 yr-1)	18.687	18.317	18.864
CO2 emissions from improved land (t CO2 equiv.)	144.708	0	151.041
Total GHG emissions from improved land (t CO2 eqiv.)	137.27	0	143.426
3. Losses without improvement			
Improved period (years)	39.9	39.9	39.9
Selected annual rate of methane emissions (t CH4-C ha-1 yr-1)	-0.033	-0.036	-0.033
CH4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO2 ha-1 yr-1)	18.687	18.317	18.864
CO2 emissions from unimproved land (t CO2 equiv.)	282.452	0	294.812
Total GHG emissions from unimproved land (t CO2 eqiv.)	282.452	0	294.812
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO2 equiv.)	145.181	0	151.385