Energy

14 Carbon Balance

14.1 Introduction

14.1.1 Given that the infrastructure of the Consented Development is not changing, the findings of the previous carbon balance assessment therefore remain valid. The previous carbon balance has been updated (Reference: 35I1-IBGH-RWJ6 v1) to account for the proposed variation that would result in a 40 year operational life for the Consented Development and to utilise the current figures relating to the carbon emissions of wind farm development and carbon savings based on the current energy mix which has greater levels of renewable generation than when this assessment was originally undertaken.

14.1.2 This chapter provides an assessment of the carbon balance that would result from the construction, operation and decommissioning of the Consented Development and has been undertaken by Wardell Armstrong. Disturbance to soil and peat in particular, can lead to mineralisation of organic matter and release of carbon in form of carbon dioxide (CO_2), as well as release of other greenhouse gases (GHGs), such as nitrous oxide (N_2O) and methane (CH_4). Peat will be disturbed as a consequence of constructing the wind farm, including the building of access tracks, and excavation of turbine foundations and areas of hardstanding. Because the installed capacity of the wind farm exceeds 50MW, the assessment of GHGs emissions is a mandatory requirement to be reported in the EIAR.

14.2 Legislative framework

14.2.1 Applications for wind farms (or extensions of wind farms) submitted under Section 36 of the Electricity Act 1989 (50MW capacity or above) are screened to establish whether loss or disturbance to peat could occur as a result of the development proceeding. Where this is the case, Scottish Ministers require all new Section 36 applications received since June 2011 to use the Scottish Government's published method for assessing carbon losses and savings associated with a wind farm development. The purpose of the tool is to assess, in a comprehensive and consistent way, the carbon (Greenhouse Gas (GHG) emissions) impact of wind farm developments.

14.3 Methodology

14.3.1 The carbon balance has been calculated using version 2.9.1 of the Scottish Government Windfarm Carbon Assessment Tool (the carbon calculator) for use in planning applications[1], which is based on a methodology described by Nayak et al., 2008[2].

14.3.2 Table 14.1 contains the main parameters used for calculations and their sources, (see Appendix 14.1: Carbon Calculator, digital appendix, for the complete design data used in the calculations).

14.3.3 Version 1.6.1 of the Carbon Calculator has been used. It is envisaged that all excavated peat will be reused on Site to restore extensive degraded areas, as described in Annex 1 of Appendix 3.6: Outline Peat Reinstatement Management Plan (OPRMP). The correct use of the calculator can be confirmed by downloading the 2.9.1 version from the Scottish Government website and using input values provided in Appendix 14.1.

Table 14.1: Carbon calculator input data

Input data	*Expected value*	*Min. value*	*Max. value*	*Source*
Dimensions				
Number of turbines	17	17	17	Design
Lifetime of windfarm (years)	40	40	40	Design
Performance				
Power rating of turbines (MW)	3.4	3.4	3.4	Design
Capacity factor	46.3	41.7	50.9	Site estimate (see Appendix 3.4: Estimated Energy Generation), min. and max. values are the estimate ±10%
Backup				
Extra capacity required for backup (%)	5	5	5	It is predicted that by the time the Beaw Field Wind Farm is operational the contribution of wind energy to UK energy mix will exceed 20% therefore there will be a need for additional reserve generation (RAE, 2014[3]). The extra capacity required is estimated to be 5% of the rated capacity (Dale et al., 2004[4]).
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	(Dale et al., 2004[4])
Carbon dioxide emissions from turbine life (e.g., manufacture, construction, decommissioning)				
(t CO_2)	46,057	46,057	46,057	Calculated using installed turbine capacity using formula embedded in the calculator.
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog			Most representative for the habitat types occurring at the Site (see Chapter 11: Ecology). An acid bog is fed primarily by rainwater and often inhabited by sphagnum moss.
Average annual air temperature at site (C)	7.63	7.45	7.8	1981–2010 Met Office average (expected) for Baltasound (min.) and Lerwick (max.) stations (MetOffice, 2015[5])
Average depth of peat at Site (m)	1.25	1.21	1.28	Average depth within the Site, min. and max. values are the average ±95% confidence interval (see Chapter 12: Soils and Peat).

Table 14.1: Carbon calculator input data

Input data	***Expected value***	***Min. value***	***Max. value***	***Source***
Carbon content of dry peat (% by weight)	55.5	49	62	Average (expected) of min. and max. values taken from Birnie et al. 1993[6].
Average extent of drainage around features at site (m)	10	5	20	Assumed values (water table measurements have not been carried out to date) taking into account site degradation resulting in low hydraulic conductivity and lack of connectivity due to intensive deep gully network.
Average water table depth at site (m)	0.3	0.27	0.45	Allot et al. 2009[7], the variation in depth is associated with site erosion status, the reported median value for intact sites is less than 0.1 m, while on sites with dense erosion gullies it is above 0.3 m. The erosion on the Site is widespread (see Chapter 12: Soils and Peat). Min. and max. values are the expected value ±10%.
Dry soil bulk density (g cm^{-3})	0.3	0.20	0.3	The expected value is the average of min. and max. values for Scottish peat taken from Dryburgh 1978[8].
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	5	3	10	Based on examples of restoration on West Yell (Alba Ecology – personal communication).
Carbon accumulation due to C fixation by bog plants in undrained peats (t C ha^{-1} yr^{-1})	0.25	0.12	0.31	Min. and max. values are taken from Botch et al. 1995[9] and Turunen et al. 2001[10], the expected value is from the NatureScot (previously SNH) guidance.
Forestry plantation characteristics – n/a as none within the Study Area				
Counterfactual emission factors				
Coal-fired emission factor (t CO_2 MWh^{-1})	0.92	0.92	0.92	Coal-fired and fossil fuel-mix are taken from DECC 2015[11] provisional estimates for 2014, which are lower than estimates for 2012 and 2013, consistent with the trend of increasing proportion of energy derived from renewable sources. The grid-mix emission factor is taken
Grid-mix emission factor (t CO_2 MWh^{-1})	0.25358	0.25358	0.25358	

Table 14.1: Carbon calculator input data

Input data	*Expected value*	*Min. value*	*Max. value*	*Source*
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.45	0.45	0.45	from Defra 2015[12]. The min. and max. are the expected value ±10%.
Improvement of Carbon sequestration at site by blocking drains, restoration of habitat etc.				
Improvement of degraded bog				
Area of degraded bog to be improved (ha)	500	300	700	There is over 1000ha of bog habitats within the Site, most of the habitats have been significantly degraded and would benefit from improvement (see Chapter 11: Ecology and Chapter 12: Soils and Peat). Refined estimates cannot be made at this stage however, as the land within the Site will be subject to a long-term habitat management plan, assumptions of the likely area to be improved can be defined.
Water table depth in degraded bog before improvement (m)	0.3	0.27	0.33	Allot et al. 2009[7], the variation in depth is associated with site erosion status, the reported median value for intact sites is less than 0.1m, while on sites with dense erosion gullies it is above 0.3m. The erosion on the Site is widespread (see Chapter 12: Soils and Peat). Min. and max. values are the expected value ±10%.
Water table depth in degraded bog after improvement (m)	0.10	0.09	0.11	See comment above.
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	5	3	10	Based on examples of restoration on West Yell (Alba Ecology – personal communication).
Period of time when effectiveness of the improvement in degrade bog can be guaranteed	20	22	15	The improvement can be guaranteed for the lifetime of the development.
Restoration of peat removed from borrow pits				

Table 14.1: Carbon calculator input data

Input data	***Expected value***	***Min. value***	***Max. value***	***Source***
Area of borrow pits to be restored (ha)	4.13	4.13	4.13	Borrow pits 3 and 4 are in areas suitable to be restored as wet bog (see Chapter 12: Soils and Peat).
Depth of water table in borrow pit before restoration with respect to the restored surface (m) bgl	0.5	0.5	0.5	Estimated to be possible to achieve with appropriate borrow pit design after extraction of the material has been completed
Depth of water table in borrow pit after restoration with respect to the restored surface (m) bgl	0.2	0.19	0.21	Estimated minimum after the peat has stabilised based on values provided by Allot et al. 2009[7]. Min. and max. values are the expected value ±10%.
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	5	3	10	Based on examples of restoration on West Yell (Alba Ecology – personal communication).
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	20	22	15	The improvement can be guaranteed for the lifetime of the development.
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)bgl	0.50	0.50	0.50	Estimated minimum after the peat has stabilised based on values provided by Allot et al. 2009[7].
Water table depth around foundations and hardstanding after restoration (m)bgl	0.25	0.25	0.25	Based on examples of restoration on West Yell (Alba Ecology – personal communication).
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	5	3	10	Backfilling and removal of any surface drains (if present) would be carried out directly after construction.

14.3.4 After decommissioning the hydrology of the Site would be restored, however the need for restoration would be very limited due to the location of infrastructure away from watercourses and no artificial drainage ditches being created, except for along the tracks and cut-off drains intercepting the runoff in construction areas Any gullies that have formed due to the wind farm would be blocked. The habitat of the site would be subject to ongoing restoration during the operation, and therefore no additional restoration outside the footprint of the infrastructure would be needed. The post commissioning grazing regime would be controlled and managed to facilitate reintroduction of moorland habitat as described in Appendix 10.4: Outline Habitat Management Plan (OHMP).

14.4 Baseline

14.4.1 The baseline conditions for GHG emissions from the Consented Development would be the GHG emissions from the supply of the equivalent typical UK fossil fuel generated electricity that the Consented Development would offset.

14.4.2 Additional design parameters and full carbon calculator output sheets can be found in Appendix 14.1.

14.4.3 For this assessment a capacity factor of 46.3% of the total installed capacity was used to calculate the average annual electricity generation of the Consented Development. The capacity factor takes into account high wind speeds in the area and is based on the results from a nearby existing windfarm (for details see Appendix 3.4: Estimated Energy Generation). The Consented Development would have an installed capacity of 57.8MW and is expected to generate approximately 234,430MWh per year.

14.4.4 The GHG emission saving was calculated using GHG emission factors listed in Table 14.2 shows the GHG emissions for three different types of electricity sources which would be produced to generate the 234,430MWh per year of electricity, which the Consented Development is predicted to generate.

Table 14.2 Grid GHG emission factors and the equivalent annual emissions

	GHG emissions factor	***GHG emissions that would be saved by the Consented Development (t CO_2e yr-1)***		
	t CO_2e MWh^{-1}	Expected	Min.	Max.
Coal-fired	0.92	205,675	194,248	237,103
Grid-mix	0.254	59,447	53,541	65,353
Fossil fuel-mix	0.45	105,493	95,012	115,974

14.4.5 By replacing the fossil fuel generated electricity, it is estimated that the development would save 150,504t CO_2e per year, equating to 3,762,600t CO_2e over the anticipated 25-year project life.

14.5 Assessment of potential effects

14.5.1 The main sources of GHG emissions generated as a result of the Consented Development would be during manufacture of the turbines and components and loss of peat during the construction phase. The emissions from turbine life were calculated according to the turbine capacity using formula embedded in the carbon calculator. This includes all losses associated with manufacture of the turbines, construction and decommissioning activities. Volumes of concrete used for construction were estimated from the design parameters and entered separately into the tool.

14.5.2 Table 14.3 details the predicted GHG emissions associated with the various elements of the Consented Development. These calculations have been updated to take account of the proposed variation increasing the lifetime of the Consented Development to 40 years. It includes losses due to damage to vegetation in disturbed areas (losses due to reduced carbon fixing potential), losses from soil organic matter, and losses due to leaching of dissolved and particulate organic carbon. The loss from soil organic matter (peat) comprises losses due to enhanced oxidation (result of drainage) and peat removal. It is planned that all surplus excavated peat, not used for restoration near place of excavation, will be used to restore degraded areas (see Appendix 3.6: OCEMP). For the purpose of the carbon balance calculations, it was assumed that up to 10, 0, and 20% (expected, min., max. values) would be removed.

Table 14.3 Total GHG emissions due to the Consented Development (t CO_2e)

	Expected (t CO_2e)	***Min. (t CO_2e)***	***Max. (t CO_2e)***
Losses due to turbine life (e.g., manufacturing, construction, decommissioning)	50,140	50,140	50,140
Losses due to backup (fossil-fuel mix of electricity generation)	45,570	45,570	45,570
Losses due to reduced carbon fixing potential	2,065	659	4,643
Losses from soil organic matter (peat)	150,677	74,359	187,262
Losses due to dissolved organic carbon and particulate organic carbon leaching	2,853	179	10,817
Losses due to felling forestry	0	0	0
Total gross GHG emissions (t CO_2e)	251,304	170,907	298,432

14.5.3 Comparing the GHG emissions created by the Consented Development with the GHG emissions saved by offsetting the current typical fossil fuel-mix electricity, enables the carbon balance of the Consented Development to be derived. Table 14.4 summarises the estimates of GHG emissions over the proposed varied lifetime of the wind farm (40 years rather than 25) and the payback time (the time after which GHG emissions generated by the Consented Development would have been offset by the replacement of the energy from other sources).

Table 14.4 Summary of GHG emissions and payback time

	Expected	***Min.***	***Max.***
Total gains due to improvement of the Site (restoration of degraded bogs, borrow pits, removal of drainage from foundations and hardstanding) (t CO_2e)¬	58,131	9,682	119,013
Net GHG emissions of the Proposed Development (t CO_2e)	189,450	43,982	297,140
GHG emissions from equivalent amount of fossil fuel derived electricity (t CO_2e)	4,219,720	3,800,480	4,638,960
Net GHG emissions benefit (t CO_2e)	4,030,270	3,756,498	4,341,820
Payback time for coal-fired plant electricity (years)	0.9	0.2	1.5
Payback time for grid-mix (years)	3.2	0.7	5.4

Payback time for fossil fuel-mix (years)	1.8	0.4	3.0

14.6 Cumulative impacts

14.6.1 The cumulative effect of the Consented Development on GHG emissions arising from the manufacture, construction, operation, and decommissioning of other wind farms is broadly linear. The increase in installed capacity arising from the development of other wind farms results in a proportional decrease in GHG emissions that would otherwise be emitted if the same amount of electricity were to continue to be generated through conventional fossil fuel means. The Consented Development would therefore make a positive cumulative contribution to wider efforts to increase renewable electricity generation and contribute to reduction in GHG emissions associated with electricity generation.

14.7 Mitigation measures

14.7.1 Mitigating GHG emissions associated with the manufacture of turbines and components and backup electricity generation would be outside the control of the Applicant and, therefore is not considered in this assessment. As such, minimising the disturbance of peat through site design is the most effective way to mitigate the generation of GHG emissions as a result of the Consented Development. Mitigation measures have been considered in Chapter 12: Soils and Peat.

14.7.2 The design of the turbine layout was adjusted to minimise the area, depth and, as a consequence, the volume of excavated or disturbed peat. Chapter 5: Design Evolution & Alternatives provides a summary of the design process. Prior to the layout being finalised peat depth surveys were completed and this data was used to inform this assessment (see Chapter 12: Soils and Peat).

14.8 Residual effects

14.8.1 Considering that the turbine layout minimises peat disturbance as much as practically possible given other constraints, the residual GHG emissions of the Consented Development are equal to the GHG emissions calculated by the carbon calculator i.e., all relevant mitigation measures were taken into account in the carbon balance calculations and as such it is not deemed possible to reduce GHG emissions through any further mitigation measures.

14.9 Monitoring

14.9.1 Monitoring of peat condition and restoration progress has been addressed in the Appendix 10.4: OHMP and Appendix 3.6: OCEMP. Peat landslide risk will be managed through the Geotechnical Risk Register prepared as a part of Appendix 12.2: Peat Slide Risk Assessment.

14.10 Summary

14.10.1 The original EIAR predicted that the Consented Development would lead to an overall reduction in GHG emissions of 3,602,653 tCO_2e over its 25 year life with a predicted GHG emissions payback time of 1.1 years. Updated calculations suggest that, over a 40 year lifetime and taking into account the evolution of the UK energy mix since the original assessment, the overall reduction in GHG emissions would be 4,030,270 tCO_2e with a predicted GHG emissions payback time of 1.8 years.

14.10.2 Therefore, the wind farm would continue to have a significant, positive effect on GHG emissions and over a longer length of time. As a result, it would contribute to a considerable overall reduction in GHG emissions compared to electricity generation from fossil fuels.

[1] Scottish Government 2014 Windfarm Carbon Assessment Tool - Version 2.9.0, available at: http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/CC2-9-0

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[3] Royal Academy of Engineering 2014 Wind Energy, implications of large-scale deployment on the GB electricity system, available at: http://www.raeng.org.uk/publications/reports/wind-energy-implications-of-large-scale-deployment

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[11] DECC 2015 Digest of United Kingdom Energy Statistics 2015, available at: https://www.gov.uk/government/statistics/digest-of-united-kingdom-energy-statistics-dukes-2015-printed-version

[12] Defra 2015 Greenhouse Gas Conversion Factor Repository, available at: http://www.ukconversionfactorscarbonsmart.co.uk/