Garrad Hassan America, Inc
11770 Bernardo Plaza Court
Suite 209
San Diego, California
92128

Tel: (1) 858-451-7013
Fax: (1) 858-451-1570

GARRAD HASSAN

Document Details

Title	**Update of Sheffield Wind Farm Energy Assessment for the Gamesa G87 – Addendum to 4776/AR/01a**
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Author	**Ryan Adams**
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INTRODUCTION

UPC Wind Management (UPC) are developing the Sheffield Wind Farm project in Vermont. Garrad Hassan America (GH) has carried out an independent assessment of the wind climate and expected energy production of the proposed wind farm for a variety of turbine options as reported in [1]. In addition to this, UPC has requested that GH undertake an update of the Sheffield Wind Farm energy assessment employing the Gamesa G87 turbine at 78 m hub height for an installed capacity of 52 MW. The results of this are reported here. It should be noted that this technical note therefore represents an addendum to and should be read in conjunction with the previous report [1].

METHODOLOGY AND RESULTS

In order to estimate the expected energy production at the Sheffield Wind Farm, it is imperative that sufficient wind data be recorded at the site. As detailed previously [1], historical wind speed and direction measurements have been recorded at 23 m, 30 m, 40 m and 48 m height throughout the Sheffield site over a period of approximately 2.4 years. GH considers these data in conjunction with long-term data from the Burke Mountain reference station to be sufficient for this review.

The data and methodology that have been employed within this assessment are identical to those employed within the analysis as reported in [1]. By applying the measured shear at each mast location the long-term mean wind speed at Masts 4716 and 5211 at 78 m are predicted to be 8.2 m/s and 6.6 m/s, respectively.

UPC has supplied the layout for the turbines [2]. A map of the site showing the proposed Sheffield Wind Farm is presented in Figure 1. The corresponding grid reference of each of the turbines is given in Table 1.

It is noted that some of the turbines near Mast 4716, in particular Turbines 1, 14, 20, and 13, have an inner-turbine spacing of approximately 3.2 rotor diameters in the northeast-southwest alignment. Though these direction sectors are non-prevailing winds, it is recommended that the turbine manufacturer be approached at an early stage to gain approval for the layout.

The variation in wind speed over the wind farm site has been predicted using the WAsP computational flow model as described in Appendix I of [1]. These outputs have then been employed within the GH WindFarmer modelling software to predict the expected energy production at the Sheffield Wind Farm.

Table 1 shows the predicted long-term mean wind speed and energy capture of each turbine location at hub height for Sheffield. The projected energy production of the Sheffield Wind Farm is detailed in the table below and definitions of the various loss factors are presented in [1].

[1] 4776/AR/01a "Assessment of the Energy Production of the Proposed Sheffield Wind Farm," Ryan Adams, 25 May 2005.
[2] Email from Mohit Dua, UPC, to Ryan Adams, GH, on 23 September 2005.

Rated Power	**52**	**MW**
Ideal output	194.1	GWh/annum
Topographic effect	89.3 %	GH calculated
Wake effect	94.5 %	GH calculated
Electrical efficiency	97.0 %	GH assumption
Availability	97.0 %	GH assumption
Icing and blade degradation	97.0 %	GH assumption
Low temperature shutdown	99.0 %	GH assumption
High wind hysteresis	99.9 %	GH estimate
Substation maintenance	99.8 %	Typical value
Utility downtime	100.0 %	Not considered by GH
Power curve adjustment	100.0 %	GH estimate
Wind sector management	100.0%	100.0%
Wake effect from other sites	100.0%	100.0%
Net output	**147.6**	**GWh/annum**
Capacity Factor	**32.4 %**	

The main sources of deviation from the central estimate have been quantified and are presented in Tables 2 and 3 for those turbines initiated from Masts 4716 and5211. The figures in each table are added as independent errors giving the following uncertainties in net energy production for the wind farm. These represent the standard deviations of what is assumed to be a Gaussian process:

In any one year period	23.2	GWh/annum
In any ten year period	17.8	GWh/annum

CONCLUSIONS

1. The long-term predicted mean wind speed averaged over all turbine locations at hub height is estimated to be 7.3 m/s.

2. The projected energy capture of the proposed wind farm is 147.6 GWh/annum. This includes calculation of the topographical, array and air density effects and assumptions or estimates for electrical transmission losses, availability, power curve adjustment, high wind hysteresis, substation maintenance, wind sector management, and the effect of blade fouling or icing.

3. The standard error associated with the prediction of energy capture has been calculated and the confidence limits for the prediction are given in the table below:

Probability of Exceedance [%]	**Net energy output**	
	1 year average [GWh/annum]	**10 year average [GWh/annum]**
90	117.8	124.7
75	131.9	135.5
50	147.6	147.6

These results should be considered in conjunction with the recommendations made in [1].

Turbine ID	Easting[1] [m]	Northing[1] [m]	Mean hub-height wind speed[2] [m/s]	Energy output[3] [GWh/annum]
1	730475	4951425	8.2	7.3
2	732025	4951775	8.2	7.5
3	730275	4951125	8.1	7.0
4	728600	4950175	7.9	7.6
5	730125	4951500	8.0	7.2
6	731500	4951825	7.8	7.3
7	730600	4951000	7.9	6.7
8	730525	4950425	7.7	6.9
9	730369	4950775	7.5	6.4
10	729925	4951175	7.3	6.3
11	729775	4951525	7.2	6.3
12	729450	4950447	7.1	6.1
13	731228	4951725	7.6	7.0
14	730727	4951513	7.3	6.4
15	731775	4951975	7.5	6.7
16	728842	4950350	7.4	6.7
17	731850	4951525	7.4	6.5
18	729125	4950900	7.4	6.6
19	729525	4951050	7.3	6.4
20	730968	4951633	7.0	6.2
21	730350	4946550	6.7	5.2
22	730550	4947050	6.6	5.3
23	730300	4946150	6.4	4.9
24	730025	4947650	6.2	4.7
25	730325	4947325	6.2	4.5
26	730025	4946425	6.0	4.4

Notes
1 Co-ordinate system is UTM NAD27
2 Wind speed at the location of the turbine, not including wake effects
3 Individual turbine output figures include topographic, array and air density adjustments only

Table 1 Turbine layout with predicted individual turbine wind speed and energy production

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer accuracy	3.0			
Correlation accuracy to Burke Mountain	2.8			
Shear prediction to 78 m	3.0			
Variability of 7.1 year period	2.2			
Overall historical wind speed		**0.46**		**11.5**
Substation metering			0.3	0.4
Wake and topographic calculation			6.0	7.3
Representative frequency distribution			0.5	0.6
Future wind variability (1 year)	6.0	0.49		12.4
Future wind variability (10 years)	1.9	0.16		3.9
Overall energy uncertainty (1 year)				**18.5**
Overall energy uncertainty (10 years)				**14.2**

Note: Sensitivity of net production to wind speed is calculated to be 25.2 GWh/annum.(m/s)

Table 2 Uncertainty in projected energy output of Turbines 1 to 20 based on Mast 4716 – G87 x 26

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer accuracy	2.5			
Correlation accuracy to Burke Mountain	4.2			
Shear prediction to 78 m	2.5			
Variability of 7.1 year period	2.2			
Overall historical wind speed		**0.39**		**3.3**
Substation metering			0.3	0.1
Wake and topographic calculation			4.0	1.0
Representative frequency distribution			0.5	0.1
Future wind variability (1 year)	6.0	0.40		3.3
Future wind variability (10 years)	1.9	0.13		1.1
Overall energy uncertainty (1 year)				**4.8**
Overall energy uncertainty (10 years)				**3.6**

Note: Sensitivity of net production to wind speed is calculated to be 8.4 GWh/annum.(m/s)

Table 3 Uncertainty in projected energy output of Turbines 21 to 26 based on Mast 5210 – G87 x 26

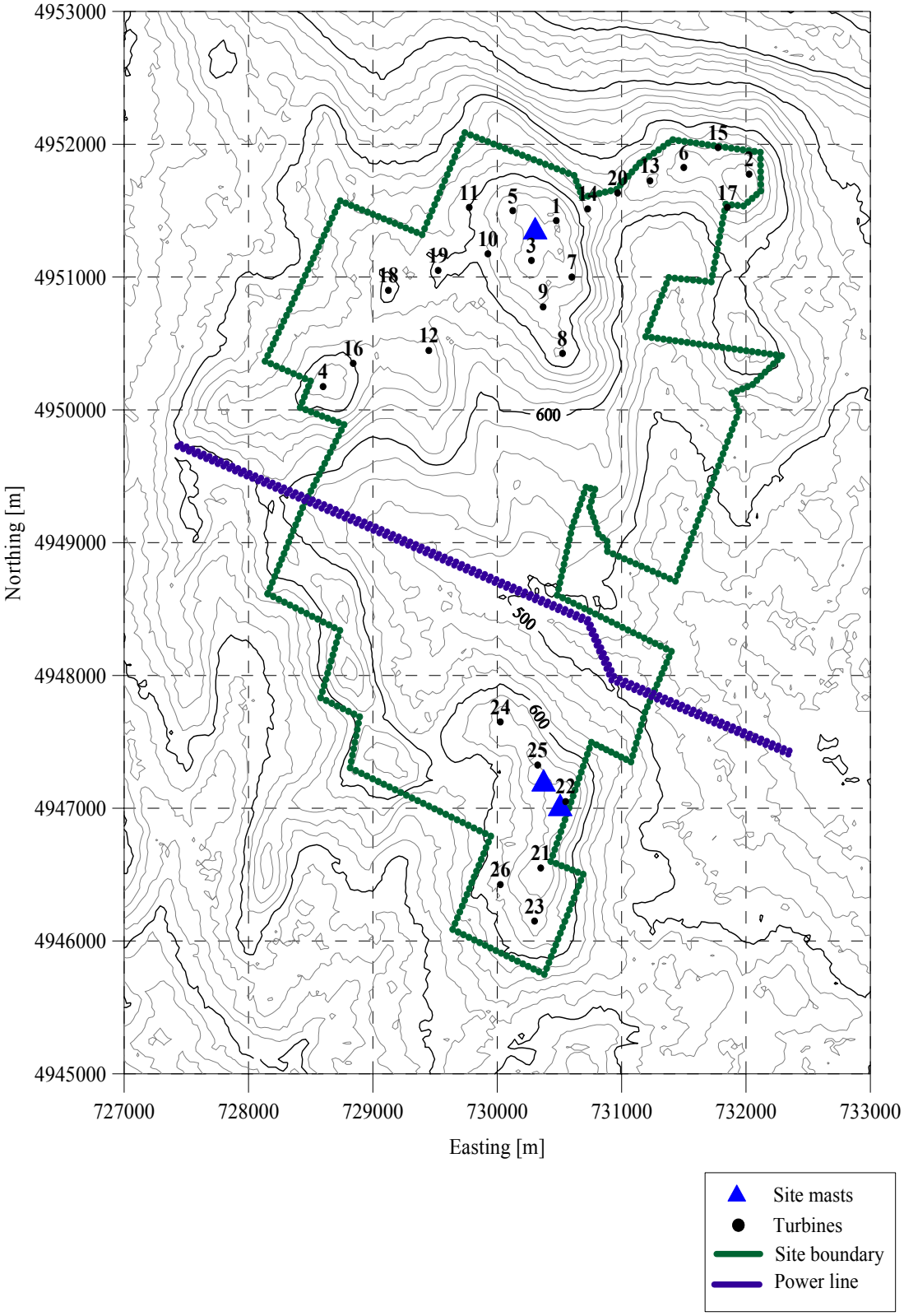

Figure 1 Layout of the Sheffield Wind Farm