



**PEEL WIND FARMS (YELL) LIMITED**

**Beaw Field Wind Farm**

**Appendix 3.4 Estimated Energy Generation**

**March 2016**

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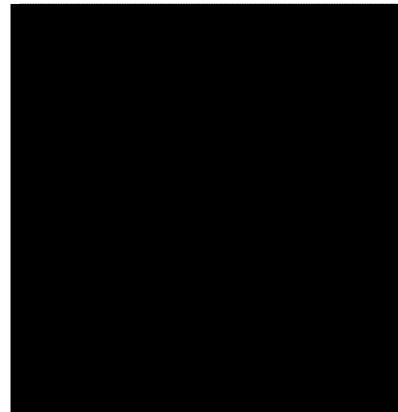
**March 2016**

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## 1 ESTIMATED ENERGY GENERATION

### 1.1 Introduction

1.1.1 This appendix provides an estimate of the energy yield of the Proposed Development and its equivalence to average household energy demand. The comparison with average household energy demand helps to put in context the amount of energy generated during a year of operation and the carbon emissions that this would offset. Chapter 14 provides further assessment of the carbon balance that would result from the construction and operation of the Proposed Development, considering among other things, the life cycle of the turbine and the release of carbon and other greenhouse gases (GHG) that result from the disturbance to soil and peat.

1.1.2 The candidate turbine selected for the Proposed Development is the Senvion 3.4M. The turbine has a hub height of 91m and a rotor diameter of 104m. Table 1 shows the installed capacity of the Proposed Development and how this is calculated.

**Table 1: Main Capacity Parameters of the Proposed Development**

<i>Turbine Details</i>	
Turbine Details	Senvion 3.4MW
Hub Height	91 m
Installed Capacity (per turbine)	3.4 MW
Number of Turbines on site	17
Installed Capacity (site)	57.8 MW
Wind speed at hub height	9.97 m/s

### 1.2 Methodology

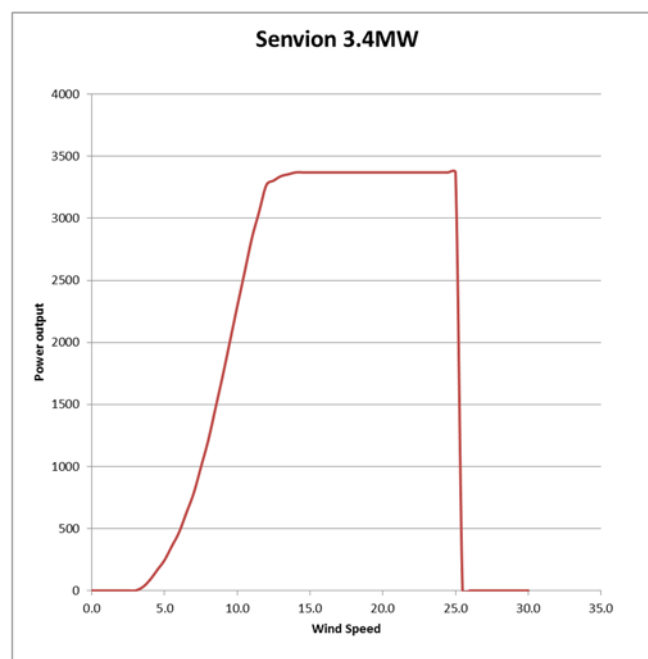
1.2.1 In the absence of onsite wind data, wind resource data from various sources have been combined to provide an indication of the likely wind regime at the Site. The resultant mean wind speed is subject to considerable uncertainty due to the lack of onsite measurements and the resolution of data sources. Nevertheless it is useful to consider these sources to obtain an approximate measure of the energy generation for the Proposed Development.

1.2.2 The resultant predicted average wind speed at turbine hub height was estimated to be 9.97 m/s. This was obtained from weighted averages of the following sources:

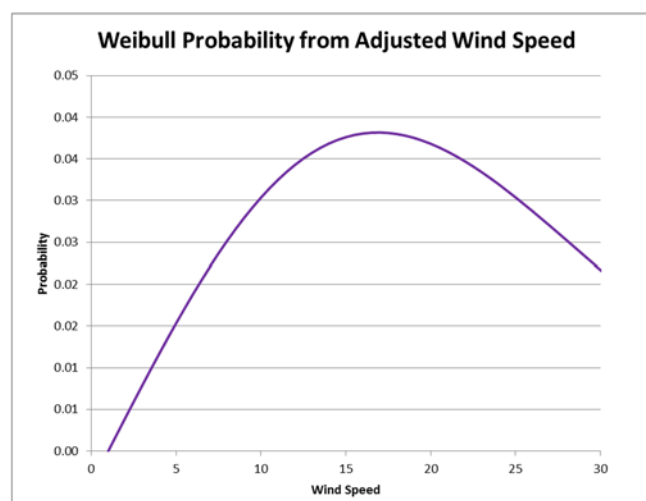
- The Met Office Virtual Met Mast (MOVMM) report for the Site, which gave an average of 9.9m/s at 100m height.

- The NOABL (Numerical Objective Analysis of Boundary Layer) wind atlas, whose gridded estimates at 45m height were corrected and adjusted for hub height.
- (ROC) Renewable Obligation Certificate data from nearby wind farms. Data from Burradale Wind Farm phase 2, consisting of 2 Vestas V52 machines at 45m hub height showed a good correlation with MERRA (Modern-Era Retrospective Analysis for Research and Applications) data and was used to obtain an estimate of the long-term mean wind speed at the Site, 10.1m/ at 100m height.

1.2.3 The wind speed frequency for the Site has been derived from a Weibull distribution with shape parameter of 2 and scale parameter 11,253. This is shown in Graph 1.



**Graph 1: Power curve of the Senvion 3.4MW**



**Graph 2: Weibull Probability Distribution for Wind Speed Adjusted to Hub Height**

1.2.4 The annual energy generation per turbine is given by multiplying each of the discrete wind speed frequency ‘bins’ that make up the wind distribution curve (derived from Graph 2) by the respective power generation taken from the wind turbine power curve (Graph 1). The outputs of these calculations are shown below in Table 2.

1.2.5 Data on the published power curve is taken from manufacturer specification in accordance with IEC – 61400-12-1: 2005. This assumes that the terrain is non-complex, that there are no areas of forest in the vicinity and that there is no vertical wind shear present. In reality this will not be the case. Losses due to wake effects, availability and electrical losses will reduce the overall generation. These have been estimated to be 14.6%, as shown in Table 2.

Turbine Loss	%
Array/Wake	0.060
Not Available	0.056
Electrical	0.030
Total	0.146

**Table 2: Turbine losses**

1.2.6 The annual energy production for the Site after turbine losses is estimated to be 234 GWh.

Turbine		Weibull Distribution	Hours per year of wind speed	Energy produced per year under wind conditions (kWh)
Wind Speed	Power Output (kW)	Probability of Wind speed		
0.0	0	0.00	0	-
0.5	0	0.00	35	-
1.0	0	0.01	69	-
1.5	0	0.01	102	-
2.0	0	0.02	134	-
2.5	0	0.02	165	-
3.0	0	0.02	193	-
3.5	28	0.03	220	6,154
4.0	87	0.03	244	21,216
4.5	166.5	0.03	265	44,170
5.0	246	0.03	284	69,842
5.5	358.5	0.03	300	107,413
6.0	471	0.04	312	147,115
6.5	627	0.04	322	201,945
7.0	783	0.04	329	257,491
7.5	996	0.04	333	331,405
8.0	1209	0.04	334	403,624
8.5	1471	0.04	332	488,876
9.0	1733	0.04	328	569,116
9.5	2013	0.04	322	648,641
10.0	2293	0.04	314	720,118
10.5	2566	0.03	304	780,357
11.0	2839	0.03	293	830,881
11.5	3054	0.03	280	855,000
12.0	3269	0.03	266	870,361
12.5	3304.5	0.03	252	831,971
13.0	3340	0.03	237	790,781
13.5	3355	0.03	221	742,938
14.0	3370	0.02	206	694,271
14.5	3370	0.02	191	642,538
15.0	3370	0.02	176	591,613
15.5	3370	0.02	161	541,975
16.0	3370	0.02	147	494,030
16.5	3370	0.02	133	448,114
17.0	3370	0.01	120	404,492
17.5	3370	0.01	108	363,363
18.0	3370	0.01	96	324,864
18.5	3370	0.01	86	289,077
19.0	3370	0.01	76	256,031
19.5	3370	0.01	67	225,713
20.0	3370	0.01	59	198,071
20.5	3370	0.01	51	173,020
21.0	3370	0.01	45	150,453
21.5	3370	0.00	39	130,240
22.0	3370	0.00	33	112,238
22.5	3370	0.00	29	96,292
23.0	3370	0.00	24	82,246
23.5	3370	0.00	21	69,939
24.0	3370	0.00	18	59,213
24.5	3370	0.00	15	49,912
25.0	3370	0.00	12	41,889
25.5	0	0.00	10	-
26.0	0	0.00	9	-
26.5	0	0.00	7	-
27.0	0	0.00	6	-
27.5	0	0.00	5	-
28.0	0	0.00	4	-
28.5	0	0.00	3	-
29.0	0	0.00	3	-
29.5	0	0.00	2	-
30.0	0	0.00	2	-

1.00 8751 16,159,010 kWh per turbine (before losses)

13,789,938 kWh per turbine (after losses)

234,429 MWh for the wind farm

**Table 3: Wind speed frequency table with energy generation**

### 1.3 Carbon savings equivalent household energy demand

1.3.1 With an installed capacity of 57.8 MW, the Proposed Development is estimated to generate 234GWh per year. This is equivalent to the average annual electrical demand of approximately 59,879 Scottish households<sup>1</sup>, or 2% of the national total and five times the number of households on the Shetland Islands<sup>2</sup>.

1.3.2 To calculate the number of households whose annual electricity demand would equal the output of the Proposed Development, domestic electric consumption figures are taken from the aggregate data provided by DECC as part of their annual meter point electricity data collection exercise<sup>1</sup>. Mean domestic electricity consumption per meter is 1% less in Scotland than in the whole of Great Britain as shown in Table 4.

<b>Scenario</b>	<b>Homes Equivalent - England</b>	<b>3976kWh/hm</b>
100%	58,961	Homes
	<b>Homes Equivalent - Scotland</b>	<b>3915kWh/hm</b>
100%	59,880	Homes
	<b>Homes Equivalent - Great Britain</b>	<b>3954kWh/hm</b>
100%	59,289	Homes

**Table 4: Energy Demand Homes Equivalent in England, Scotland and Great Britain**

1.3.3 The estimated CO<sub>2e</sub> that the energy generated by the Proposed Development would offset in a year is 108,351 tonnes. Carbon emissions equivalent is the universal unit of measurement to indicate the global warming potential (GWP) of Greenhouse Gases (GHGs), expressed in terms of the GWP of one unit of carbon dioxide. This conversion factor applies to electricity supplied to the grid and does not include the emissions associated with the transmissions and distribution of electricity<sup>3</sup>.

<sup>1</sup> DECC, Department of Energy & Climate Change, Sub-national electricity and gas consumptions statistics, 22 December 2015, available at: [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/489723/Sub-national\\_electricity\\_and\\_gas\\_consumption\\_summary\\_report\\_2014v2.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/489723/Sub-national_electricity_and_gas_consumption_summary_report_2014v2.pdf) (accessed: 20/01/2016)

<sup>2</sup> National Records of Scotland, Shetland Islands Council Area-Demographic Factsheet, updated 17/12/2015, available at: <http://www.nrscotland.gov.uk/search/node/shetland%20islands...> (accessed: 20/01/2016)



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<sup>3</sup> DEFRA 2015 Greenhouse Gas Conversion Factor Repository, available at <http://www.ukconversionfactorscarbonsmart.co.uk/>, (accessed: 20/01/2016).