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Witness: David C. Gomez
REDACTED VERSION

BEFORE THE WASHINGTON
UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY,** **Respondent.**	**DOCKETS UE-170033 and UG-170034 (*Consolidated*)**

EXHIBIT TO
TESTIMONY OF

David C. Gomez

STAFF OF
WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

PSE's Response to Staff DR No. 311, Preconstruction Forecasts; Hopkins Ridge, Wild Horse, Wild Horse Expansion, Lower Snake River and Klondike III, Attachments B through F

CONFIDENTIAL PER PROTECTIVE ORDER – REDACTED VERSION

ASSESSMENT OF THE ENERGY PRODUCTION OF THE PROPOSED HOPKINS RIDGE WIND FARM

Client	**Puget Sound Energy**
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GH has not conducted wind measurements itself and cannot, therefore, be responsible for the accuracy of the data supplied to it.

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1 INTRODUCTION

Renewable Energy Systems (RES) is developing the Hopkins Ridge Wind Farm in Washington. Puget Sound Energy (PSE), as potential investors, have retained Garrad Hassan America (GH) to carry out an independent assessment of the wind climate and expected energy production of the proposed wind farm. The results of the work are reported here.

A description of the long-term wind climate at a potential wind farm is best determined using wind data recorded at the site. RES has supplied approximately 3 years of data recorded at the Hopkins Ridge site to GH.

When only a short period of site data are available, it is usual to combine the site measurements with long-term measurements from a local meteorological station. RES has supplied data from a reference meteorological station located near Kennewick, however, given the poor level of correlation to the site, this reference has not been considered in the assessment. As a result, there is additional uncertainty associated with the assumption that the three year period of site data is representative of the long-term.

The proposed layout and turbine model currently under consideration have been supplied by RES. These have been analysed here, in conjunction with the results of the wind analysis, to predict the long-term energy output of the proposed wind farm.

2 DESCRIPTION OF THE SITE AND MONITORING EQUIPMENT

2.1 The site

The site is located in the southeast region of Washington State approximately 150 km south-southwest of Spokane, as shown in Figure 2.1.

The proposed wind farm is located to the northwest of the Blue Mountains and lies within an area comprised of rolling hills and several ridges of elevation between approximately 500 m and 800 m. The escarpments to the northeast of the site, dropping into the Tucannon River Valley, are aligned approximately perpendicular to the predominant south-southwest wind direction. The general terrain at the site can be described as complex with local vegetation consisting of winter wheat and hay fields throughout.

It is noted that there are areas of dense forest approximately 20 km to the south-southeast of the site. Due to this distance with regard to the predominant wind direction for this region this is not expected to have a significant impact on this assessment.

A more detailed map showing the site area is presented in Figure 2.2, which also shows the location of the anemometry masts. A view of the site is shown in Figure 2.3 as seen from Mast 35 facing southwest.

The surface roughness length of the site and surrounding area was assessed during a site visit made by GH staff. Following the Davenport classification [2.1], the following general figures are considered appropriate:

Site and surrounding areas	0.03 m
Wooded areas	0.3 m

2.2 Monitoring equipment

Details of the measurements recorded on site and the grid co-ordinates of each mast are presented in Table 2.1.

The wind data have been recorded using Campbell Scientific loggers throughout with Vector Instruments anemometers and wind vanes.

Campbell Scientific CR10X and CR510 data loggers have been utilised, programmed to record ten-minute mean wind speed and direction, wind speed and direction standard deviation, instantaneous gust and 3-second gust. It is noted that in the case of Mast 35 a short segment of five-minute data was recorded for the period of 8 September 2002 to 22 October 2002. The following transfer function was applied to the output signal from the anemometers by these data loggers:

$$\text{Recorded wind speed [m/s]} = 1 \text{ [m/s/Hz]} \times \text{Data frequency [Hz]} + 0 \text{ [m/s]}$$

The anemometers on the site have been individually calibrated. The individual calibrations have been retrospectively applied by GH to all the data recorded on the site masts.

All of the anemometers used at the site have been calibrated by the Deutsches Windenergie-Institut GmbH, DEWI (German Wind Energy Institute), a MEASNET certified facility. Copies of the calibration certificates are included in Appendix 2.

Maintenance records for the site measurements have been provided. The standard of documentation is good and certainly sufficient to ensure full traceability of the instrumentation.

The site comprises of eight Rohn-25G lattice towers. The towers have a face width of 12 inches with the top of the towers at approximately 53 m height above ground level. All towers with the exception of Mast 153 have an additional top mount extension of 2.75 m resulting in a total tower height of approximately 56 m.

The exact heights of the instruments have been provided in the RES site masts commissioning forms [2.2]. Instruments mounted on Masts 33 and 35 include boom-mounted anemometers at 56 m and 30 m and a wind vane at 54 m. Instruments mounted on Masts 37, 85, 87, 88 and 154 include boom-mounted anemometers at 56 m and 35 m and a wind vane at 54 m with an additional wind vane at 34 m at Masts 85 and 154. Instruments mounted on Mast 153 include boom-mounted anemometers at 53 m and 36 m and wind vanes at 50 m and 34 m. All site masts include a temperature sensor at approximately 3 m and Masts 35 and 88 include a barometric pressure sensor at approximately 3 m.

All anemometers are mounted on booms approximately 3.5 to 5 mast face widths long oriented to the west at all masts except for Masts 33 and 35 where the booms are oriented to southwest. The booms are comprised of square stock approximately 1 inch square. The cups of the anemometers are approximately 10 boom diameters above the boom. These mounting arrangements are broadly consistent with the recommendations of the IEA [2.3].

It is noted that the Mast 35 CR10X data logger had failed and was replaced by a new CR10X data logger on 23 June 2003. The CR510 data loggers at Masts 153 and 154 were recalled by Campbell Scientific due to possible communication failures [2.2] and were subsequently replaced with new CR510 data loggers on 23 June 2003. It is assumed that these changes are not to have any effect with respect to the consistency or validity of the measurements.

It is noted that, as a consequence of the locations of Masts 35, 85, 88 and 154 with respect to the proposed turbine layout, these data were not required for the present analysis. Given the period of data from Mast 33, these data were retained for the assessment as an onsite reference only.

3 SELECTION OF A REFERENCE METEOROLOGICAL STATION

In the assessment of the wind regime at a potential wind farm site it is generally necessary to correlate data recorded on the site with data recorded from a nearby long-term reference meteorological station. Wind data at a site are often only recorded for a short period and such correlation is required to ensure that the estimates of the wind speeds at the site are representative of the long-term. When selecting an appropriate meteorological station for this purpose it is important that it should have good exposure and that data are consistent over the measurement period being considered.

A meteorological station located at Kennewick has been identified by RES as a potential reference station and wind data have been supplied to GH for the period from 1994 to 2004. This station is operated as part of the Oregon State University Energy Resources Research Laboratory network. This station is situated approximately 100 km west-southwest of the site. It is noted, however, that due to poor correlations between the Kennewick reference station and the site, Kennewick is not considered to be suitable as a quantitative long-term reference in this assessment.

The analysis of the long-term wind regime therefore relies on data recorded at the Hopkins Ridge site since July 2001. This data set is of shorter duration than that which is ideal, and the uncertainty associated with assuming this period to be representative of the long-term is considered in Section 6.

4 WIND DATA

4.1 Wind data recorded at the site

The data sets which have been used in the analysis described in the following sections are summarised in Table 2.1.

The wind data have been subject to a quality checking procedure by GH to identify records which were affected by equipment malfunction and other anomalies. The check of the site mast data revealed several hours where wind speed data were missing or suspect. These data were excluded from the analysis. The main periods for which valid data were not available are summarised below, together with details of the errors identified:

Mast 35

- Datalogger malfunction: 24 May 2003 to 23 June 2003.

Mast 37

- 56 m anemometer malfunction: 29 March 2002 to 17 May 2002.

The duration, basic statistics and data coverage for the Masts 33, 37, 87 and 153 data are summarised in Tables 4.1 through 4.4..

5 DESCRIPTION OF THE PROPOSED WIND FARM

5.1 The wind turbine

The turbine which is proposed for the Hopkins Ridge Wind Farm is the Vestas V80 IEC Class 1 machine. The basic parameters of the turbine are presented in Table 5.1.

The power curve used in this analysis has been supplied by RES [5.1] and is presented in Table 5.2. This power curve is for an air density of 1.15 kg/m³, and a turbulence intensity of 10 %.

The supplied power curve is based on measurement and exhibits a peak power coefficient, Cp, of 0.47. This is considered to be high but attainable for a modern wind turbine. No review of the supplied power curve against a measured power curve from an independent test of the performance of the wind turbine has been undertaken at this stage.

Using historical pressure and temperature records from nearby meteorological stations and standard lapse rate assumptions, GH has estimated the long-term mean air density at the site to be 1.152 kg/m³ at an average hub elevation of 712 m above sea level.

The supplied power curve used in this analysis has been adjusted to the predicted site air density, in accordance with the recommendations of [5.2]. This has been undertaken on an individual turbine basis.

5.2 Wind farm layout

RES have supplied the layout for the Wind Farm [5.1]. A map of the site showing the wind turbine locations is presented in Figure 5.1 with the grid reference of each of the turbines given in Table 5.3.

It is noted that inter-turbine spacing of as small as 1.9 rotor diameters is proposed. Even though these separations are in non-prevailing wind directions, the increased turbulence levels will increase fatigue loads. It is noted that at this stage GH is not aware of any wind sector management strategy that may be employed at the site. It is strongly recommended that the turbine supplier be approached at an early stage to gain approval for the proposed layout.

6 RESULTS OF THE ANALYSIS

The analysis of the wind farm involved several steps, which are summarised below:

- The long-term mean wind speed and direction frequency distribution at Mast 37 at 56 m height was derived for the period from September 2001 to August 2004.
- Data recorded at Masts 87 and 153 were correlated to data recorded at Masts 33 and 37, respectively. These correlations were used to synthesise data at Masts 87 and 153 to develop the long-term wind speed and direction frequency distributions.
- The measured shear derived at the masts was used to extrapolate the mast height long-term mean wind speed and direction frequency distributions to the proposed hub height of 67 m.
- Wind flow modelling was carried out to determine the hub height wind speed variations over the site relative to the anemometry masts.
- The energy production of the wind farm was calculated taking account of array losses, topographic effects, availability, electrical transmission efficiency, air density effects and other potential losses.
- An assessment of the uncertainty in the predicted wind farm energy production was undertaken.

A more complete description of the methods employed is included in Appendix 1.

6.1 Long-term mean wind regime at Mast 37 at mast height

As detailed in Section 4, wind measurements from Mast 37 over a period of approximately 2.8 years were available for the analysis. From the 2.8 years of measurements a total of approximately 2.6 years of valid wind data were available. As noted in Section 4, the 56 m anemometer malfunctioned in March 2002 and was replaced with a new anemometer in May 2002. In order to account for the missing wind speed measurements for this period, it is considered appropriate to synthesise missing data through a correlation analysis with the 35 m anemometer. The correlation of ten minute mean wind speeds on a directional basis was therefore undertaken between the 56 m and 35 m measurements and the results used to synthesise 10-minute data on a directional basis.

In order to avoid the introduction of bias into the annual mean wind speed estimate from seasonally uneven data coverage, the following procedure was followed:

- The mean wind speed and direction frequency distribution for each month was determined from the average of all valid data recorded in that month over the period. This was taken as the monthly mean thereby assuming that the valid data are representative of any missing data.
- The mean of the monthly means was taken to determine the annual mean ("mean of means") to eliminate the effect of seasonal bias in the data.

[redacted]

6.2 Long-term mean wind regime at Masts 87 and 153 at mast height

As described in Section 4, valid wind measurements at Masts 87 and 153 over periods of approximately 2.2 years and 1.5 years, respectively, were available for the analysis. In order to reference these data to the longer term, a correlation analysis between Masts 33 and 37 were undertaken. The correlations of ten-minute mean wind speeds on a directional basis were therefore undertaken between Masts 33 and 87 and between Masts 37 and 153.

Data have been recorded at Masts 87 since April 2002. In order to extend the duration of the reference period used for the analysis of the wind regime at the site a correlation approach described in Appendix 1 was used to synthesise the wind speed at Mast 87 at 56 m from data recorded at Mast 33 at 56 m over the period July 2001 through April 2002 and small intermittent periods continuing through August 2004. As a check of the validity of the synthesis methodology, synthesised data were compared with concurrent periods of measured data and were noted to be in close agreement. By combining the actual data recorded at Mast 87 at 56 m and the synthesised data from Mast 33, approximately 3.0 years of valid wind speed data were obtained. The long-term mean wind speed and direction frequency distribution for Mast 87 at 56 m was derived, as for Mast 37 above, from these data.

The measured wind speeds at Mast 87 at a height of 56 m in each of the twelve 30 degree direction sectors are compared to the concurrent wind speeds measured at Mast 33 at 56 m in Figure 6.2. The correlation of wind speeds is reasonable in all sectors, albeit with considerable levels of scatter for the most frequent direction sectors. It is noted that while the scatter within these correlations appears to be quite significant, the review and validation of the synthesis methodology indicates this method to be appropriate for use in this assessment.

Figure 6.3 presents the correlation of wind direction between the two masts. The data are observed to be well correlated, albeit with some non-linearity which has been corrected for in the prediction of wind direction frequency distribution at the target mast.

Directional speed-up factors have been calculated and are presented in Table 6.3. The factors for winds other than from the southwest show a significant deviation from the ratios in the other sectors. This phenomenon may be due to the limited data in these other sectors or the influence of one or both of the local exposure to the predominant wind flow or the vast differences in local terrain to the north through east. It is not expected to have any significant impact on the energy production analysis, as very little energy is available from these winds.

[redacted]

It is observed that the wind rose at Mast 87 has a predominance of winds from the south-southwest through west-southwest.

Data have been recorded at Masts 153 since November 2002. Similar to the process described above, in order to extend the duration of the reference period used for the analysis of the wind regime at the site a correlation approach was used to synthesise the wind speed at Mast 153 at 53 m from data recorded at Mast 37 at 56 m and 35 m over the period September 2001 through November 2002 and small intermittent periods continuing through August 2004. As a check of the validity of the synthesis methodology, synthesised data were compared with concurrent periods of measured data and were noted to be in close agreement. By combining the actual data recorded at Mast 153 at 53 m and the synthesised data from Mast 37, approximately 2.7 years of valid wind speed data were obtained. The long-term mean wind speed and direction frequency distribution for Mast 153 at 53 m was derived from these data.

The measured wind speeds at Mast 153 at a height of 53 m in each of the twelve 30 degree direction sectors are compared to the concurrent wind speeds measured at Mast 37 at 56 m in Figure 6.5. The correlation of wind speeds is good in all sectors, with reasonable levels of scatter for the most frequent direction sectors.

Figure 6.6 presents the correlation of wind direction between the two masts. The data are observed to be well correlated, albeit with some non-linearity which has been corrected for in the prediction of wind direction frequency distribution at the target mast.

Directional speed-up factors have been calculated and are presented in Table 6.5. The factors for winds other than from the west show a slight deviation from the ratios in the other sectors. This phenomenon may be due to the limited data in these other sectors or the influence of one or both of the local exposure to the wind flow or the differences in local terrain. It is not expected to have any significant impact on the energy production analysis, as very little energy is available from these winds.

[redacted]

[redacted]

6.3 Hub height wind speeds

Measured wind speed data were used to derive the boundary layer power law exponents at each site mast. These values were used to predict the 67 m long-term mean wind speed at each mast. By this method, the measured vertical shear exponents for Masts 37, 87 and 153 were predicted to be 0.12, 0.15 and 0.18, respectively. The resulting 67 m long-term mean wind speed predictions are 7.6 m/s, 7.5 m/s and 7.7 m/s at Masts 37, 87 and 153, respectively.

6.4 Site wind speed variations

The variation in wind speed over the wind farm site has been predicted using the WAsP computational flow model as described in Appendix 1. The wind flow model has been initiated

from the long-term mean wind speed and direction frequency distributions derived for Masts 37, 87 and 153 at 67 m.

Table 6.7 includes a comparison of predicted long-term mean wind speeds at the site masts derived above and using WAsP initiated from Mast 37 at 56 m. These results indicate that the model is predicting the wind speed predictions with reasonable accuracy to masts situated in similar terrain and within similar distances to the back edge of the site. However, with the limited number of site masts, this modelling validation is limited and should be treated as indicative only.

The wind farm is located within complex terrain which includes areas of steep slopes. The presence of steep slopes can cause localised separation of the flow. In regions of separated flow it is known that the accuracy of wind flow modelling is poor due to the formation of a separation bubble which reduces the effective slope, as described by Cook [6.1].

A review of the wind farm was therefore undertaken to establish whether such conditions were present. Areas of steep slopes were noted to be throughout the site, in particular to the north-northeast of the site as the ridge drops off into the Tucannon River Valley as well as to the south-southwest of the ridge features extruding off the main ridge near Turbines 1 to 9, 57 to 59, 69 and 70.

[redacted]. For the remainder of the site GH has initiated the WAsP model from masts most representative of each turbine location without further adjustment.

It is clear from the above that the prediction of the variation in wind speed over the site is challenging, particularly in the areas where the local terrain at the turbine locations is significantly different than that at the mast locations, and an additional allowance has been made for the uncertainty in the wind flow modelling, as detailed in Section 6.6.

In complex terrain, GH generally recommends that all proposed turbine locations are within 1 km of a measurement mast which is at least two thirds of the proposed turbine hub height. [redacted]

Table 5.3 shows the predicted long-term mean wind speed at each turbine location at hub height. The average long-term mean hub height wind speed for the wind farm as a whole was found to be 7.7 m/s.

6.5 Projected energy production

The energy production of the wind farm is detailed in the table below and definitions of the various loss factors are included in Appendix 1. The energy capture of individual turbines is given in Table 5.3.

Rated Power	149.4	MW
[redacted]	[redacted]	[redacted]

The values for topographic and array effect have been calculated using the methods described in Appendix 1. It has been assumed that there are no other operational wind farms in the vicinity of the development.

The table above includes potential sources of energy loss that have been either estimated, assumed or not considered. It is recommended that the client consider each of these losses and the possible effect they may have on the wind farm.

6.6 Uncertainty analysis

The main sources of deviation from the central estimate have been quantified and are shown in Tables 6.8 to 6.10. 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 deviation of what is assumed to be a Gaussian process:

[redacted]

The uncertainties that have been considered in the analysis of the Hopkins Ridge Wind Farm include the following:

- Accuracy of the wind measurements;
- Correlation accuracy;
- The assumption that the period of data available to is representative of the long-term wind regime;
- The accuracy of the extrapolation of wind speeds from the mast height to hub height;
- The accuracy of the wind flow modelling;
- The accuracy of the wake modelling;
- The accuracy of the fiscal sub-station meter;
- The variability of the future annual wind speeds at the site.

There are a number of uncertainties that have not been considered at this stage, including those listed below. It is recommended that the client consider each of these uncertainties carefully. They can often be mitigated to some extent, especially in early years of the project, through appropriate warranty provisions. Therefore these uncertainties should be considered in combination with these provisions, for instance as part of a full technical due diligence exercise.

- Compliance with the assumed power curve;
- Turbine availability;
- Electrical losses;
- High wind hysteresis;
- Icing and blade degradation;
- Substation maintenance;
- Utility downtime;
- Wind sector management.

6.7 Seasonal and diurnal variation

The expected long-term average seasonal and diurnal variation in energy production has been approximately assessed from the available measured and synthesised site measurements at Masts 37, 87 and 153.

In order to establish the seasonal and diurnal variations in expected energy production, a time-series of air density was derived from on site temperature and pressure records from data recorded at Mast 88. These data were scaled to reflect the long-term site air density of 1.152 kg/m³. These data, together with expected wind speed variations, were used to model the expected variation in energy production on a seasonal and diurnal basis.

Based on the modelled sensitivity of energy production to wind speed, the expected seasonal and diurnal variation in energy production is presented in Table 6.11 in the form of a 12 x 24 matrix. It is noted that the uncertainty associated with the prediction of any given month or hour of day is significantly greater than that associated with the prediction of the mean annual production as presented above.

It is noted that these results presented are inclusive of the topographic effect and array losses only.

7 CONCLUSIONS AND RECOMMENDATIONS

Wind data have been recorded at the Hopkins Ridge site for a period of approximately 3 years. Based on the results from the analysis of these data the following conclusions are made concerning the site wind regime.

1. The long-term mean wind speeds are estimated to be 7.6 m/s, 7.5 m/s and 7.7 m/s at a height of 67 m above ground level at the locations of Masts 37, 87 and 153.

2. The standard error associated with these predictions of long-term mean wind speeds is 0.3 m/s at each mast. If a normal distribution is assumed, the confidence limits for the predictions are as given in the table below:

Probability of exceedance [%]	Long-term mean wind speeds at site masts at 67 m [m/s]		
	Mast 37	Mast 87	Mast 153
[redacted]	[redacted]	[redacted]	[redacted]

Site wind flow and array loss calculations have been carried out and from these we draw the following conclusions:

3. [redacted]

4. The projected energy capture of the proposed wind farm is [redacted] 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, and the effect of blade fouling or icing.

   There are a number of other losses that could affect the net energy output of the wind farm, as detailed in Appendix 1, but these have not been considered here. It is recommended that the client considers each of these losses and the possible effect they may have on the net energy production.

   The net energy prediction presented above represents the long-term mean, [redacted] % exceedance level, for the annual energy production of the wind farm. This value is the best estimate of the long-term mean value to be expected from the project. There is therefore a [redacted]% chance that, even when taken over very long periods, the mean energy production will be less than the value given.

5. 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]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

There are a number of uncertainties that have not been considered at this stage, as detailed in Section 6. It is recommended that the client consider each of these uncertainties carefully. They can often be mitigated to some extent, especially in early years of the project, through appropriate warranty provisions. Therefore these uncertainties should be considered in combination with these provisions, for instance as part of a full technical due diligence exercise.

6. The manufacture-supplied power curve assumed in this assessment should be verified against an independently measured power curve.

7. It is noted that the prediction of wind speeds at the extremities of this site is particularly challenging as there are currently no meteorological masts in these regions. A significant extrapolation has therefore been required using the WAsP wind flow model, which is subject to large uncertainties in this type of flow regime. The model has been adjusted based on GH experience. Higher wind speeds are expected in these areas and the adjusted model is predicting this trend. [redacted]

REFERENCES

2.1 "Wind speed profiles over terrain with roughness changes", Engineering Sciences Data , Item No. 84011, April 1993.

2.2 RES Hopkins Ridge site mast commissioning forms and maintenance records obtained from RES ftp site; ftp details provided via email from Andrew Oliver, RES, to Adam Schwarz, GH, 13 August 2004.

2.3 Recommended Practices for Wind Turbine Testing and Evaluation, "11. Wind speed measurement and use of cup anemometry", IEA, Edition 1, 1999.

5.1 Email from Andrew Oliver, RES, to Ryan Adams, GH, 8 November 2004.

5.2 "Wind turbine generator systems – Part 12: Wind turbine power performance testing", BS EN 61400-12: BSI, 1998.

6.1 Cook N J "The Designer's" guide to wind loading of building structures"., Part 1, Butterworths, 1985.

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6.7 Predicted annual wind rose for Mast 153 at 53 m

Location	Description of measurements	Period
Mast 33 (445944, 5133615)	Ten minute mean, standard deviation, maximum and 3-second gust wind speed recorded at 56 m and 30 m height.	1 Jul 2001 – 2 Aug 2004
	Ten minute mean and standard deviation direction recorded at 54 m height.	
Mast 35 (442882, 5140942)	Ten minute mean, standard deviation, maximum and 3-second gust wind speed recorded at 56 m and 30 m height.	30 Jun 2001 – 8 Sep 2002, 22 Oct 2002 – 2 Aug 2004
	Ten minute mean and standard deviation direction recorded at 54 m height.	
	Five minute mean, standard deviation, maximum and 3-second gust wind speed recorded at 56 m and 30 m height.	8 Sep 2002 – 22 Oct 2002
	Five minute mean and standard deviation direction recorded at 54 m height.	
Mast 37 (434593, 5143903)	Ten minute mean, standard deviation, maximum and 3-second gust wind speed recorded at 56 m and 35 m height.	28 Sep 2001 – 3 Aug 2004
	Ten minute mean and standard deviation direction recorded at 54 m height.	

Table 2.1 Summary of measurements made at the site (continued)

Location	Description of measurements	Period
Mast 85 (444185, 5135619)	Ten minute mean, standard deviation, maximum and 3-second gust wind speed recorded at 56 m and 35 m height. Ten minute mean and standard deviation direction recorded at 54 m and 34 m height.	5 Apr 2002 – 2 Aug 2004
Mast 87 (440427, 5139611)	Ten minute mean, standard deviation, maximum and 3-second gust wind speed recorded at 56 m and 35 m height. Ten minute mean and standard deviation direction recorded at 54 m height.	5 Apr 2002 – 8 Jul 2004
Mast 88 (441342, 5136954)	Ten minute mean, standard deviation, maximum and 3-second gust wind speed recorded at 56 m and 35 m height. Ten minute mean and standard deviation direction recorded at 54 m height.	5 Apr 2002 – 8 Jul 2004
Mast 153 (436032, 5142356)	Ten minute mean, standard deviation, maximum and 3-second gust wind speed recorded at 53 m and 35 m height. Ten minute mean and standard deviation direction recorded at 50 m and 34 m height.	27 Nov 2002 – 10 Jul 2004

Table 2.1 Summary of measurements made at the site (continued)

Location	Description of measurements	Period
Mast 154 (438431, 5136106)	Ten minute mean, standard deviation, maximum and 3-second gust wind speed recorded at 56 m and 35 m height. Ten minute mean and standard deviation direction recorded at 54 m and 34 m height.	27 Nov 2002 – 8 Jul 2004

Table 2.1 Summary of measurements made at the site (concluded)

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.1 **Measurements made at Mast 33 at a height of 56 m**

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.2 **Measurements made at Mast 37 at a height of 56 m**

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.3 **Measurements made at Mast 87 at a height of 56 m**

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.4 **Measurements made at Mast 153 at a height of 53 m**

Diameter	80	m
Hub height	67	m
Rotor speed	16.8	rpm
Power regulation	Pitch	
No. of blades	3	
Nominal rated power	1800	kW

Table 5.1 Main parameters of the wind turbine analysed – V80 IEC Class 1

Wind speed [m/s at hub height]	**Electrical power [kW]**

Performance for air density 1.15 kg/m^3 and 10 % turbulence intensity

Table 5.2 Performance data for the wind turbine analysed– V80 IEC Class 1

Turbine	Easting[1] [m]	Northing[1] [m]	Mean hub-height wind speed[2] [m/s]	Energy output[3] [GWh/annum]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

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 5.3 Turbine layout with predicted individual turbine wind speed and energy production (continued)

Turbine	Easting[1] [m]	Northing[1] [m]	Mean hub-height wind speed[2] [m/s]	Energy output[3] [GWh/annum]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

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 5.3 Turbine layout with predicted individual turbine wind speed and energy production (continued)

Turbine	Easting[1] [m]	Northing[1] [m]	Mean hub-height wind speed[2] [m/s]	Energy output[3] [GWh/annum]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

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

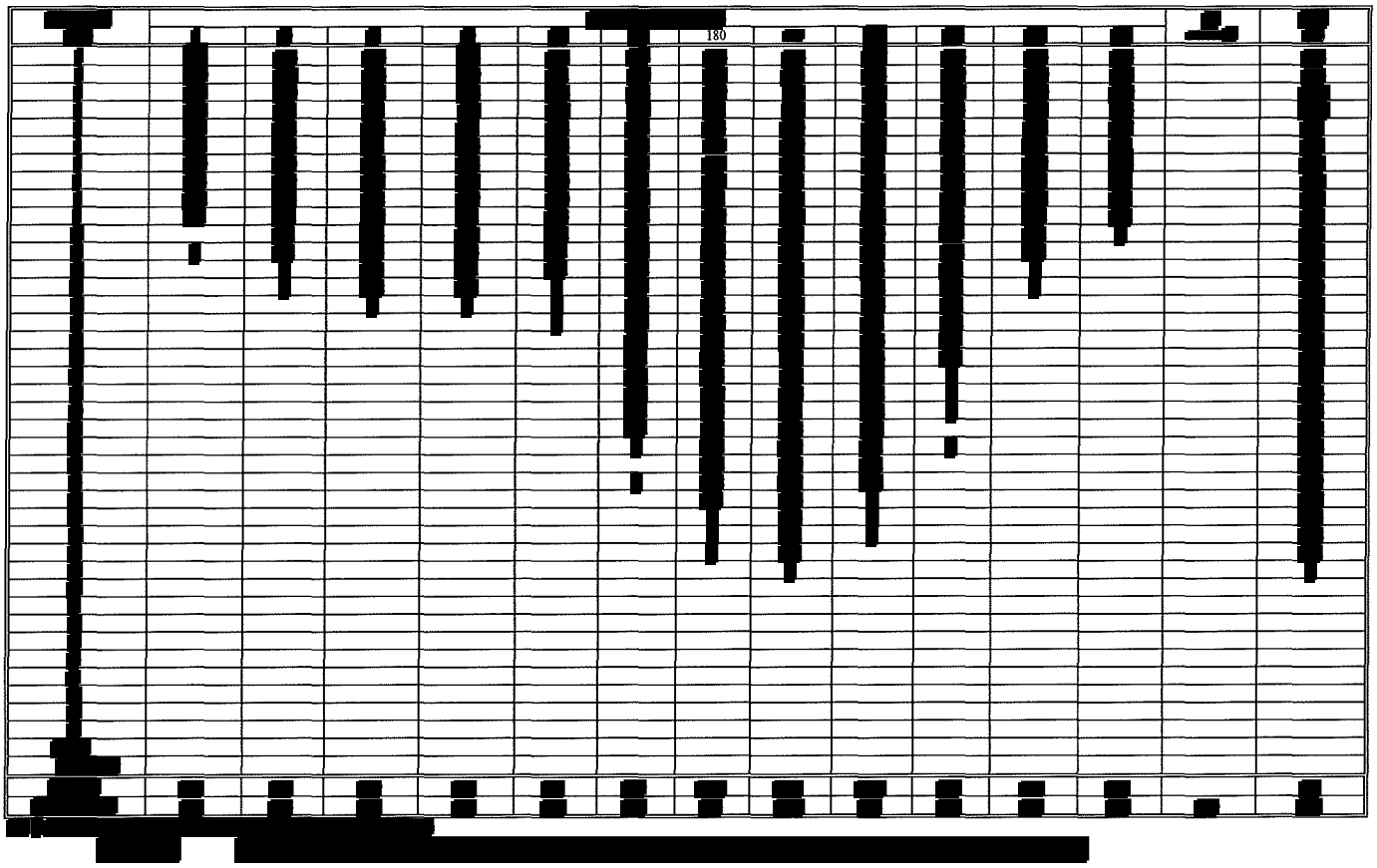
Table 5.3 [redacted]

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
January	[redacted]	[redacted]	[redacted]
February	[redacted]	[redacted]	[redacted]
March	[redacted]	[redacted]	[redacted]
April	[redacted]	[redacted]	[redacted]
May	[redacted]	[redacted]	[redacted]
June	[redacted]	[redacted]	[redacted]
July	[redacted]	[redacted]	[redacted]
August	[redacted]	[redacted]	[redacted]
September	[redacted]	[redacted]	[redacted]
October	[redacted]	[redacted]	[redacted]
November	[redacted]	[redacted]	[redacted]
December	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		

Table 6.1 [redacted]

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Site: **Mast 33 at 56 m** **Period:** **Annual (2001 to 2004)**



Direction sector [degrees]	Number of records	Correlation ratio
[redacted]	[redacted]	[redacted]

Table 6.3 [redacted]

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Site: Mast 87 at 56 m **Period:** Annual (2001 to 2004)

Wind Speed (m/s)	Wind Direction (degrees)												No Direction	Total (%)
	0	30	60	90	120	150	180	210	240	270	300	330		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	8.66	33.69	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

Direction sector [degrees]	Number of records	Correlation ratio
[redacted]	[redacted]	[redacted]

Table 6.5 [redacted]

Site: Mast 153 at 53 m **Period:** Annual (2001 to 2004)

Wind Speed	Wind Direction (degrees)												No	Total
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

NB: + indicates non-zero percentage <0.005%, blank indicates zero percentage

Table 6.6 [redacted]

Mast	Hub height [m]	Long-term mean wind speed MCP [m/s]	WAsP [m/s]
[redacted]	[redacted]	[redacted]	[redacted]

* indicates WAsP initiation mast

Table 6.7 [redacted]

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer accuracy	2.0	0.15		
Correlation accuracy 35 m to 56 m	0.0	0.00		
Shear extrapolation to 67 m	1.0	0.08		
Variability of 2.7 year period	3.6	0.28		
Overall historical wind speed		[redacted]		[redacted]
Substation metering			[redacted]	[redacted]
Wake and topographic calculation			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]			[redacted]
Future wind variability (10 years)	[redacted]			[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 26.6 GWh/annum.(m/s)

Table 6.8 [redacted]

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer accuracy	2.0	0.15		
Correlation accuracy Mast 33 to Mast 87	0.4	0.03		
Shear extrapolation to 67 m	1.0	0.07		
Variability of 3.0 year period	3.4	0.26		
Overall historical wind speed		[redacted]		[redacted]
Substation metering			[redacted]	[redacted]
Wake and topographic calculation			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]			[redacted]
Future wind variability (10 years)	[redacted]			[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 27.3 GWh/annum.(m/s)

Table 6.9 [redacted]

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer accuracy	2.0	0.15		
Correlation accuracy Mast 37 to 153	0.3	0.03		
Correlation accuracy Mast 37 to 153	0.0	0.00		
Shear extrapolation to 67 m	1.0	0.08		
Variability of 2.7 year period	3.6	0.28		
Overall historical wind speed		[redacted]		[redacted]
Substation metering			[redacted]	[redacted]
Wake and topographic calculation			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]			[redacted]
Future wind variability (10 years)	[redacted]			[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 14.4 GWh/annum.(m/s)

Table 6.10 [redacted]

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Energy production[1] [%]												
Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[redacted]												

Note Energy production has been modelled using the Hopkins Ridge 83 x V80 layout at 67 m. The values presented are inclusive of topographical and array losses only.

Table 6.11 Predicted seasonal and diurnal variation in energy production

APPENDIX 1

Data analysis procedure

1. Correlation of wind speed and direction.
2. Site wind speed variations.
3. Projected energy production
4. Confidence analysis
5. References

1 Correlation of wind speed and direction

The method used to determine the long-term mean wind speed for a "target" site from a "reference" site is based on the Measure-Correlate-Predict approach, which is outlined below.

The first stage in the approach is to measure, over a period of about one year, concurrent wind data from both the "target" site and the nearby "reference" site for which well established long-term wind records are available. The short-term measured wind data are then used to establish the correlation between the winds at the two locations. Finally, the correlation is used to adjust the long-term historical data recorded at the "reference" site to calculate the long-term mean wind speed at the site.

The concurrent data are correlated by comparing wind speeds at the two locations for each of twelve 30 degree direction sectors, based on the wind direction recorded at the "reference" site. This correlation involves two steps:

- Wind directions recorded at the two locations are compared to determine whether there are any local features influencing the directional results. Only those records with speeds in excess of 5 m/s at both locations are used.

- Wind speed ratios are determined for each of the direction sectors using a principal component analysis with the solution forced through the origin. This method is equivalent to a linear least-squared regression forced through the origin minimising the orthogonal offset.

In order to minimise the influence of localised winds on the wind speed ratio, the data are screened to reject records where the speed recorded at the "reference" site falls below 3 m/s or a slightly different level at the "target" site. The average wind speed ratio is used to adjust the 3 m/s wind speed level for the "reference" site to obtain the higher level for the "target" site, to ensure unbiased exclusion of data. The wind speed at which this level is set is a balance between excluding low winds from the analysis and still having sufficient data for the analysis. The level used excludes only winds below the cut-in wind speed of a wind turbine which do not contribute to the energy production.

The result of the analysis described above is a table of wind speed ratios, each corresponding to one of twelve direction sectors. These ratios are used to factor the wind data measured at the "reference" site over the historical reference period, to obtain the long-term mean wind speed at the "target" site.

2 Site wind speed variations

To calculate the variation of mean wind speed over the site, the computer wind flow model, WAsP is used. Details of the model and its validation are given by Troen and Petersen [1].

The inputs to the model are a digitised map of the topography and surface roughness length of the terrain for the site and surrounding area. A digitised map of an area surrounding the site of 30 km x 30 km was derived from USGS 1:24000 scale maps. Although this domain size is much larger than the area of the site itself, such an area is necessary since the flow at any point is dictated by the terrain several kilometres upwind.

Wind flow is affected by the roughness of the ground. The surface roughness length of the site and surrounding area has been estimated, as detailed in the main text.

The wind flow calculations were carried out for 30 degree steps in wind direction corresponding to the measured wind rose and results were produced as speed-up factors relative to the mast location for a grid encompassing the site area.

To determine the long-term mean wind speed at any location, the speed-up factor for each wind direction was weighted with the measured probability previously derived for the mast location. All directions were then summed to obtain the long-term mean wind speed at the required location.

3 Projected energy production

The components of the derivation of the wind farm net energy output prediction are listed and described below:

Ideal energy output

The ideal energy production is the theoretical output of the wind farm with the hub height wind speeds at the appropriate mast location applied for all associated turbines. Any density adjustment required due to a difference between the air density at hub height at the reference mast location and that assumed for the turbine power curve is applied as discussed in the main body of the report and included in the ideal energy output.

Topographic and wake effect calculations

The first step in modelling flow through an array of wind turbines is the calculation of the flow in the wake of a single machine. Immediately downstream of the rotor, there is a momentum deficit with respect to free stream conditions, which is equal to the thrust force on the machine. As the flow proceeds downstream, there is a spreading of the wake and recovery to free stream conditions. Turbulent momentum transfer is important in this process.

The model used here, WindFarmer, has been developed by GH and validated using measurements on both full-scale machines and on wind-tunnel models [2, 3, 4].

The model is employed in a scheme which, taking each wind speed and direction in turn calculates the power production of the wind farm. The important parameters used in this process are:

- array layout
- upstream mean wind speed
- ambient turbulence
- wind turbine thrust characteristic
- wind turbine power characteristic
- rotor speed
- topographical speed-up factors from site wind flow calculations

Topographical effects are accounted for in the model using the speed-up factors calculated by the wind flow model described above. Any air density adjustments required due to differences between the hub height air density at the turbine locations and that at the reference mast location is applied as discussed in the main body of the report and included in the topographic effect. The array model is used to calculate the wind speed in the turbine wakes, assuming the terrain is flat, and the wind speed is adjusted by the speed-up factor when the wake reaches a downstream turbine.

Electrical transmission efficiency

A figure of [redacted] % has been assumed for the electrical efficiency of the wind farm based on GH's experience of typical wind farm electrical distribution system designs. A formal calculation of the electrical loss should be undertaken when the electrical system has been defined.

Turbine availability

A figure of [redacted] % has been assumed for turbine availability based on data from modern operational wind farms. However, availability may be a matter of warranty between the owner and the turbine supplier and the assumed figure should be reviewed when the terms of that warranty are clear.

Blade degradation and fouling

The turbine production may be affected by the build up of insects, dirt or ice on the blades. This build up will change the characteristics of the blade and therefore effect the performance of the blades and the turbine output.

An adjustment has been included to allow for lost production due to blade fouling. A figure of [redacted] % has been assumed to be appropriate for the pitch regulated turbines.

High wind hysteresis

This is caused by the turbine cut in and cut out control criteria for high wind speeds. The magnitude of this loss is influenced by three factors.

1. The turbine will cut out when the maximum mean wind speed is exceeded and it will not cut in again until this mean wind speed is below a mean wind speed level lower than the cut out mean wind speed.
2. The turbine will cut out if the instantaneous gust wind speed exceeds a maximum level and the turbine will not cut in until the wind speed drops to a lower value.
3. The accuracy of the calibration of the instruments that are determining the wind characteristics at the turbine.

These three effects will cause the turbine to possibly lose production for some proportion of high mean wind speed occurrences. The magnitude of this lost production has been estimated by GH by repeating the analysis using a power curve with the cut out wind speed reduced by [redacted]

Substation maintenance

Net wind farm production may be reduced due to the electrical output not being transferred to the grid network while the substation is shutdown for maintenance. A typical figure of [redacted] % is assumed in this analysis to represent one day per year of planned maintenance. This is included

as scheduled maintenance can not generally be accurately planned to occur on a day with low wind speeds.

Utility downtime

Net wind farm production will be reduced if the grid is not available for the wind farm to output electricity to it. This type of loss must be considered on a site specific basis. It has not been considered in this analysis.

Power curve adjustment

Adjustment to the energy prediction to account for variations in the actual turbine performance in comparison to the supplied power curve. This may be a matter of warranty between the owner and the turbine supplier and the estimated figure should be reviewed when the terms of that warranty are clear and a detailed assessment of this issue has been conducted.

Wind sector management

If wind turbine spacing is close the site conditions may exceed the wind conditions within the wind turbine certification criteria. In these circumstances it may be necessary to shut down some turbines which are closely spaced when the wind direction is parallel to the line of turbines. This issue has not been considered in this analysis.

4 Confidence analysis

There are 5 categories of uncertainty associated with the site wind speed prediction at the proposed site:

1. There is an uncertainty associated with the measurement accuracy of the anemometers. The instruments used have been individually calibrated. The mounting arrangements of the instruments are not to industry standards. A figure of [redacted] % is assumed here to account for these and other second order effects such as over-speeding, degradation, air density variations and additional turbulence effects.

2. The long-term mean wind speed and direction frequency distributions at [redacted] The uncertainty associated with correlating and extrapolating between masts is evaluated from the statistical scatter in the correlation plots. These uncertainties were applied to the ratio of data that were used to develop the long-term wind speed and direction frequency distributions at Masts 87 and 153.

3. There is uncertainty associated with the derivation of the wind shear between heights on the masts and the assumption that this is representative of the wind flow at heights up to hub height. A figure of [redacted]

4. There is an uncertainty associated with the assumption made here that the historical period at the meteorological site is representative of the climate over longer periods. A study of historical wind records indicates a typical variability of [redacted]% in the annual mean wind speed

[5]. This figure is used to define the uncertainty in assuming the long-term mean wind speed is defined by a period approximately 3 years in length.

5. Additionally, even if the long-term mean wind speed were perfectly defined there will be variability in future mean wind speeds observed at the wind farm site. The variability in future mean wind speeds is dependant on the period considered. Performance over one and ten years of operation are therefore included in the uncertainty analysis. Account is taken of the future variability of wind speed in the energy confidence analysis but not the wind speed confidence analysis.

It is assumed that the time series of wind speed is random with no systematic trends. Care was taken to ensure that consistency of the reference measurement system and exposure has been maintained over the historical period and no allowance is made for uncertainties arising due to changes in either.

For each mast, uncertainties type 1 to 4 from above are added as independent errors on a root-sum-square basis to give the total uncertainty in the mast wind speed prediction for the historical period considered.

It is considered here that there are 5 categories of uncertainty in the energy output projection:

1. Long-term mean wind speed dependent uncertainty is derived from the total wind speed uncertainty (types 1 to 4 above) using a factor for the sensitivity of the annual energy output to changes in annual mean wind speed. This sensitivity is derived by a perturbation analysis about the central estimate.

2. Wake and topographic modelling uncertainties. Validation tests of the methods used here, based on full-scale wind farm measurements made at small wind farms have shown that the methods are accurate to [redacted] % in most cases. For this development an uncertainty in the wake and topographic modelling of [redacted] % to [redacted] % is assumed due to the expanse of distance and difference in local exposure and topographical features between the site masts and the associated proposed turbine locations.

3. Future wind speed-dependent uncertainties described in 5 above have been derived using the factor for the sensitivity of the annual energy output to changes in annual mean wind speed.

4. Accuracy of the fiscal substation energy meter. An uncertainty of [redacted] % is assumed here based on typical utility meter accuracy.

5. Turbine uncertainties are generally the subject of contract between the developer and turbine supplier and we have therefore made no allowance for them in this work.

For each mast, those uncertainties which are considered are added as independent errors on a root-sum-square basis to give the total uncertainty in the projected energy output for turbines initiated from each mast.

5 References

1. I Troen and E L Petersen, "European Wind Atlas", Risø National Laboratory, Denmark, 1989.

2. U Hassan, A G Glendinning and C A Morgan, " A Wind Tunnel Investigation of the wake structure and machine loads within small wind turbine farms", Proc of the 12th BWEA Wind Energy Conference, IMechE, 1990.

3. J Højstrup, "Turbulence measurements in a windfarm", Proc. EWEA Wind Energy Conference, Madrid, 1990.

4. J G Warren et al. "Performance of wind farms in complex terrain", Proc. Of the 17th BWEA Wind Energy Conference, 1995.

5. P Raftery, A J Tindal and A D Garrad, "Understanding the risks of financing windfarms", Proc. EWEA Wind Energy Conference, Dublin, 1997.

APPENDIX 2

Anemometer calibration certificates

ASSESSMENT OF THE ENERGY PRODUCTION OF THE PROPOSED WILD HORSE WIND FARM

Client	**Puget Sound Energy**
Contact	Tom Hiester
Document No	4743/AR/01
Issue	B
Status	FINAL
Classification	Client's Discretion
Date	09 September 2005

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DISCLAIMER

Acceptance of this document by the client is on the basis that Garrad Hassan America are not in any way to be held responsible for the application or use made of the findings of the results from the analysis and that such responsibility remains with the client.

GH has not conducted wind measurements itself and cannot, therefore, be responsible for the accuracy of the data supplied to it.

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B	09 Sept 05	Update to original issue with Vestas V80 turbine option

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REDACTED VERSION

1 INTRODUCTION

Zilkha Renewable Energy (Zilkha) is developing the Wild Horse Wind Farm and has submitted the project in response to a recent RFP from Puget Sound Energy (PSE). PSE have instructed Garrad Hassan and Partners (GH) to carry out an independent assessment of the wind climate and expected energy production of the proposed wind farm. The results of the work are reported here.

A description of the long-term wind climate at a potential wind farm is best determined using wind data recorded at the site. Zilkha has supplied 2.6 years of data recorded at the Wild Horse site to GH.

At present, no suitable source of long-term reference wind data has been identified. As a result of this, there is considerable uncertainty associated with the assumption that the site data are representative of the long-term and these uncertainties are included in the present assessment.

The proposed layout and turbine model currently under consideration have been supplied by Zilkha. These have been analyzed here, in conjunction with the results of the wind analysis, to predict the long-term energy output of the proposed wind farm.

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2 DESCRIPTION OF THE SITE AND MONITORING EQUIPMENT

2.1 The site

The site is located above the Kittitas Valley on the eastern edge of a major pass through the Cascade Range, approximately 125 km east of Seattle, as shown in Figure 2.1.

The proposed wind farm lies just east of the town of Ellensburg and at the foot of the Wenatchee Mountains. The terrain on site is complex, consisting of a broad, elevated plateau from which two parallel ridges aligned north-northwest to south-southeast extend in the southern portion of the site and several smaller ridges aligned west to east extend in the northern extent of the site. A large number of the proposed turbine sites are situated on these steep ridgelines.

The site elevation ranges from 1100 m on the plateau to 840 m at the foot of one of the principal ridgelines at the southern extent of the proposed wind farm. The ground cover on the site comprises primarily a mixture of short grasses and sagebrush less than 1 m in height. Much of the surrounding area consists of irrigated wheat fields interspersed by homes, outbuildings, and small stands of deciduous trees. Extensive coniferous forests are situated outside of the valley to the north and northwest of the project boundary.

A more detailed map showing the site is presented in Figure 2.2, which also shows the locations of the anemometry masts. A view of the site is shown in Figure 2.3 as seen facing east from Mast 309.

The surface roughness length of the site and surrounding area was assessed during a site visit made by GH staff. Following the Davenport classification [2.1], the following general figures are considered appropriate:

Areas of grasses and sagebrush	0.02 m
Cultivated farmland	0.05 m
Forested areas and towns	0.4 m
Water	0.0002 m

2.2 Monitoring equipment

Details of the measurements recorded on site and the grid co-ordinates of each mast are presented in Table 2.1.

The wind data have been recorded using NRG systems throughout with Maximum 40 anemometers and 200 P wind vanes. Zilkha has provided mast installation documents from which, in combination with details from the site visit, the following information is derived.

Primarily, NRG Symphonie data loggers have been utilized, programmed to record hourly mean wind speed and direction, wind speed and direction standard deviation and 3-second gust measurements. Masts 301, 310 and 311 employed NRG 9300 data loggers which did not include gust measurements. The following transfer function was applied to the output signal from the anemometers by both types of data loggers:

Recorded wind speed [m/s] = 0.765 x Data frequency [Hz] + 0.35 m/s

The anemometers on the site have not been individually calibrated. An investigation of the calibration of 472 NRG Maximum 40 anemometers has been reported in [2.2], the results of which include a proposed consensus transfer function for this model of anemometer. Since the applied transfer function is equivalent to the consensus calibration, no adjustment of the mean wind speed was necessary.

With the exception of Masts 301, 302, 303, 310 and 311, instruments are mounted on NRG 50 m guyed towers and include two boom-mounted anemometers at both 49 m and 30 m, one boom-mounted anemometer at 10 m, and wind vanes at approximately 40 m and 10 m. Mast 301 has a similar configuration with the exception of two boom-mounted anemometers at 50 m instead of 49 m.

Mast 302 consists of an NRG 60 m guyed tower with two boom-mounted anemometers at 60 m and 50 m and one boom-mounted anemometer at 30 m and 10 m. Wind vanes are mounted at 40 m and 10 m.

Mast 303 consists of an NRG 15 m guyed tower with two boom-mounted anemometers at 15 m and a wind vane at 13 m.

From documentation provided in [2.3], it is understood that Mast 310 was originally configured with one boom-mounted and one top-mounted anemometer at 49 m, two boom-mounted anemometers at 30 m, a boom-mounted anemometer at 10 m, and wind vanes at approximately 40 m and 10 m. In May 2004, the top-mounted anemometer was moved to a south-facing boom at 49 m. The west-oriented anemometer at 49 m is assumed to have remained consistent throughout the entire measurement period.

Mast 311 consists of an NRG 30 m guyed tower with two boom-mounted anemometers at 30 m and 20 m and one boom-mounted anemometer at 10 m. Wind vanes are mounted at 29m and 10 m.

With the exception of the top-mounted anemometer at Mast 310, all anemometers are mounted on booms approximately 7 mast diameters long oriented primarily to the west and south. The cups of the anemometers are at least 6 boom diameters above the boom. These anemometer mounting arrangements are not considered to be consistent with IEA recommendations [2.4] and therefore additional uncertainty has been associated with the measurements as detailed in Section 6.

Detailed documentation describing the top-mount configuration at Mast 310 is not available. Furthermore, since the configuration of Mast 310 was modified prior to the GH site visit, the original mounting arrangements have not been independently verified by GH. As a consequence of the uncertainty regarding the original installation, data recorded by the top-mounted anemometer at Mast 310 have not been used as absolute measurements in the current assessment.

It is also noted that prior to the site inspection performed by GH, Mast 301 was removed after falling and has since not been replaced. In addition, Masts 307 and 309 were no longer at their original locations as they were moved to other locations on site. Consequently, GH was unable to independently verify the measurement configuration of these masts.

3 SELECTION OF A REFERENCE METEOROLOGICAL STATION

In the assessment of the wind regime at a potential wind farm site it is generally necessary to correlate data recorded on the site with data recorded from a nearby long-term reference meteorological station. Wind data at a site are often only recorded for a short period and such correlation is required to ensure that the estimates of the wind speeds at the site are representative of the long-term. When selecting an appropriate meteorological station for this purpose it is important that it should have good exposure and that data are consistent over the measurement period being considered.

GH has reviewed potential sources of long-term meteorological data, including the National Weather Service ASOS station located at the Bowers Field Airport in Ellensburg, Washington. Wind data are available from the Bowers Field ASOS station starting in October 1998. However, between May 2001 and February 2002 a change in measurement consistency was identified in the data. In addition, wind speed correlation analyses conducted between the reference and the site masts exhibited poor correlation. Consequently, the Bowers Field ASOS station was not considered suitable as a quantitative reference.

The analysis of the long-term wind regime therefore relies on data recorded at the Wild Horse site since December 2002. This data set is of shorter duration than that which is ideal, and the uncertainty associated with assuming this period to be representative of the long-term is considered in Section 6.

It is worth noting that recent research [3.1] suggests that the Pacific Northwest experienced below average wind speeds during the 2004/2005 winter season, due largely to the presence of El Nino conditions. Since this analysis relies on the relatively short period of data recorded on site, the long-term predictions presented in this report may be potentially biased low due to the inclusion of the 2004/2005 winter period in this data set. Given the lack of suitable long-term references in the vicinity of the Wild Horse site however, GH has not quantified the magnitude of this potential bias, and no adjustments to the long-term predictions have been applied in this assessment at this stage.

4 WIND DATA

4.1 Wind data recorded at the site

The data sets which have been used in the analysis described in the following sections are summarized in Table 2.1.

The wind data have been subject to a quality checking procedure by GH to identify records which were affected by equipment malfunction and other anomalies. Characteristic of this region, the instruments on all masts experienced significant periods of icing, resulting in erroneous or inconsistent data during the winter months. These data were excluded from the analysis. The main periods for which valid data were not available are summarized below, together with details of the errors identified:

- Mast 306, 20 Jun 2004 to 31 Jul 2005 – anemometer malfunction wind speed 49 m west and 30 m south;
- Mast 308, 04 Oct 2004 to 20 Oct 2004 – logger malfunction all sensors;
- Mast 310, 11 Oct 2003 to 31 Jul 2005 – anemometer malfunction wind speed 30 m south.

As noted in Section 2, redundant anemometers at the upper two measurement heights were installed at all 60 m, 50 m and 30 m masts. In an attempt to reduce mast effects from the measured wind speed data, measurements recorded by these south and west oriented boom-mounted anemometers at a given height were averaged. Missing data were synthesized from the redundant sensor where necessary before averaging. Hereafter, data presented from such a mast configuration refers to the averaged data set unless stated otherwise.

The duration, basic statistics and data coverage for each mast are summarized in Tables 4.1 to 4.14.

5 DESCRIPTION OF THE PROPOSED WIND FARM

5.1 The wind turbine

The turbine which is proposed for the Wild Horse Wind Farm is the Vestas V80 1800 kW with a hub height of 67 m. The basic parameters of the turbine are presented in Table 5.1.

The power curve used in this analysis has been supplied by Zilkha [5.1] and is presented in Table 5.2. This power curve is for an air density of 1.12 kg/m³, and is valid for turbulence intensity of 10 %. It is noted that the actual turbulence intensity across the site at 15 m/s is approximately 7 % based on ten-minute averaging periods. It is recommended that the turbine manufacturer provide a power curve based on the site turbulence intensity.

The supplied power curve is based on calculations and exhibits a peak power coefficient, Cp, of 0.46. This is considered to be high but attainable for a modern wind turbine.

A measured power curve from an independent test of the performance of the turbine has been obtained [5.2]. This has been produced for an air density of 1.11 kg/m³. The turbulence intensity during the measurements was not stated.

A comparison between the supplied and the measured power curves has been conducted and this generally supports the assumption that the supplied power curve is achievable.

Using historical pressure and temperature records from nearby meteorological stations and standard lapse rate assumptions, GH has estimated the long-term mean air density at the site to be 1.116 kg/m³ at an average hub elevation of 1070 m above sea level.

The supplied power curve used in this analysis has been adjusted to the predicted site air density, in accordance with the recommendations of [5.3]. This has been undertaken on an individual turbine basis.

5.2 Wind farm layout

Zilkha has supplied the layout for the wind farm [5.1]. A map of the site showing the wind turbine locations is presented in Figure 5.1 with the grid reference of each of the turbines given in Table 5.3.

It is noted that an inter-turbine spacing of as small as 1.5 rotor diameters is proposed for the Vestas V80 layout. Consequently, it is understood that a Wind Sector Management (WSM) strategy is to be implemented in order to reduce fatigue loads on the turbines and Zilkha has supplied a WSM strategy [5.4] for the current V80 layout. An energy loss figure associated with WSM has therefore been estimated within the analysis of the expected energy production presented in Section 6.

It is recognized that the close spacing of turbines also results in a reduction to the rate of recovery of the wakes from individual turbines compared to that modelled by the existing industry standard wake models, including the Eddy Viscosity model employed here. This is believed to be due to the lack of free-stream flow between the turbines and results in increased wake losses for turbines downwind of such closely-spaced turbine rows. Such conditions exist for the prevailing wind

directions for a number of turbines on the Wild Horse site and the additional loss associated with this expected under-prediction of wake loss has been estimated and is included in Section 6.

6 RESULTS OF THE ANALYSIS

The analysis of the wind farm involved several steps, which are summarized below:

- Data at each mast were correlated to other nearby site masts. These correlations were used to synthesize data and thereby extend the period of data available at each mast.
- The wind speed and direction frequency distributions at each mast, as detailed in Table 2.1, at the highest measurement height were derived from the period of measured and synthesized data.
- Boundary layer power law shear exponents at all site masts were estimated using the measured data at two different heights at each of these masts. These were used to extrapolate the long-term wind speed and direction frequency distribution to the proposed hub height of 67 m.
- Wind flow modelling was carried out to determine the hub height wind speed variations over the site relative to the anemometry masts.
- The energy production of the wind farm was calculated taking account of array losses, topographic effects, availability, electrical transmission efficiency, wind sector management, air density effects and other potential losses.
- An assessment of the uncertainty in the predicted wind farm energy production was undertaken.

A more complete description of the methods employed is included in Appendix 1.

6.1 Long-term mean wind regime at site masts

Data have been recorded on-site, as detailed in Section 2, since December 2002. In order to maximize the duration of the reference period used for the analysis of the wind regime at each mast, the correlation analysis described below was used to synthesize the wind speeds across the site.

As an example of a correlation used at the Wild Horse site, the measured wind speeds at Mast 312 at a height of 49 m in each of the twelve 30 degree direction sectors are compared to the concurrent wind speeds measured at Mast 309 at 49 m in Figure 6.1. The correlation of wind speeds is acceptable in all sectors, with mild scatter in the most frequent direction sectors.

Figure 6.2 presents the correlation of wind direction between these two masts. The data are observed to be correlated, albeit with some non-linearity which has been accounted for in the prediction of wind direction at the target mast.

The following check on the correlation was undertaken. Wind data from Mast 309 at 49 m were factored by the directional speed up ratios determined in the correlation to the Mast 312 at 49 m. These figures are presented in Table 6.1. If the correlation is reliable then the mean wind speed of the synthesized wind data would be similar to the actual data for exactly the same period. This was the case and therefore the correlation has been deemed appropriate for this analysis.

The same process was repeated for each correlation step presented in Table 6.2.

The resulting speedup factors were then applied to the hourly data at each reference mast in order to synthesize the wind speed at each target mast. When combining the measured data with the synthesized data to create the long-term time series at each mast, the measured data were used whenever possible. After combining the actual data recorded at each mast with the synthesized data, approximately 2.6 years of data are obtained comprising 2.5 years of valid wind speed data. The long-term mean wind speed and direction frequency distribution at each mast were then derived from these data sets.

In order to avoid the introduction of bias into the annual mean wind speed estimate from seasonally uneven data coverage, the following procedure was followed for each mast:

- The mean wind speed and direction frequency distribution for each month was determined from the average of all valid data recorded in that month over the period. This was taken as the monthly mean thereby assuming that the valid data are representative of any missing data.

- The mean of the monthly means was taken to determine the annual mean ("mean of means") to eliminate the effect of seasonal bias in the data.

Tables 6.3 to 6.14 present the predicted long-term mean wind speed across the site at each mast using this methodology.

As mentioned in Section 2, the wind speeds recorded at Mast 310 by the 49 m top-mounted anemometer were excluded in preference to the two boom-mounted anemometers at 49 m. In order to extend the period of data available at the south-facing anemometer at 49 m, data were correlated between the 49 m west-oriented anemometer and the 49 m south-oriented anemometer. From this correlation, data from the 49 m south-facing anemometer were synthesized over the period for which the top-mounted anemometer was present.

It is noted that Masts 303 and 311, as a consequence of their low measurement heights, were not used in the analysis, nor were they updated with the latest June and July 2005 data.

6.2 Hub height wind speeds

The ratio of concurrent measured mean wind speeds between the two highest wind speed measurement heights was used to derive boundary-layer power-law shear exponents at each mast location. These values were applied to extrapolate the long-term mean wind speed and direction frequency distribution at each of the site masts to the 67 m hub height. It is noted that for Mast 302, the power law shear exponent was calculated between the 60 m and 30 m heights rather than the two highest heights of 60 m and 50 m. In addition, due to data being available from only one anemometer at the 30 m level at Masts 302 and 310, shear calculations employed only measurements from the anemometer at the highest height with the same orientation as the 30 m anemometer, rather than the average of the wind speed measurements as described in Section 4, in order to avoid introducing any potential bias due to differing exposure and mast effects.

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As an example, the resultant corresponding long-term joint wind speed and direction frequency distribution at Mast 304 at 67 m is presented in Table 6.15 and in Figure 6.3 in the form of a wind rose.

It is observed that the wind rose at the Wild Horse site has a predominance of winds from the west, with a significant proportion from the northeast.

A summary of the estimated shear exponent and extrapolated hub height mean wind speed for each mast is presented in Table 6.16.

6.3 Site wind speed variations

The variation in wind speed over the wind farm site has been predicted using the WAsP computational flow model as described in Appendix 1. The wind flow model has been initiated from the long-term mean hub height wind speed and direction frequency distributions derived for each mast.

The wind farm is located within complex terrain which includes areas of steep slopes. The presence of steep slopes can cause localized separation of the flow. In regions of separated flow it is known that the accuracy of wind flow modelling is poor due to the formation of a separation bubble which reduces the effective slope, as described by Cook [6.1].

For turbine locations with slopes significantly in excess of 17 degrees in the prevailing wind directions, to a greater extent than at the initiation anemometry mast location, there is a tendency for the WAsP model to over-predict the wind speed and consequently energy production of such turbines. Conversely, if the initiation anemometry mast is located in an area more heavily influenced by slopes in excess of 17 degrees than the turbine locations, there is a tendency for the WAsP model to under-predict the wind speed at such turbines.

A review of the wind farm was therefore undertaken to establish whether such conditions were present. Areas of steep slopes are marked as grey shaded areas in Figure 6.4 and it can be seen that there are steep slopes along the majority of the principal ridges, the severest slopes lying between the 'C' and 'D' row of turbines and to the north of the project.

[redacted]

It is clear from the above that the prediction of the variation in wind speed over the site is challenging and an additional allowance has been made for the uncertainty in the wind flow modelling, as detailed in Section 6.5.

Table 5.3 shows the predicted long-term mean wind speed at each turbine location at hub height. The average long-term mean hub height wind speed for the wind farm as a whole was found to be 7.8 m/s.

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6.4 Projected energy production

The energy production of the wind farm is detailed in the table below and definitions of the various bss factors are included in Appendix 1. The energy capture of individual turbines is given in Table 5.3.

Rated Power	**228.6**	**MW**
[redacted]	[redacted]	[redacted]

The values for topographic and array effect have been calculated using the methods described in Appendix 1. It has been assumed that there are no other operational wind farms in the vicinity of the development.

The table above includes potential sources of energy loss that have been estimated, assumed or not considered. It is recommended that the client consider each of these losses and the possible effect they may have on the wind farm.

[redacted]

[redacted]

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6.5 Uncertainty analysis

The main sources of deviation from the central estimate have been quantified and are shown in Tables 6.17 to 6.28. 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 deviation of what is assumed to be a Gaussian process:

[redacted]

The uncertainties that have been considered in the analysis of the wind farm include the following:

- Accuracy of the wind measurements;
- Correlation accuracy;
- The assumption that the period of data available to is representative of the long-term;
- The accuracy of the extrapolation of wind speeds from the mast height to hub height;
- The accuracy of the wind flow modelling;
- The accuracy of the wake modelling;
- The accuracy of the fiscal sub-station meter;
- The variability of the future annual wind speeds at the site.

There are a number of uncertainties that have not been considered at this stage, including those listed below. It is recommended that the client consider each of these uncertainties carefully. They can often be mitigated to some extent, especially in early years of the project, through appropriate warranty provisions. Therefore these uncertainties should be considered in combination with these provisions, for instance as part of a full technical due diligence exercise.

- Compliance with the assumed power curve;
- Turbine availability;
- Electrical losses;
- High wind hysteresis;
- Icing and blade degradation;
- Substation maintenance;
- Utility downtime;
- Wind sector management.

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7 CONCLUSIONS AND RECOMMENDATIONS

Wind data have been recorded at the Wild Horse site for a period of approximately 2.6 years. Based on the results from the analysis of these data the following conclusions are made concerning the site wind regime.

1. The long-term mean wind speed at a height of [redacted] m above ground level is presented in the table below for each mast. Also included are the standard errors associated with each of these predictions. If a normal distribution is assumed, the confidence limits for the predictions are presented for the P50, P75 and P90 exceedance levels.

Probability of exceedance [%]	Long-term mean wind speed at 67 m [m/s]											
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Site wind flow and array loss calculations have been carried out and from these we draw the following conclusions:

2. [redacted]

3. The projected energy capture of the proposed wind farm is [redacted] 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, wind sector management, substation maintenance, and the effect of blade fouling or icing.

   There are a number of other losses that could affect the net energy output of the wind farm, as detailed in Appendix 1, but these have not been considered here. It is recommended that the client considers each of these losses and the possible effect they may have on the net energy production.

   The net energy prediction presented above represents the long-term mean, 50% exceedance level, for the annual energy production of the wind farm. This value is the best estimate of the long-term mean value to be expected from the project. There is therefore a 50% chance that, even when taken over very long periods, the mean energy production will be less than the value given.

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4. 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]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

There are a number of uncertainties that have not been considered at this stage, as detailed in Section 6. [redacted]

5. In order to reduce the uncertainty in the expected energy production it is recommended that the analysis be updated once additional data have been recorded on site or should a suitable source of longer-term reference data be identified.

REDACTED VERSION

REFERENCES

2.1 "Wind speed profiles over terrain with roughness changes", Engineering Sciences Data, Item No. 84011, April 1993.

2.2 Lockhart T J and Bailey B H, "The Maximum Type 40 Anemometer Calibration Project", Proceedings of the AWEA Conference, California 1998.

2.3 Letter from Eli Reich, GEC to Andrew Young, Zilkha, 14 November 2003

2.4 Recommended Practices for Wind Turbine Testing and Evaluation, "11. Wind speed measurement and use of cup anemometry", IEA, Edition 1, 1999.

3.1 Storck, P and Hiester, T, "Integrating wind energy resource assessment and forecasting strategies to provide medium range forecasts of wind energy output", Proceedings of the AWEA Conference, Colorado 2005.

5.1 Email from Matthew Hendrickson, Zilkha to Regina Sweet, GH, 02 September 2005.

5.2 "Power Performance Test at Pincher Creek", AB, Vestas, 952407.R3, 13 February 2003.

5.3 "Wind turbine generator systems – Part 12: Wind turbine power performance testing", BS EN 61400-12: BSI, 1998.

5.4 "Site Layout Approval Wild Horse – Washington", Vestas, WS-9016SLA, 02 September 2005.

6.1 Cook N J "The Designer's" guide to wind loading of building structures", Part 1, Butterworths, 1985.

6.2 Email from Tom Hiester, PSE to Clint Johnson, GH, 31 August 2005.

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Location	Description of measurements	Period
Mast 301 (710972,5211103)	Hourly mean wind speed recorded at 50, 30 and 10m. Hourly mean wind direction recorded at 40 and 10m.	01 Apr 2003 –22 Dec 2003
Mast 302 (712062,5213150)	Hourly mean wind speed recorded at 60, 50, 30 and 10m. Hourly mean wind direction recorded at 40 and 10m.	08 Apr 2003 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 60, 50, 30 and 10m. Ten-minute mean wind direction recorded at 40 and 10m.	01 Aug 2004 – 31 Jul 2005
Mast 303 (709876,5214436)	Hourly mean wind speed recorded at 14.6m. Hourly mean wind direction recorded at 13.4m.	30 Mar 2003 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 14.6m. Ten-minute mean wind direction recorded at 13.4m.	01 Aug 2004 – 31 Jul 2005
Mast 304 (712791,5210161)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 41 and 10m.	13 Dec 2002 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 49, 30 and 10m. Ten-minute mean wind direction recorded at 41 and 10m.	01 Aug 2004 –31 Jul 2005
Mast 305 (714630,5208226)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 40 and 10m.	09 Oct 2003 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 49, 30 and 10m. Ten-minute mean wind direction recorded at 40 and 10m.	01 Aug 2004 – 31 Jul 2005
Mast 306 (713536,5212669)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 41 and 10m.	14 Dec 2002 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 49, 30 and 10m. Ten-minute mean wind direction recorded at 41 and 10m.	01 Aug 2004 – 31 Jul 2005
Mast 307 (714054,5211405)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 41 and 10m.	16 Dec 2002 – 12 Jun 2004
Mast 308 (713786,5213767)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 41 and 10m.	19 Dec 2002 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 49, 30 and 10m. Ten-minute mean wind direction recorded at 41 and 10m.	01 Aug 2004 – 31 Jul 2005
Mast 309 (714472,5210705)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 41 and 10m.	17 Dec 2002 – 11 Jun 2004

Table 2.1 Summary of measurements made at the site - continued.

Location	Description of measurements	Period
Mast 310 (711112,5209695)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 41 and 10m.	11 Oct 2003 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 49, 30 and 10m. Ten-minute mean wind direction recorded at 41 and 10m.	01 Aug 2004 – 30 Jun 2005
Mast 311 (711801,5211724)	Hourly mean wind speed recorded at 30, 20 and 10m. Hourly mean wind direction recorded at 29 and 10m.	08 Oct 2003 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 30, 20 and 10m. Ten-minute mean wind direction recorded at 29 and 10m.	01 Aug 2004 – 30 Jun 2005
Mast 312 (715094,5209643)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 40 and 10m.	21 Nov 2003 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 49, 30 and 10m. Ten-minute mean wind direction recorded at 40 and 10m.	01 Aug 2004 – 31 Jul 2005
Mast 313 (713687,5214300)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 40 and 10m.	12 Jun 2004 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 49, 30 and 10m. Ten-minute mean wind direction recorded at 40 and 10m.	01 Aug 2004 – 31 Jul 2005
Mast 314 (711594,5214646)	Hourly mean wind speed recorded at 49, 30 and 10m. Hourly mean wind direction recorded at 40 and 10m.	12 Jun 2004 – 31 Jul 2004
	Ten-minute mean wind speed recorded at 49, 30 and 10m. Ten-minute mean wind direction recorded at 40 and 10m.	01 Aug 2004 – 31 Jul 2005

Table 2.1 Summary of measure ments made at the site - concluded

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.1 Measurements made at Mast 301 at a height of 50 m.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.2 Measurements made at Mast 302 at a height of 60 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.3 Measurements made at Mast 303 at a height of 14.6 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.4 Measurements made at Mast 304 at a height of 49 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.5 Measurements made at Mast 305 at a height of 49 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.6 Measurements made at Mast 306 at a height of 49 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.7 Measurements made at Mast 307 at a height of 49 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.8 Measurements made at Mast 308 at a height of 49 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.9 Measurements made at Mast 309 at a height of 49 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.10 Measurements made at Mast 310 at a height of 49 m.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.11 Measurements made at Mast 311 at a height of 30 m.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.12 Measurements made at Mast 312 at a height of 49 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.13 Measurements made at Mast 313 at a height of 49 m.

Month	Mean wind speed [m/s]	Wind speed data coverage [%]	Wind direction data coverage [%]
[redacted]	[redacted]	[redacted]	[redacted]

Table 4.14 Measurements made at Mast 314 at a height of 49 m.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Diameter	80	m
Hub height	67	m
Rotor speed	16.8	rpm
Power regulation	Pitch	-
Nominal rated power	1800	kW

Table 5.1 Main parameters of the Vestas V80 wind turbine analyzed.

Wind speed [m/s at hub height]	Electrical power [kW]
[redacted]	[redacted]

[redacted] kg/m³ and 10 % turbulence intensity

Table 5.2 Performance data for the Vestas V80 wind turbine analyzed.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Turbine	Easting[1] [m]	Northing[1] [m]	Mean hub-height wind speed[2] [m/s]	Energy output[3] [GWh/annum]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Notes

1 Co-ordinate system is 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 5.3 Turbine layout with predicted individual turbine wind speed and energy production – continued.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Turbine	Easting[1] [m]	Northing[1] [m]	Mean hub-height wind speed[2] [m/s]	Energy output[3] [GWh/annum]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Notes

1 Co-ordinate system is 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 5.3 Turbine layout with predicted individual turbine wind speed and energy production – continued.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Turbine	Easting[1] [m]	Northing[1] [m]	Mean hub-height wind speed[2] [m/s]	Energy output[3] [GWh/annum]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Notes

1 Co-ordinate system is 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 5.3 Turbine layout with predicted individual turbine wind speed and energy production – continued.

Turbine	Easting[1] [m]	Northing[1] [m]	Mean hub-height wind speed[2] [m/s]	Energy output[3] [GWh/annum]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Notes

1 Co-ordinate system is 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 5.3 Turbine layout with predicted individual turbine wind speed and energy production – concluded.

Direction sector [degrees]	Number of records	Correlation ratio
[redacted]	[redacted]	[redacted]

Table 6.1 Directional correlation ratios betweenMasts 309 at 49 m and 312 at 49 m.

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Target mast	Reference mast	Correlation	Period
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.2 Synthesis steps to predict the long-term mean wind speed at each mast location.

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.3 Predicted monthly and annual mean wind speeds at Mast 301 at 50m (Dec 2002 to Jul 2005).

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.4 Predicted monthly and annual mean wind speeds at Mast 302 at 60m (Dec 2002 to Jul 2005).

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.5 Predicted monthly and annual mean wind speeds at Mast 304 at 49m (Dec 2002 to Jul 2005).

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.6 Predicted monthly and annual mean wind speeds at Mast 305 at 49m (Dec 2002 to Jul 2005).

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.7 Predicted monthly and annual mean wind speeds at Mast 306 at 49m (Dec 2002 to Jul 2005).

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.8 Predicted monthly and annual mean wind speeds at Mast 307 at 49m (Dec 2002 to Jul 2005).

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.9 Predicted monthly and annual mean wind speeds at Mast 308 at 49m (Dec 2002 to Jul 2005).

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.10 Predicted monthly and annual mean wind speeds at Mast 309 at 49m (Dec 2002 to Jul 2005).

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.11 Predicted monthly and annual mean wind speeds at Mast 310 at 49m (Dec 2002 to Jul 2005).

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.12 Predicted monthly and annual mean wind speeds at Mast 312 at 49m (Dec 2002 to Jul 2005).

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.13 Predicted monthly and annual mean wind speeds at Mast 313 at 49m (Dec 2002 to Jul 2005).

Month	Mean wind speed [m/s]	Wind speed data coverage [records]	Wind direction data coverage [records]
[redacted]	[redacted]	[redacted]	[redacted]

Table 6.14 Predicted monthly and annual mean wind speeds at Mast 314 at 49m (Dec 2002 to Jul 2005).

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Mast	Wind speed measurement heights [m]	Long-term mean wind speed at highest measurement height [m/s]	Power law shear exponent 'a' from measurement	Estimated long-term mean wind speed at 67 m [m/s]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 6.16 Predictions of the wind speeds at the site masts.

Source of uncertainty	Wind speed		Energy output[1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.25		
Period rep. of long-term	3.8%	0.32		
Correlation	1.1%	0.09		
Shear to 67 m	1.5%	0.12		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 1.88 GWh/annum. (m/s)

Table 6.17 Uncertainty in projected energy output of Turbines A1 to A2 based on Mast 301.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.23		
Period rep. of long-term	3.8%	0.29		
Correlation	0.1%	0.01		
Shear to 67 m	0.5%	0.04		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 30.46 GWh/annum. (m/s)

Table 6.18 Uncertainty in projected energy output of Turbines D1 to D2, E1B to E10B, K1 to K6, L1 to L4, M1 to M6 and P1 to P2 based on Mast 302.

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.25		
Period rep. of long-term	3.9%	0.32		
Correlation	0.0%	0.00		
Shear to 67 m	1.5%	0.13		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 6.64 GWh/annum. (m/s)

Table 6.19 Uncertainty in projected energy output of Turbines C1 to C8 based on Mast 304.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.25		
Period rep. of long-term	3.8%	0.31		
Correlation	0.5%	0.04		
Shear to 67 m	1.5%	0.12		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 8.58 GWh/annum. (m/s)

Table 6.20 Uncertainty in projected energy output of Turbines C9 to C18 based on Mast 305.

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.25		
Period rep. of long-term	3.8%	0.32		
Correlation	0.1%	0.01		
Shear to 67 m	1.5%	0.12		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 9.44 GWh/annum. (m/s)

Table 6.21 Uncertainty in projected energy output of Turbines D3 to D9 and J1A to J4B based on Mast 306.

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.26		
Period rep. of long-term	3.8%	0.33		
Correlation	0.3%	0.02		
Shear to 67 m	1.5%	0.13		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 6.20 GWh/annum. (m/s)

Table 6.22 Uncertainty in projected energy output of Turbines D10 to D18 based on Mast 307.

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.23		
Period rep. of long-term	3.9%	0.30		
Correlation	0.0%	0.00		
Shear to 67 m	1.5%	0.12		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 8.62 GWh/annum. (m/s)

Table 6.23 Uncertainty in projected energy output of Turbines F2 to F5, G4 to G7 and I1 to I2 based on Mast 308.

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.24		
Period rep. of long-term	3.8%	0.30		
Correlation	0.3%	0.03		
Shear to 67 m	1.5%	0.12		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 4.19 GWh/annum. (m/s)

Table 6.24 Uncertainty in projected energy output of Turbines D19 to D23 based on Mast 309.

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.23		
Period rep. of long-term	3.8%	0.29		
Correlation	0.5%	0.03		
Shear to 67 m	1.5%	0.11		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 11.98 GWh/annum. (m/s)

Table 6.25 Uncertainty in projected energy output of Turbines A3 to A8, B1 to B2 and Q1 to Q5 based on Mast 310.

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.25		
Period rep. of long-term	3.8%	0.32		
Correlation	0.7%	0.06		
Shear to 67 m	1.5%	0.13		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 9.71 GWh/annum. (m/s)

Table 6.26 Uncertainty in projected energy output of Turbines D24 to D37 based on Mast 312.

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.23		
Period rep. of long-term	3.8%	0.30		
Correlation	0.4%	0.03		
Shear to 67 m	1.5%	0.12		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 5.94 GWh/annum. (m/s)

Table 6.27 Uncertainty in projected energy output of Turbines F1, G1 to G3 and H1 to H3 based on Mast 313.

Source of uncertainty	Wind speed		Energy output [1]	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer	3.0%	0.22		
Period rep. of long-term	3.8%	0.28		
Correlation	0.4%	0.03		
Shear to 67 m	1.5%	0.11		
Overall historical wind speed		[redacted]		[redacted]
Substation Metering accuracy			[redacted]	[redacted]
Wake and Topographic error			[redacted]	[redacted]
Future wind variability (1 year)	[redacted]	[redacted]		[redacted]
Future wind variability (10 years)	[redacted]	[redacted]		[redacted]
Overall energy uncertainty (1 year)				[redacted]
Overall energy uncertainty (10 years)				[redacted]

Note: Sensitivity of net production to wind speed is calculated to be 7.82 GWh/annum. (m/s)

Table 6.28 Uncertainty in projected energy output of Turbines N1 to N4 and O1 to O4 based on Mast 314.

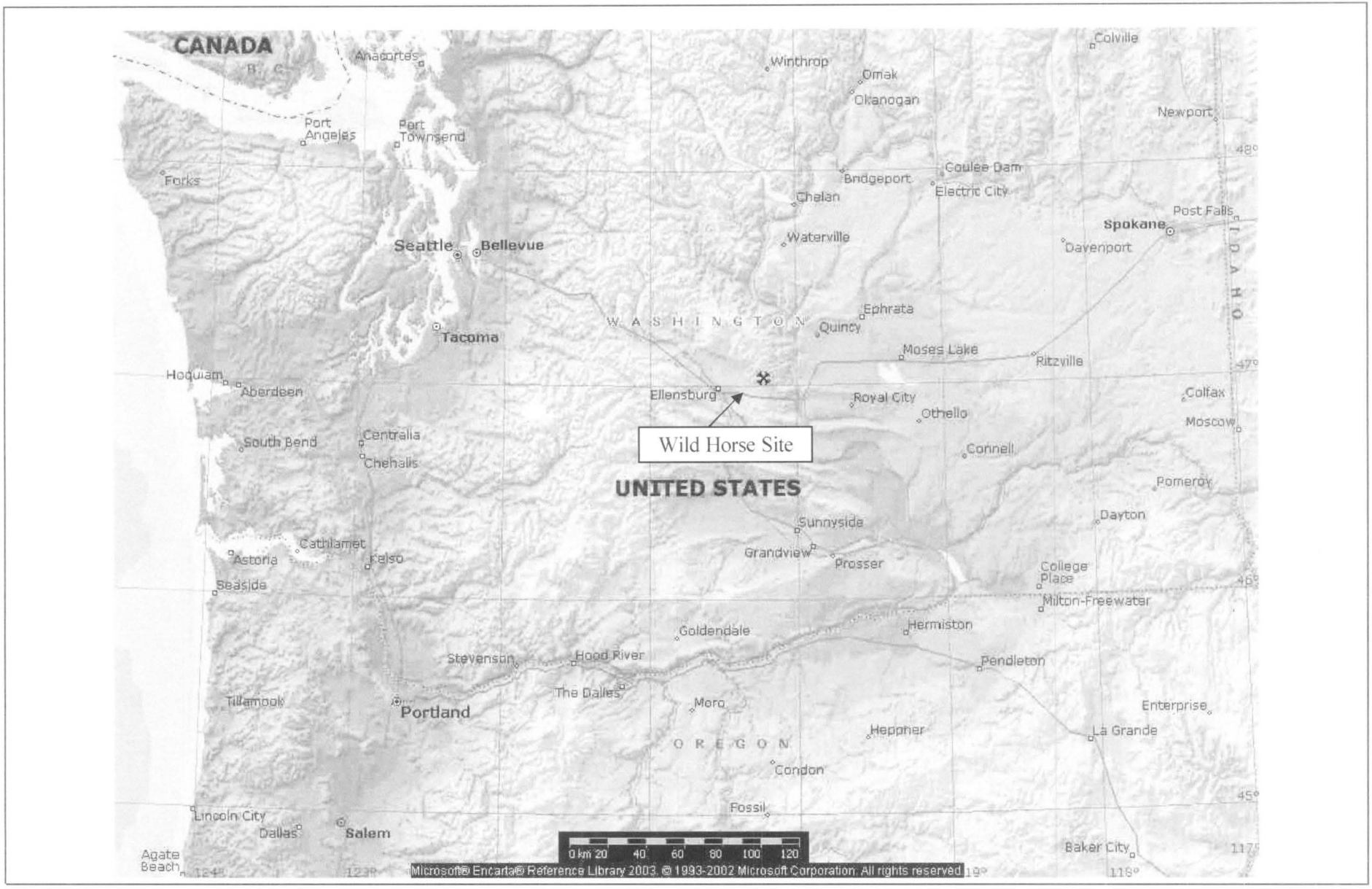

Figure 2.1 **Location of the Wild Horse site.**

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[redacted]

Figure 2.3 View of the Wild Horse site from Mast 309 looking east.

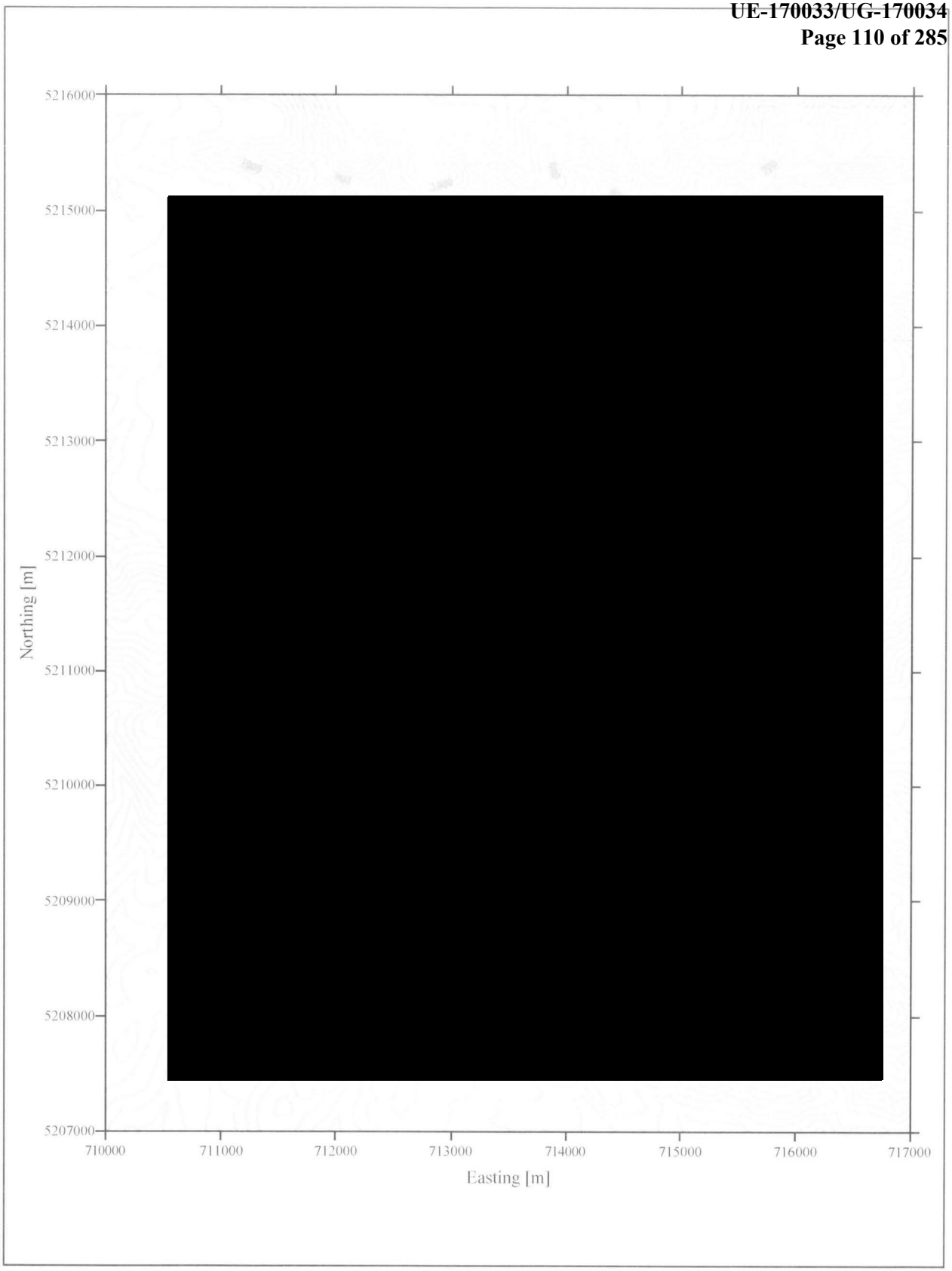

Figure 5.1 Wild Horse Wind Farm proposed turbine layout.

[redacted]

[redacted]

[redacted]

[redacted]

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[redacted]

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

[redacted]

APPENDIX 1

Data analysis procedure

1. Correlation of wind speed and direction across the site.
2. Site wind speed variations.
3. Projected energy production
4. Confidence analysis
5. References

1 Correlation of wind speed and direction across the site

The method used to determine the long-term mean wind speed for a "target" site from a "reference" site is based on the Measure-Correlate-Predict approach, which is outlined below.

The first stage in the approach is to measure, over a period of about one year, concurrent wind data from both the "target" site and the nearby "reference" site for which well established long-term wind records are available. The short-term measured wind data are then used to establish the correlation between the winds at the two locations. Finally, the correlation is used to adjust the long-term historical data recorded at the "reference" site to calculate the long-term mean wind speed at the site.

The concurrent data are correlated by comparing wind speeds at the two locations for each of twelve 30 degree direction sectors, based on the wind direction recorded at the "reference" site. This correlation involves two steps:

- Wind directions recorded at the two locations are compared to determine whether there are any local features influencing the directional results. Only those records with speeds in excess of 5 m/s at both locations are used.

- Wind speed ratios are determined for each of the direction sectors using a principal component analysis with the solution forced through the origin. This method is equivalent to a linear least-squared regression forced through the origin minimising the orthogonal offset.

In order to minimize the influence of localized winds on the wind speed ratio, the data are screened to reject records where the speed recorded at the "reference" site falls below 3 m/s or a slightly different level at the "target" site. The average wind speed ratio is used to adjust the 3 m/s wind speed level for the "reference" site to obtain the higher level for the "target" site, to ensure unbiased exclusion of data. The wind speed at which this level is set is a balance between excluding low winds from the analysis and still having sufficient data for the analysis. The level used excludes only winds below the cut-in wind speed of a wind turbine which do not contribute to the energy production.

The result of the analysis described above is a table of wind speed ratios, each corresponding to one of twelve direction sectors. These ratios are used to factor the wind data measured at the "reference" site over the historical reference period, to obtain the long-term mean wind speed at the "target" site.

2 Site wind speed variations

To calculate the variation of mean wind speed over the site, the computer wind flow model, WAsP is used. Details of the model and its validation are given by Troen and Petersen [1].

The inputs to the model are a digitized map of the topography and surface roughness length of the terrain for the site and surrounding area. A digitized map of an area surrounding the site of 28 km x 28 km was derived from 1:24,000 USGS scale maps. Although this domain size is much larger than the area of the site itself, such an area is necessary since the flow at any point is dictated by the terrain several kilometres upwind.

Wind flow is affected by the roughness of the ground. The surface roughness length of the site and surrounding area has been estimated, as detailed in the main text.

The wind flow calculations were carried out for 30 degree steps in wind direction corresponding to the measured wind rose and results were produced as speed-up factors relative to the mast location for a grid encompassing the site area.

To determine the long-term mean wind speed at any location, the speed-up factor for each wind direction was weighted with the measured probability previously derived for the mast location. All directions were then summed to obtain the long-term mean wind speed at the required location.

3 Projected energy production

The components of the derivation of the wind farm net energy output prediction are listed and described below:

Ideal energy output

The ideal energy production is the theoretical output of the wind farm with the hub height wind speeds at the appropriate mast location applied for all associated turbines. Any density adjustment required due to a difference between the air density at hub height at the reference mast location and that assumed for the turbine power curve is applied as discussed in the main body of the report and included in the ideal energy output.

Topographic and wake effect calculations

The first step in modelling flow through an array of wind turbines is the calculation of the flow in the wake of a single machine. Immediately downstream of the rotor, there is a momentum deficit with respect to free stream conditions, which is equal to the thrust force on the machine. As the flow proceeds downstream, there is a spreading of the wake and recovery to free stream conditions. Turbulent momentum transfer is important in this process.

The model used here, WindFarmer, has been developed by GH and validated using measurements on both full-scale machines and on wind-tunnel models [2, 3, 4].

The model is employed in a scheme which, taking each wind speed and direction in turn calculates the power production of the wind farm. The important parameters used in this process are:

- array layout
- upstream mean wind speed
- ambient turbulence
- wind turbine thrust characteristic
- wind turbine power characteristic
- rotor speed
- topographical speed-up factors from site wind flow calculations

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It is noted that due to the relatively tight spacing of the turbines in the prevailing wind directions, an additional pragmatic margin has been included in the array loss to account for the likely reduced rate of wake recovery compared to that modelled.

Topographical effects are accounted for in the model using the speed-up factors calculated by the wind flow model described above. Any air density adjustments required due to differences between the hub height air density at the turbine locations and that at the reference mast location is applied as discussed in the main body of the report and included in the topographic effect. The array model is used to calculate the wind speed in the turbine wakes, assuming the terrain is flat, and the wind speed is adjusted by the speed-up factor when the wake reaches a downstream turbine.

Electrical transmission efficiency

[redacted] Neither a review of the Zilkha figure nor a detailed analysis of the electrical system has been undertaken by GH. It is recommended that this figure be reviewed once such an analysis has been performed.

Turbine availability

[redacted] based on data from modern operational wind farms. However, availability may be a matter of warranty between the owner and the turbine supplier and the assumed figure should be reviewed when the terms of that warranty are clear.

Blade degradation and fouling

The turbine production may be affected by the build up of insects, dirt or ice on the blades. This build up will change the characteristics of the blade and therefore affect the performance of the blades and the turbine output.

An adjustment has been included to allow for lost production due to blade fouling. A figure of 98.0 % has been assumed to be appropriate for these pitch regulated turbines.

High wind hysteresis

This is caused by the turbine cut in and cut out control criteria for high wind speeds. The magnitude of this loss is influenced by three factors.

1. The turbine will cut out when the maximum mean wind speed is exceeded and it will not cut in again until this mean wind speed is below a mean wind speed level lower than the cut out mean wind speed.
2. The turbine will cut out if the instantaneous gust wind speed exceeds a maximum level and the turbine will not cut in until the wind speed drops to a lower value.
3. The accuracy of the calibration of the instruments that are determining the wind characteristics at the turbine.

These three effects will cause the turbine to possibly lose production for some proportion of high mean wind speed occurrences. The magnitude of this lost production has been estimated by GH by repeating the analysis using a power curve with the cut out wind speed reduced by 2.5 m/s.

Substation maintenance

Net wind farm production may be reduced due to the electrical output not being transferred to the grid network while the substation is shutdown for maintenance. A typical figure of 99.8% is assumed in this analysis to represent one day per year of planned maintenance. This is included as scheduled maintenance can not generally be accurately planned to occur on a day with low wind speeds.

Utility downtime

Net wind farm production will be reduced if the grid is not available for the wind farm to output electricity to it. This type of loss must be considered on a site specific basis. It has not been considered in this analysis.

Wind sector manageme nt

If wind turbine spacing is close the site conditions may exceed the wind conditions within the wind turbine certification criteria. In these circumstances it may be necessary to shut down some turbines which are closely spaced when the wind direction is parallel to the line of turbines. Details of a WSM strategy for the final V80 layout to be employed have been provided and the effect included in this assessment.

4 Confidence analysis

There are 5 categories of uncertainty associated with the site wind speed prediction at the proposed site:

1. There is an uncertainty associated with the measurement accuracy of the anemometers. The instruments used have not been individually calibrated. In addition the mounting arrangement of the instruments is not to recommended standards. A figure of 3.0 % is assumed here to account for these and other second order effects such as over-speeding, degradation, air density variations and additional turbulence effects.

2. The long-term mean wind speed at each mast was derived from correlation analyses, using other site masts as a long-term reference. The uncertainty associated with correlating and extrapolating between masts is evaluated from the statistical scatter in the correlation plots.

3. There is an uncertainty associated with the assumption made here that the historical period at the meteorological site is representative of the climate over longer periods. A study of historical wind records indicates a typical variability of 6 % in the annual mean wind speed [5]. This figure is used to define the uncertainty in assuming the long-term mean wind speed is defined by a period approximately 2.5 years in length.

4. There is uncertainty associated with the derivation of the wind shear between heights on the mast and the assumption that this is representative of the wind flow at heights up to hub height. A figure of either 0.5 or 1.5 % has been assumed here to account for this uncertainty dependent upon the extent of extrapolation.

5. Additionally, even if the long-term mean wind speed were perfectly defined there will be variability in future mean wind speeds observed at the wind farm site. The variability in future mean wind speeds is dependant on the period considered. Performance over one and ten years of operation are therefore included in the uncertainty analysis. Account is taken of the future variability of wind speed in the energy confidence analysis but not the wind speed confidence analysis.

It is assumed that the time series of wind speed is random with no systematic trends. Care was taken to ensure that consistency of the reference measurement system and exposure has been maintained over the historical period and no allowance is made for uncertainties arising due to changes in either.

Uncertainties type 1 to 4 from above are added as independent errors on a root-sum-square basis to give the total uncertainty in the site wind speed prediction for the historical period considered.

It is considered here that there are 5 categories of uncertainty in the energy output projection:

1. Long-term mean wind speed dependent uncertainty is derived from the total wind speed uncertainty (types 1 to 4 above) using a factor for the sensitivity of the annual energy output to changes in annual mean wind speed. This sensitivity is derived by a perturbation analysis about the central estimate.

2. Wake and topographic modelling uncertainties. Validation tests of the methods used here, based on full-scale wind farm measurements made at small wind farms have shown that the methods are accurate to 2 % in most cases. For this development an uncertainty in the wake and topographic modelling of 4 % to 7 % is assumed due to complex terrain and close turbine spacing.

3. Future wind speed-dependent uncertainties described in '5' above have been derived using the factor for the sensitivity of the annual energy output to changes in annual mean wind speed.

4. Accuracy of the fiscal substation energy meter. An uncertainty of 0.3 % is assumed here based on typical utility meter accuracy.

5. Turbine uncertainties are generally the subject of contract between the developer and turbine supplier and we have therefore made no allowance for them in this work.

Again those uncertainties which are considered are added as independent errors on a root-sum-square basis to give the total uncertainty in the projected energy output.

5 References

1. I Troen and E L Petersen, "European Wind Atlas", Risø National Laboratory, Denmark, 1989.

2. U Hassan, A G Glendinning and C A Morgan, "A Wind Tunnel Investigation of the wake structure and machine loads within small wind turbine farms", Proc of the 12th BWEA Wind Energy Conference, IMechE, 1990.

3. J Højstrup, "Turbulence measurements in a windfarm", Proc. EWEA Wind Energy Conference, Madrid, 1990.

4. J G Warren et al. "Performance of wind farms in complex terrain", Proc. Of the 17th BWEA Wind Energy Conference, 1995.

5. P Raftery, A J Tindal and A D Garrad, "Understanding the risks of financing windfarms", Proc. EWEA Wind Energy Conference, Dublin, 1997.

DRAFT

Wind Resource and Energy Assessment Wild Horse Expansion Wind Power Project

EARP0030

CONFIDENTIAL

October 7, 2008

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Approvals

Prepared by Date

Prepared by Date

Reviewed by Date

Version Block

Version	Release Date	Summary of Changes
DRAFT		

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Executive Summary

DNV Global Energy Concepts Inc. (DNV-GEC) has been retained by Puget Sound Energy (PSE) to complete an energy assessment for the proposed Wild Horse Expansion wind power project, located approximately 16 km (25 miles) east of Ellensburg, Washington. Table 1 presents a summary of the key features of the project site, wind resource and estimated energy production. Full details of DNV-GEC's methodology and analysis results are included in the main body of the report.

Table 1. Wild Horse Expansion Executive Summary

Project Summary	
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
Wind Resource Summary	
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted] [redacted]
	[redacted] [redacted]
[redacted]	[redacted]
Energy Assessment Summary	
[redacted]	[redacted]
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[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
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Background and Project Description

DNV Global Energy Concepts Inc. (DNV-GEC) has been retained by Puget Sound Energy (PSE) to complete an energy assessment for the proposed Wild Horse Expansion wind power project, located approximately 16 km (25 miles) east of Ellensburg, Washington. The location of the project is displayed in Figure 1. This report presents an energy assessment for a 22-turbine layout consisting of Vestas V80 2.0 MW wind turbines installed a 67-m hub height.

The total installed project capacity for the Vestas V80 turbines is 44.0 MW. The principal features of the proposed turbines are shown in Table 2.

In addition to the energy assessment presented here, DNV-GEC has prepared several other estimates for the Wild Horse Expansion project at different phases of the development process. In January 2008 DNV-GEC reviewed an energy assessment report prepared by RAM Associates (RAM) for a 22-turbine layout that differs from the current layout under consideration. Based on that review, DNV-GEC made preliminary energy estimates based on RAM's met tower wind speeds and wind distribution while applying DNV-GEC adjustments for topography and technical losses. In that analysis, [redacted]

In May 2008 DNV-GEC issued a draft energy assessment for the same 22-turbine layout evaluated in the RAM report based on DNV-GEC's independent processing and review of the met tower data measured on site. Energy estimates for three configurations listed below were presented:

- [redacted]
- [redacted]
- [redacted]

[redacted]

Since issuing the draft energy assessment in May 2008, DNV-GEC has performed several high level analyses of project variations ranging in size from 22 to 28 turbines. On May 16, 2008, estimates for the same three configurations listed above were supplied for a layout consisting of 27 turbines. The net capacity factors were within 0.1% of the estimates for the 22 turbines reported in the May draft.

[redacted]

[redacted]

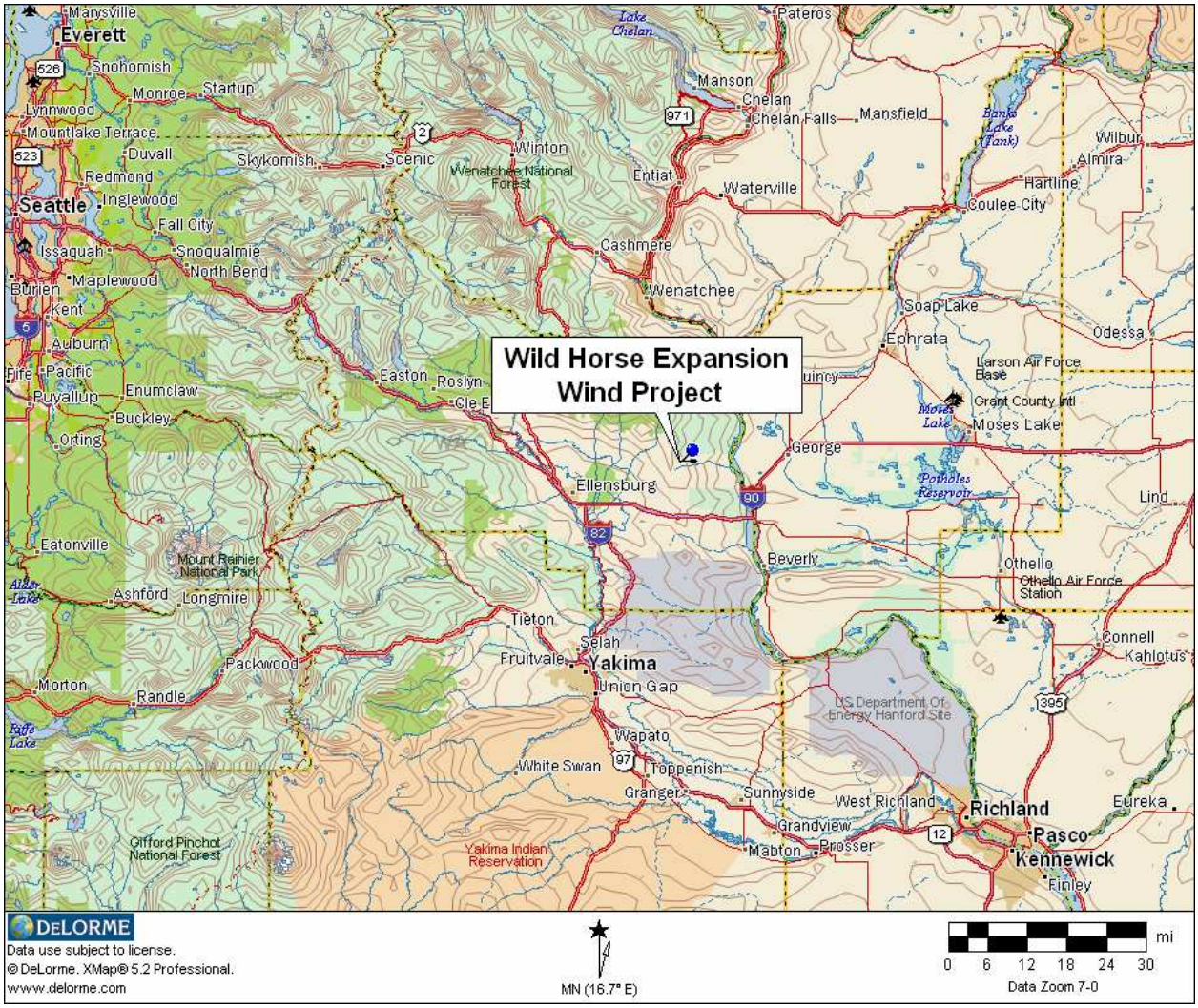

Figure 1. Location of the Proposed Wild Horse Expansion Wind Power Project

Table 2. Proposed Wind Turbine Specifications

[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Site Description and Wind Resource Measurements

[redacted]

[redacted]

[redacted]

Figure 2. Project Meteorological Tower Locations

All five met towers are NRG Systems, Inc., tubular pole-type towers erected specifically for wind resource measurements. Table 3 summarizes the met tower data used in this analysis including the data start and end dates, measurement levels and sensor orientations. DNV-GEC compiled, validated, and incorporated into this analysis all available on-site tower data.

Table 3. Met Tower Summary

Met	Ground Elevation (masl)	Period of Record	Nominal Wind Speed Collection Heights (m)[1]	Anemometer Orientations (º)	Sampling Rate[2]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

1. (2) indicates that two wind speed sensors are mounted at or very near that level.
2. A "mixed" sampling rate indicates that data were collected at an hourly rate and a 10-minute rate for different data periods.

Representative photos of the met towers are presented in Appendix A. The commissioning sheets for Met 319 and Met 320 are included in Appendix B.

Met 207, Met 208, and Met 319 used NRG 9300 data loggers. Met 303 and Met 320 used NRG Symphonie data loggers.

When two sensors are mounted at or very near the same measurement level, DNV-GEC designates a primary and secondary anemometer orientation based on the tower configuration and the prevailing winds at the site. For the met towers in the Wild Horse Expansion area, DNV-GEC designated the west-oriented anemometers as primary and the south-oriented anemometers as secondary. Wind speeds from the primary anemometers are used in this analysis except when the data are invalid, in which case the secondary sensor data are used, if valid.

Data from all met towers were evaluated; however, the energy assessment is primarily based on the data collected at Met 319 and Met 320. Met 303 data were used to extend the period of record at Met 319 and to evaluate the long-term representativeness of the period of record at Met 320. The shear exponent could not be calculated from Met 303 data because it is not instrumented with sensors at multiple measurement levels and the tower height is too short to extrapolate to hub height with confidence. For this reason, the data from Met 303 were not used to characterize hub-height wind speeds or to estimate energy production for the project. Met 207 and Met 208 were not used directly in the energy estimate. Data from these met towers could not be adjusted to represent the long-term wind speeds for the site because these data sets do not have concurrent periods of record with Met 303, the tower with the longest period of record, and do not correlate well to nearby long-term reference stations. The inability to extend these towers' records resulted in periods of record inconsistent with Met 319 and Met 320. While not used directly in the assessment, Met 207 and Met 208 were used to confirm on-site wind characteristics indicated by the other on-site measurements.

The percent of valid data per month is presented in Table 4. A valid data record is defined as a record for which both a valid upper level wind speed and a direction measurement are available. Some reasons for invalid records include missing data, tower shadow of anemometers and icing. The data recovery rates for this site are fair. The lower data recovery in the winter months is primarily due to the icing of the measurement sensors. Overall recovery values for the met

towers represent the annual average recovery excluding months of partial data collection at the beginning and end of the period of record.

For Met 319, data are missing from July 16, 2005, to July 23, 2005, and from October 22, 2005, to October 26, 2005. No data were collected from late November 2005, when the tower collapsed, to June 20, 2006, when the tower was replaced. From June 20, 2006 forward, the ratio of the wind speeds measured by the sensors at the 50-m level indicate a gradual decline of the wind speed measurement from the secondary sensor. This trend continued until a complete malfunction of that sensor in June 2007. At the time of the site visit, a broken cup on this anemometer was observed. The data from this sensor were removed from the analysis beginning in June 2006, resulting in a lower recovery rate because there is no secondary measurement available when the primary sensor is shadowed by the tower.

Data are missing for Met 319 between October 27, 2006, and February 2, 2007, when an Anabat rope became tangled with the tower. The tower was lowered to remove the rope and the secondary 30-m sensor was replaced. Data are also missing from October 22, 2007, to October 26, 2007, for Met 319. The overall recovery value listed in Table 4 for Met 319 includes the periods of missing data in the average.

Recovery for Met 207 and 208 is lower than the other towers because there is no secondary sensor on the tower that would provide a valid measurement when the primary sensor is waked by the tower.

Table 4. Percent Valid Data

Month		Met 207	Met 208	Met 303	Met 319	Met 320
2001	June	62%	70%	N/A	N/A	N/A
	July	93%	92%	N/A	N/A	N/A
	August	83%	86%	N/A	N/A	N/A
	September	80%	85%	N/A	N/A	N/A
	October	85%	90%	N/A	N/A	N/A
	November	78%	87%	N/A	N/A	N/A
	December	46%	54%	N/A	N/A	N/A
2002	January	74%	81%	N/A	N/A	N/A
	February	81%	86%	N/A	N/A	N/A
	March	95%	95%	N/A	N/A	N/A
	April	91%	87%	N/A	N/A	N/A
	May	95%	91%	N/A	N/A	N/A
	June	98%	87%	N/A	N/A	N/A
	July	98%	86%	N/A	N/A	N/A
	August	97%	87%	N/A	N/A	N/A
	September	98%	87%	N/A	N/A	N/A
	October	93%	81%	N/A	N/A	N/A
	November	94%	82%	N/A	N/A	N/A
	December	43%	46%	N/A	N/A	N/A

Month	Met 207	Met 208	Met 303	Met 319	Met 320
2003 January	53%	52%	N/A	N/A	N/A
February	90%	82%	N/A	N/A	N/A
March	32%	32%	5%	N/A	N/A
April	N/A	N/A	99%	N/A	N/A
May	N/A	N/A	100%	N/A	N/A
June	N/A	N/A	100%	N/A	N/A
July	N/A	N/A	100%	N/A	N/A
August	N/A	N/A	100%	N/A	N/A
September	N/A	N/A	100%	N/A	N/A
October	N/A	N/A	100%	N/A	N/A
November	N/A	N/A	98%	N/A	N/A
December	N/A	N/A	56%	N/A	N/A
2004 January	N/A	N/A	54%	N/A	N/A
February	N/A	N/A	78%	N/A	N/A
March	N/A	N/A	98%	N/A	N/A
April	N/A	N/A	95%	N/A	N/A
May	N/A	N/A	100%	N/A	N/A
June	N/A	N/A	100%	N/A	N/A
July	N/A	N/A	100%	N/A	N/A
August	N/A	N/A	100%	N/A	N/A
September	N/A	N/A	100%	N/A	N/A
October	N/A	N/A	100%	N/A	N/A
November	N/A	N/A	99%	N/A	N/A
December	N/A	N/A	75%	N/A	N/A
2005 January	N/A	N/A	78%	N/A	N/A
February	N/A	N/A	97%	N/A	N/A
March	N/A	N/A	96%	N/A	N/A
April	N/A	N/A	98%	N/A	N/A
May	N/A	N/A	100%	N/A	N/A
June	N/A	N/A	100%	19%	49%
July	N/A	N/A	100%	77%	100%
August	N/A	N/A	100%	100%	100%
September	N/A	N/A	100%	100%	100%
October	N/A	N/A	100%	69%	100%
November	N/A	N/A	70%	17%	75%
December	N/A	N/A	70%	0%	76%
2006 January	N/A	N/A	81%	0%	93%
February	N/A	N/A	94%	0%	98%
March	N/A	N/A	96%	0%	98%
April	N/A	N/A	97%	0%	100%
May	N/A	N/A	99%	0%	100%

Month	Met 207	Met 208	Met 303	Met 319	Met 320
June	N/A	N/A	100%	26%	100%
July	N/A	N/A	100%	88%	100%
August	N/A	N/A	100%	86%	100%
September	N/A	N/A	100%	81%	100%
October	N/A	N/A	98%	77%	99%
November	N/A	N/A	84%	0%	93%
December	N/A	N/A	68%	0%	88%
2007 January	N/A	N/A	77%	0%	83%
February	N/A	N/A	84%	68%	81%
March	N/A	N/A	91%	91%	98%
April	N/A	N/A	94%	87%	100%
May	N/A	N/A	99%	85%	100%
June	N/A	N/A	100%	85%	100%
July	N/A	N/A	100%	87%	100%
August	N/A	N/A	100%	87%	100%
September	N/A	N/A	100%	91%	100%
October	N/A	N/A	98%	80%	100%
November	N/A	N/A	80%	77%	83%
December	N/A	N/A	75%	69%	81%
2008 January	N/A	N/A	84%	80%	89%
February	N/A	N/A	98%	88%	100%
March	N/A	N/A	N/A	43%	52%
Overall*	**83%**	**81%**	**93%**	**56%**	**95%**

*Excludes partial months at beginning and end of the period of record or due to periods of missing data.

Wind Analysis Methodology

This section presents an overview of the methodology used to process the data. Details of the analysis and results are provided in following sections.

All wind speed sensors used at the site were uncalibrated NRG #40 anemometers. Raw data from the site met towers were processed using the consensus transfer function for these sensors: wind speed (m/s) = 0.765 x Hz + 0.35.

DNV-GEC followed a standard validation process to identify and remove erroneous data (e.g., due to icing or tower shadow). Wind speed data were considered invalid due to icing if the temperature was near or below freezing and an additional criterion was met, such as the wind vane or anemometer standard deviation equaling zero for consecutive records or the 10-minute/hourly average wind speed being lower than expected, relative to the wind speeds at other levels. Data were also considered invalid when the tower shadowed the sensors (waked data). This occurs when the wind comes from directions that place the tower between the wind and a sensor. For example, an anemometer mounted to the east of the tower will record invalid wind speed data when the winds are from the west. All invalid data are removed from the data set. For NRG tubular towers, the significant tower wake influence is approximately 50° wide. Wind direction for each data record was determined using the upper level wind vane. The vane at a lower level was used when data from the upper level vane were unavailable for a given record.

Hub-height wind speeds were estimated using the monthly diurnal wind shear pattern measured at the site. DNV-GEC computed shear from wind speed sensors on booms with the same orientation.

Long-term reference stations were consulted for the purpose of adjusting on-site data to reflect the long-term mean wind speed. Due to poor correlations with the off-site long-term reference stations DNV-GEC chose not to make a long-term adjustment to the on-site data. The considerations and methodology for this decision are discussed in *Monthly and Long-Term Wind Speeds* section of this report.

The wind speeds were normalized to 8,760 hours so that hub-height annual frequency distributions could be created. To normalize the data set to 8,760 hours, DNV-GEC developed a monthly record-length correction factor by counting the number of records with valid upper sensor wind speed and wind direction observations available in each month. The data were then categorized by wind direction sector (30° sectors centered on 0°, 30°, etc.) and wind speed bin (intervals of 0.5 m/s centered on 0.5 m/s, 1.0 m/s, etc.) in order to generate hub-height annual frequency distributions showing the number of observations in each wind speed bin and for each wind direction sector.

DNV-GEC also calculated the turbulence intensity (TI) for each measurement level at each met tower. TI was calculated as the standard deviation of the wind speed observation divided by the mean wind speed observation within the 10-minute interval. Only 10-minute data were used in

calculation of TI. TI at 67-m was estimated by using the standard deviation of the upper level sensor with the hub-height estimated wind speed, which results in somewhat lower TI than actually measured at the upper level sensor and is consistent with the expected decrease in TI with increased height.

Wind Analysis Results

Evaluation of the data, including a discussion of the wind shear, wind speed correlations, turbulence, and a presentation of the wind roses, is included in this section. Because data from the met towers had varying degrees of influence on the energy assessment, only the results from the primary met towers, Met 319 and Met 320, are provided below. Analysis results for Met 207, Met 208 and Met 303 are discussed when relevant to the energy assessment.

Wind Shear

DNV-GEC calculated the wind shear exponent[1] between a lower and an upper anemometer for sensors located on booms with the same orientation. Only wind speeds greater than 4 m/s were included in the calculation. Primary sensors were used except for cases where the primary sensor was waked by the tower, iced or malfunctioning, in which case the shear was calculated between the secondary sensors if available.

Shear at Met 319 and Met 320 was calculated between the [redacted]-m and [redacted]m sensors and is shown in Figure 3 and Figure 4, respectively. Directional shear is shown in Figure 5.

[redacted]

[1] Wind shear describes the typical increase in wind speed at greater heights above the ground. The wind shear exponent (alpha or α) is one method of describing the extent to which wind speeds vary with increasing height above ground level. The equation that uses the exponent is $(V_1 / V_2) = (H_1 / H_2)^{\alpha}$, where V_1 and V_2 are wind speeds at heights H_1 and H_2, respectively (measured from the ground level), and α is the dimensionless wind shear exponent.

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[redacted]

Resulting overall average shear exponents for each met tower are listed in Table 5 by hour and in Table 6 by direction. Average annual shear exponents are [redacted] and 0.08 for Met 319 and Met 320, respectively. Shear could not be calculated at Met 303 because there are not sensors at multiple measurement levels. Met 207 confirms the [redacted] at Met 319 and Met 320 with an average annual shear exponent 0.09. The [redacted] The calculated shear exponent can vary

from met tower to met tower due to different terrain and vegetation surrounding each met tower and the distance between sites. Inaccurate reporting of the wind speed measurement heights on a tower can also affect the calculated shear exponent.

Shear calculated at Met 319 and Met 320 was applied to measurement-height wind speeds on a monthly and diurnal basis to estimate hub-height wind speeds.

Table 5. Average Shear Exponents by Hour

Hour	Met 319	Met 320
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
Average	[redacted]	[redacted]

Table 6. Average Shear Exponents by Direction

Direction Sector (º)	Met 319	Met 320
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
Overall	[redacted]	[redacted]

Note: Shear values from 0º and 330º are based on less than 34 hours of measurement for Met 319 and less than 66 hours for Met 320.

Turbulence

Turbulence intensity (TI) was calculated as the ratio of the wind speed standard deviation to the wind speed. Average TI was calculated for all wind speeds, and average TI at wind speeds greater than 4 m/s was calculated by direction. Turbulence decreases with height above ground level; consequently, TI at the upper measurement levels on each tower were extrapolated to the 67-m turbine hub heights by applying wind shear to calculate a hub-height wind speed while keeping the standard deviation constant. This method has been shown to reliably predict the decrease in turbulence with height across measurement levels on towers, and should produce reasonable predictions of the hub-height turbulence.

The estimated TI at 67-m and the average measured TI by direction at the upper measurement level (50-m) are presented in Table 7, for Met 319 and Met 320. TI values are shown by wind speed in Table 8 for upper measurement level and hub height. TI versus wind speed at the 67-m hub height is plotted in Figure 6. Excluding TI from wind speeds less than 4 m/s, [redacted] with weighted averages of [redacted] respectively, at the 67-m hub height. Met 207 and Met 208 data confirm the TI pattern at Met 319 and Met 320 with an [redacted] calculated at both towers for the 67-m hub height.

Table 7. Mean Turbulence Intensity by Direction Sector (%)

Direction Sector (°)	Met 319		Met 320	
	50 m	67 m	50 m	67 m
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Average (>4m/s)	[redacted]	[redacted]	[redacted]	[redacted]

Table 8. Mean Turbulence Intensity by Wind Speed (%)

Wind Speed (m/s)	Met 319		Met 320	
	50 m	67 m	50 m	67 m
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Average (>4m/s)	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

Figure 6. Turbulence Intensity by Wind Speed at 67-m Hub Height

Wind Rose

A wind rose depicts the frequency and energy content of wind by direction. Annualized wind roses estimated at 50 m for Met 319 and Met 320 are presented in Figure 7 and Figure 8, respectively. As shown in the figures, the wind roses show a similar pattern, with significant energy-producing winds coming from the west.

[redacted]

Monthly and Long-Term Wind Speeds

To extend the period of record to better represent the long-term wind speeds at the site, long-term adjustments based on on-site met towers and nearby reference stations were considered.

Data were synthesized at Met 319 from data measured at Met 303 to extend the period of record and to fill in periods of missing data. The data were synthesized based on linear regressions between Met 319 and Met 303 derived over concurrent measurement periods. These regressions were generated using hourly average wind speeds greater than 3 m/s, and were established on a directional basis using 30° wind direction sectors, in order to capture potential differences in relationships resulting from variations in the terrain surrounding the towers. These comparisons were made between the upper measurement levels on each tower. The overall R-squared value including all data was 0.90 indicating a good relationship. Summary statistics describing the observed relationships by direction are presented in Table 9. The slopes and intercepts shown in this table were applied to the measured 15-m wind speeds at Met 303 to synthesize upper level data at Met 319. Data were only synthesized for periods where no measured data were available.

Table 9. Summary Statistics of Correlations from Met 303 to Met 319

Direction Sector (º)	Slope	Intercept	R^2	Number of Data Points
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Overall	[redacted]	[redacted]	[redacted]	[redacted]

*Slope and intercept values for sectors where the correlation coefficient was low were replaced with the overall slope and intercept value.

Data were not synthesized at Met 320 because the hourly correlation between Met 320 and Met 303 was poor with an overall R-squared value of 0.64. As an alternative method, monthly adjustment factors were developed based on the 5-year record at Met 303 as possible means for adjusting the measurements at Met 320 to reflect a longer-term wind speed for the site. Monthly adjustment factors indicated the region's winds during the period of on-site record were 0.3% lower than the long-term average. Due to the small correction indicated by the data, DNV-GEC chose not to adjust the data at Met 320. Although an adjustment was not made to the measured data from Met 320, the estimated wind speeds were treated as equivalent to the length of record at Met 303.

Monthly averages of upper level measured and synthesized wind speeds for each met tower are presented in Table 10. The monthly averages are based on the data available during that month and may not be representative of the full month. The overall averages are annualized.

Table 10. Monthly Average Wind Speeds (m/s)

Month	Met 303 (15-m)	Met 319* (50-m)	Met 320 (50-m)
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Month	Met 303 (15-m)	Met 319* (50-m)	Met 320 (50-m)
Average Wind Speed (m/s)			

*Data in Bold Italics include synthesized based on the relationship to Met 303

Long-Term Reference Stations Consulted

Various long-term reference stations were consulted for correlation to on-site data for the purpose of adjusting the on-site data to reflect the long-term mean wind speed. The reference stations and the site are shown together in Figure 9. On-site data were correlated to regional long-term meteorological data from Automated Surface Observing System (ASOS) stations and a radiosonde observation station. On-site data were also correlated to modeled data from the U.S. National Centers for Environmental Prediction/National Center for Atmospheric Research Reanalysis Project (Reanalysis data). After analysis of the reference data, DNV-GEC chose not to make a long-term adjustment to the on-site wind speeds based on the reference stations due to poor correlations. The considerations and methodology for this decision are discussed below.

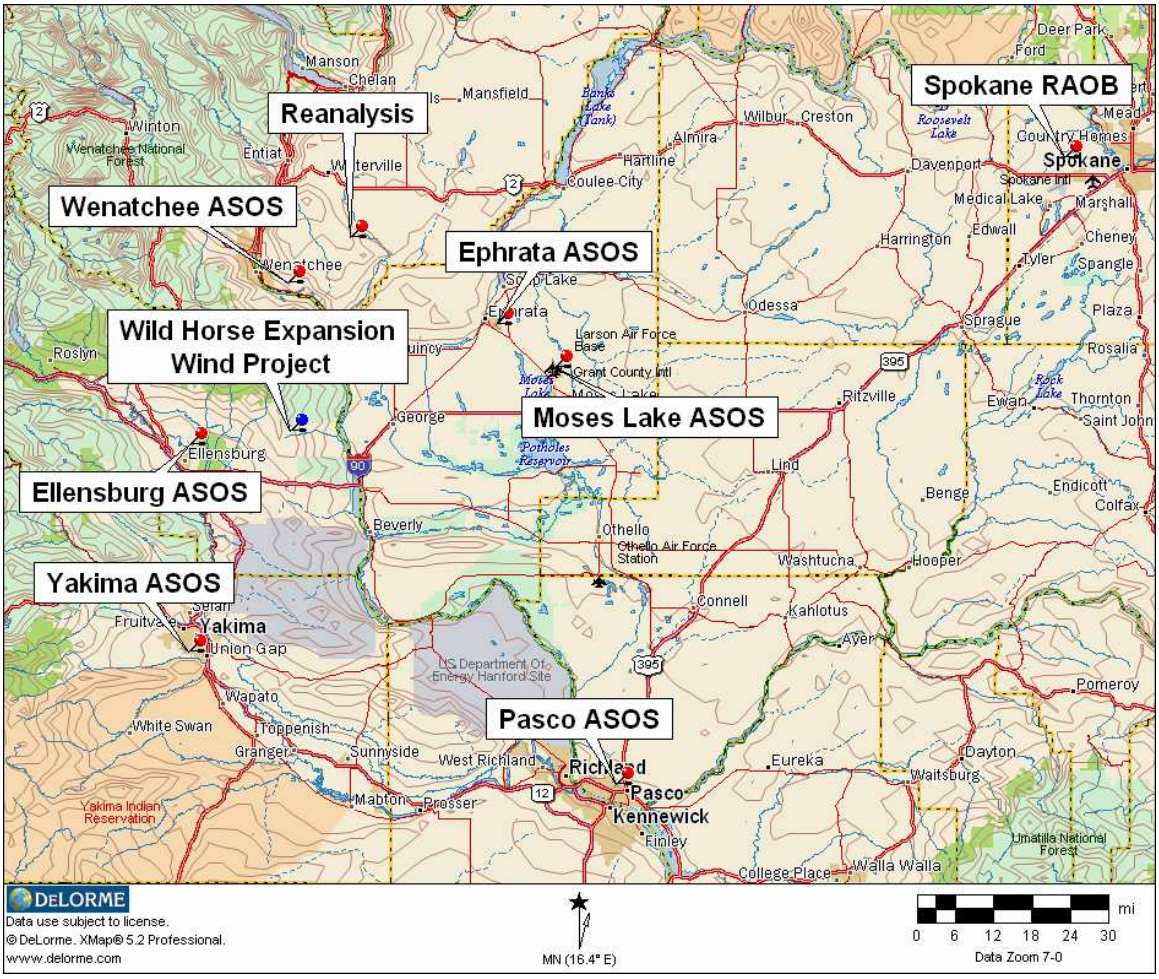

Figure 9. Location of Wild Horse Expansion and Long-term Reference Stations

Wind data from the Automated Surface Observing System (ASOS) stations near Ellensburg, Wenatchee, Yakima, Ephrata, Moses Lake, and Pasco were consulted. Monthly averages have a poor correlation to on-site monthly averages; with the greatest R-squared value being 0.39. Over the past few years, the National Weather Service and Federal Aviation Administration have been converting ASOS station anemometry to sonic sensors. This type of instrumentation change can affect the long-term consistency of the data. All ASOS stations consulted report a sensor change during the on-site period of record. Due to this sensor change and poor correlations to site data, the ASOS stations were not considered further as potential long-term references.

Wind data from the Spokane radiosonde observation station (Spokane RAOB) were consulted. The Spokane RAOB is located approximately 200 km (125 miles) east of the project. Data were investigated at the 1000 m height. The Spokane RAOB data demonstrated a fair correlation to on-site data, with a monthly R-squared value of 0.62 when correlated to Met 320. The data were examined over the period October 1995 to March 2008. The Spokane RAOB data indicated the region's winds during the period of on-site record were [redacted] % higher than the long-term average. The Spokane RAOB data were found to be consistent over the entire period with no indications

of upward or downward trends; however, long-term adjustments from this station were not pursued further due to relatively poor correlations with site data.

DNV-GEC also evaluated Reanalysis data. The Reanalysis model is a global climate model that assimilates a network of meteorological observations to simulate past weather. The output includes wind speed and wind direction on a 2.5º latitude by 2.5º longitude grid, four times daily, at 28 vertical levels. DNV-GEC evaluated the grid point 47.5º N and 120º W, at pressure levels of 925 millibars (mb) and 850 mb, corresponding to approximately 750 m and 1500 m above sea level, respectively. The Reanalysis grid point examined is located approximately 50 km (30 miles) northeast of the project. The Reanalysis data demonstrated a poor correlation to on-site data, with a monthly R-squared value of 0.28 observed at the 850-mb level when correlated to Met 320.

Correlation parameters derived from the relationship between the on-site and reference station monthly average wind speeds are shown in Table 11.

Table 11. Correlation Parameters for Met 319 and Met 320 to Long-Term Stations

Reference Station	Quality of Correlation (R^2 Value) with Met 319	Quality of Correlation (R^2 Value) with Met 320
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

As shown in Table 11, the correlation between the data measured on site and at the local reference stations is poor; therefore, DNV-GEC chose not to use the reference station data to adjust on-site wind speeds as it would not reduce the uncertainty on the long-term average wind speed.

Hub-Height Wind Speeds

Based on the estimated met tower wind speeds and wind shear, DNV-GEC developed a wind speed frequency distribution representing the hub-height (67-m) wind speeds and wind direction at each met tower location. Shear conditions observed between a lower and upper level sensor at each tower were assumed to continue up to hub height.

Data from each tower over their entire period of record were binned into annual distributions and normalized to represent 8,760 hours per year. Wind speed frequency distributions were generated for each tower from this data set. Annual hub-height wind speeds computed from the frequency distributions are presented in Table 12.

Table 12. Annual Average Hub Height Wind Speeds

Met Tower	Wind Speed (m/s) at 67-m Hub-Height
[redacted]	[redacted]
[redacted]	[redacted]

Turbine Layout and Gross Energy Estimates

[redacted]

DNV-GEC estimated the average air density for the site to be 1.10 kg/m^3 based on measured temperature data (an average of approximately 7ºC) from the on-site met towers and the average turbine hub-height elevation (1153 m). Density-specific power curves at 1.10 kg/m^3 for the Vestas V80 turbine was used to calculate energy production.

The power curve and wind speed distributions from the met towers were used to estimate annual gross energy for each turbine location. Table 13 presents the long-term annual frequency at the met tower locations and the power curve for the Vestas V80. The gross energy and gross capacity factor at the met tower locations for the proposed turbine type and hub height are listed in Table 14.

Table 13. Hub-Height Average Wind Speed Frequency Distributions and Power Curves at 1.10 kg/m^3 Air Density

Wind Speed (m/s)	Vestas V80 Power (kW)	Met 319 at 67 m (hours)	Met 320 at 67 m (hours)
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Wind Speed (m/s)	Vestas V80 Power (kW)	Met 319 at 67 m (hours)	Met 320 at 67 m (hours)
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
Average Wind Speed (m/s)		[redacted]	[redacted]

Table 14. Gross Energy and Gross Capacity Factor for Vestas V80 at 67 m

	Met 319	Met 320
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

1. Capacity factors are based on a turbine rating of 2000 kW for the Vestas V80 2.0MW.

Estimated wake losses have been calculated using the WindFarm software package. The contribution of the existing Wild Horse project turbines to wake losses at Wild Horse Expansion was included in the calculation. Annual wake losses were estimated using four calculation methods. The four methods utilize combinations of two wake models (Ainslie and Park) that predict the deficit behind single turbines and two wake combination models (square root of the sum of squares of velocity deficit, and energy balance) that combine the single wakes when they overlap. Detailed investigations have shown wake model performance to be sensitive to terrain type, atmospheric stability, turbulence intensity, and inter-turbine spacing.

The performance of each model is not completely understood; therefore, DNV-GEC took the average of the four models as a best approximation of the expected wake losses. The spread of the four model results was also used to quantify the expected uncertainty of the calculations.

To incorporate the different measured wind distributions into the wake analysis, wake calculations were made using distributions from Met 319 and Met 320. Individual wake loss calculations were then averaged based on the squared-distance between each turbine and each met tower.

Estimates of wind speed, gross energy, and wake loss for each of the turbines in the project are presented in Table 15.

Table 15. Location, Average Wind Speed, Gross Energy Estimate, and Wake Loss for Vestas V80 Turbines at 67-m Hub-Height

Turbine ID	WGS84 UTM10		Assigned 67-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy Minus Wakes (MWh/yr)
	Easting (m)	Northing (m)				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Losses, Uncertainties, and Net Energy Calculations

Based on the gross annual energy estimated above, DNV-GEC estimated net energy production using a stochastic model to evaluate each source of loss or uncertainty identified for the project. Distributions appropriate for each loss or uncertainty were determined and a probabilistic description of the annual net energy was built, integrating each source. The model was then run in 10,000 iterations with each parameter changed randomly and independently to describe the distribution of potential net energy. These results were then summarized to determine the probability of exceedance of various levels. A summary of the model inputs and resulting energy projections follows.

Note that many of the losses and uncertainties are estimated based on DNV-GEC's current knowledge of the project and DNV-GEC's experiences with other wind farms. For example, the mechanical availability assumptions used are based on DNV-GEC's experiences monitoring performance of modern megawatt-scale wind turbines of similar design, but the availability at this particular site may be higher or lower for a variety of reasons. To some extent, low availability or performance may be mitigated through turbine warranties, insurance, or other factors; these issues are not considered explicitly in this analysis.

Losses

The following losses were estimated for the project. For the purpose of uncertainty modeling, the following losses are normally distributed with uncertainty values listed at one standard deviation, unless otherwise noted.

Routine Maintenance Downtime

This item includes energy lost during periods of routine maintenance of the wind turbines. Time spent for maintenance of typical modern megawatt-scale wind turbines is approximately 40 to 120 hours per year. The magnitude can vary depending on turbine complexity, cleaning requirements, and frequency of larger tasks such as gear oil changes.

DNV-GEC estimated routine maintenance downtime of 60 hours per year (or [redacted]% of the year). In general, operators seek to schedule maintenance for low-wind times. However, with a large number of turbines requiring maintenance and with the schedule constraints of the maintenance crews who perform maintenance, there is only limited flexibility to avoid windy periods, so the energy loss cannot be eliminated entirely. The relationship between time spent on routine maintenance and energy loss was also modeled as an uncertainty, with a best estimate of a multiplier of [redacted] of energy per unit time and an uncertainty of [redacted] around this estimate. Consequently, the P50 case represents an energy loss of approximately [redacted]%.

Fault Downtime

Some downtime will be incurred associated with turbine faults. The P50-case fault downtime values estimated by DNV-GEC were approximately [redacted]% for Year 1, and approximately [redacted]% [redacted] thereafter. Based on DNV-GEC's experience with other projects using pitch-regulated turbines, this downtime is heavily weighted towards high-wind periods.

Consequently, the relationship between faults and energy loss was also modeled as an uncertainty, with a best estimate of a multiplier of [redacted] of energy per unit time and an uncertainty of [redacted] around this estimate. DNV-GEC estimated the resulting P50 average energy loss as approximately [redacted]%.

Minor Component Failure Downtime

Some downtime will be incurred associated with failures of smaller components such as motors, relays, valves, power electronics, sensors, controllers, and bushings; and other small malfunctions normally experienced by modern megawatt-scale wind turbines. As the equipment ages, failure of minor components with design lives less than 20 years is expected to increase.

Based on experience, DNV-GEC estimated the minor component failure downtime values to be [redacted]% over [redacted]% over [redacted] and [redacted]% thereafter. The majority of the components evaluated are expected to have mean lives of approximately 10 years, so the replacement rate tends to level off later in the project life. DNV-GEC's expectation based on experience with operating wind projects is that component failures will be slightly weighted towards high-wind periods; consequently, the relationship between minor component failures and energy loss was also modeled as an uncertainty, with a best estimate of a multiplier of 1.2 of energy per unit time and an uncertainty of 0.1 around this estimate. DNV-GEC estimated the resulting P50 average energy loss as approximately [redacted]%.

Major Component Failures

Some downtime will be associated with major systems in the turbines. Examples of such events include gearbox, generator, or blade replacements, yaw system failures, turbine fires, or similar problems. These issues affect individual turbines but may cause those turbines to be off line for an extended period of time. While a typical year may have relatively limited downtime associated with major failures relative to the project life average, the infrequent events can result in significant lost energy. These losses are also expected to increase over time, as turbine systems wear out and more gearboxes and other components fail. DNV-GEC estimates that the frequency of failure of major components is expected to begin increasing in Years 6 through 10 of the turbine's life and continue to increase for the remainder of the turbine design life. The increasing failure rate will be offset somewhat by increased efficiency as experience is gained in replacing major components. However, as the number of major component failures increases, the total time required for component replacement will also increase, which will adversely impact turbine availability.

The modeled failure rate and associated downtime for major components was based on experience with similar projects. The P50-case major component failure downtime values estimated by DNV-GEC were [redacted] The losses associated with major failures were modeled as an asymmetrical distribution with a long tail, representing small possibilities of significant downtime; however, the majority of losses are expected to be at or less than the mean. DNV-GEC's expectation based on experience with operating wind projects is that component failures will be slightly weighted towards high-wind periods. Consequently, the relationship between major component failures and energy loss was also modeled as an uncertainty, with a

best estimate of a multiplier of [redacted] per unit time and an uncertainty [redacted] %.

Balance-of-Plant Downtime

Approximately 10 to 20 hours of downtime are associated with annual maintenance on project infrastructure (such as the project substation, pad mount transformers, etc.). These activities are typically planned events that coincide with low-wind months and/or days. Unplanned failures and repairs associated with the balance of plant, such as substation transformer failures, electrical collection system or communication system problems, or transmission outages are uncommon; however, their impact on lost production could be considerable if the failures impact the whole project or large groups of turbines. The mean loss related to both planned and unplanned balance-of-plant events has been estimated to be [redacted] % and is not expected to increase over time.

The losses associated with balance-of-plant failures were modeled as an asymmetrical distribution with a long tail, representing small possibilities of significant downtime; however, the majority of losses are expected to be at or less than the mean.

Turbine Wake/Array

[redacted]

DNV-GEC estimated the uncertainty on the model accuracy by evaluating results predicted by different combinations of wake loss models and wake combination methods available within the WindFarm software package; these included axisymmetric wake and WAsP/Park wake velocity deficit models, and sum of squares of wakes and energy balance combination methods. The average of these results was used as the base case, with the highest of the four models predicting [redacted] m hub height case. The spread of the model results for the other two project configurations is comparable. The average of the model outcomes is a reasonable approximation of wake losses on most projects. The resulting estimated wake losses for each turbine are shown in Table 15.

In addition to uncertainty associated with the loss model, DNV-GEC considered uncertainty on the model inputs, including turbulence at hub height and wind direction distribution. Based on the results of the various tests of model combinations and consideration of these other issues, DNV-GEC estimated a combined wake loss uncertainty of 1.0% of energy.

Electrical Line

DNV-GEC assumed [redacted] and in-project parasitic consumption. This estimate is based on information provided to DNV-GEC by PSE including actual electrical line losses at the existing Wild Horse project and simplified estimates of line losses for the Wild Horse Expansion project. This value is within the typical range for a modern wind project. These losses represent the difference between energy measured at each wind turbine and energy measured at the project

substation. Actual losses will depend on the efficiency of the transformers used at the facility, collection wire sizing, and internal parasitic consumption "behind the meter" in very low wind conditions. A standard deviation of 0.5% was assumed and the range of possible losses ranged between [redacted]

Blade Soiling

Turbine performance may be reduced as dust or insects on the blades. DNV-GEC estimated losses for this issue [redacted]

Weather

Weather losses encompass a range of issues that result in lost production, including but not limited to the following:

- High- or low-temperature shutdowns
- Lightning damage to turbines
- Grid outages or communications failures caused by lightning
- Hail damage to blades or facility shutdowns to prevent such damage
- Turbines shut down due to ice-related faults
- Reduced power performance due to ice build-up on blades
- Reduced site access due to inclement weather
- Other weather-related turbine faults that are classified as the owner's responsibility

Based on a review of the meteorological data and DNV-GEC's experiences with other wind projects in the area, [redacted] It should be noted that this value represents energy loss and not percentage of time lost, as weather downtime frequently occurs during higher-than-average wind conditions.

Based on the technical specifications for the Vestas V80 turbine, the range of operating [redacted]

The upper NRG sensors were iced on average [redacted] % of the time. There is no industry standard for estimating the impact of icing on turbines relative to its impact on the NRG anemometer. DNV-GEC estimates that approximately half of the time lost to icing of an unheated NRG 40 anemometer the turbines may be adversely affected by icing. The estimate of weather related energy losses considers the fact that the icing occurs in the relatively high-wind winter months (although potentially during lower wind periods) and will likely impact both turbine performance and availability.

DNV-GEC's experience with operating projects in similar climates indicates that the weather-related losses are highly variable from site to site, and from year to year. For example, the frequency and duration of icing events can vary substantially, with most years having little ice

while others experience events where sites are frozen for days at a time with little or no turbine production. Similarly, lightning damage to turbines occurs in infrequent, intermittent events, but can produce significant periods of downtime. Note that some such events may be covered by business interruption insurance that may compensate the project owner for lost revenue; such insurance is not considered in this energy analysis. The overall loss estimate is typical as an approximate overall average based on a variety of operating projects monitored by DNV-GEC.

Turbulence and Controls

This topic includes potential differences in turbine performance, relative to the reference power curve, due to conditions such as high turbulence, variable winds creating significant off-yaw operations, and high-wind hysteresis. DNV-GEC estimated losses for these issues at [redacted]

Blade Degradation

Typically, turbine performance decreases somewhat over the life of a project. Degradation of the blade surface is the largest factor that can produce such a change. The turbine blade performance will gradually degrade over time. A small annual decrease in performance was included in the model, with a most likely case loss averaging approximately [redacted] (beginning with zero losses and slowly increasing following an exponential decay curve to [redacted].

Power Performance

There is a probability that the turbines will perform at a level different from the reference power curve for reasons other than those counted in other losses (such as blade soiling and degradation, turbulence, etc.). This is modeled as a distribution of possible outcomes with a most likely value of [redacted]

Wind Sector Management

PSE provided DNV-GEC with a preliminary wind sector management strategy proposed by Vestas. Based on the proposed wind sector management strategy, DNV-GEC estimates losses associated with the wind sector management will be on the order of [redacted]%.

Uncertainties

The following uncertainties were estimated as percentages of the mean wind speed for the site. Based on the wind frequency distribution for the project, there is an approximate relationship of a 1.4% uncertainty on energy for each 1% uncertainty on wind speed for the Vestas V80 turbine. This relationship varies with speed because the power curve flattens at high wind speeds; there is a smaller increase in energy when wind speeds increase relative to the magnitude of the decrease in energy as wind speeds decrease. This is reflected in the uncertainty model by shifting the wind speed frequency distribution up or down as the mean wind speed changes and recalculating the gross energy as a ratio of the best-estimate case. Except as noted below, all uncertainties on wind speed shown are assumed to be normally distributed; uncertainty values listed are at one standard deviation. However, because of the non-linear relationship of wind speed to energy, the resulting energy uncertainties are not normally distributed.

Anemometer Accuracy

This parameter represents the variability in measurement of wind by individual anemometers. An uncertainty of approximately [redacted]% on wind speed was assumed based on the typical error on measurements found in testing of a large number of NRG 40 anemometers[2] used as the primary sensor at the site. This uncertainty is reduced based on the number of independent measurements; consequently, DNV-GEC estimates the overall project uncertainty associated with anemometer accuracy at [redacted]% on wind speed, based on the [redacted]% uncertainty on a single measurement divided by the square root of two, representing the two met towers used in this analysis.

Tower Effects on Measurements

Some uncertainty is associated with the mounting effects of anemometers on towers; even when mounted according to industry-standard procedures, small speed-up and slow-down effects are seen on measurements on tubular tilt-up towers. Larger effects are observed on lattice towers, particularly where the boom lengths are short relative to the tower face width. At each of the towers at the site, pairs of anemometers are present at the upper measurement level, allowing for selection of unwaked wind speeds and minimization of measurement effects. Based on the site visit, a review of the documentation of the mounting arrangements on the towers and a review of the data, DNV-GEC estimated an overall site-wide average wind speed uncertainty of [redacted]% for this issue. The uncertainty in this category is relatively high because the sensors are oriented directly into and perpendicular to the predominant wind direction. Both of these orientations lead to higher tower effects than the preferred orientation of 45° off predominant wind direction.

Data Capture/QC/Validation

Several periods of data were missing or removed from each tower because of icing, sensor malfunction and other issues. DNV-GEC estimated an uncertainty of [redacted]% on wind speed for this issue, based on the amount of missing or invalid data and other factors informing a potential influence of icing.

Representativeness of Period of Data

Data from local long-term meteorological stations, radiosonde data and a nearby Reanalysis grid point were investigated to determine the interannual wind conditions for the region. The interannual variability was estimated at approximately [redacted]. This degree of variability is consistent with the expected wind variability in the region. [redacted]

Reference Site Relationships/Consistency of Long-Term References

This uncertainty represents the uncertainty on the relationship to the long-term reference station used to adjust the observed site wind speeds to long-term conditions, and also on the consistency of the long-term data sets used to describe the wind conditions between tower locations. DNV-GEC did not make a long-term adjustment based on a reference station so there is no uncertainty associated with this category.

[2] Lockhart, Thomas J. and Bailey, Bruce H., *The NRG Maximum Type 40 Anemometer Calibration Project*. National Renewable Energy Laboratory, March 1998.

[redacted]

Effect of Asymmetric Uncertainties

Some of the loss factors described earlier are "lopsided" or asymmetric in nature. To the extent loss factors are asymmetric, the effect of the asymmetry is captured in the spread of the P1-P99 values in Table 16 as well as the P50 loss values described above and in Table 17. Although the uncertainties described above are symmetric, their effect on energy is asymmetric because of the non-linear relationship of wind speed to energy. That is, small increases in average winds result in proportionally smaller changes in energy compared to small decreases in average winds. The effect of this asymmetric energy uncertainty distribution is small compared to other losses, but it does result in a small energy loss factor that is included as the "effect of asymmetric uncertainties" entry in Table 17.

Net Energy

Based on the model inputs described above, Table 16 shows the probabilities of various levels of annual energy production, for long-term and one-year periods. P50 losses are presented in Table 17 and Table 18 presents the net energy for each turbine. Percent of production on a 12-month by 24-hour basis is presented in Table 19.

Table 16. Summary of Net Average Energy Production for the Vestas V80 2.0 MW Turbine with a 67-m Hub Height

Probability of Exceedance	20-Year Average	10-Year Average (First Ten Years)	One-Year (Entire Project Life)	One-Year (During First Ten Years)
Net Annual Energy Production (GWh/yr)				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Net Annual Capacity Factor[1]				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

1. Capacity factors are based on the turbine rating of 2000 kW for the Vestas V80 2.0MW.

Table 17. Summary of P50 Long-Term Average Losses for Vestas V80 2.0 MW at 67-m Hub Height

Gross Energy (GWh/year)	106.9
Losses	**Long-Term P50 Losses, % of Energy**
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

1. Values are long-term averages over a 20-year project life and are lower in initial years of operation.

2. Capacity factors are based on the turbine rating of 2000 kW for the Vestas V80 2.0MW.

Table 18. Average Net Energy Estimate for Each Turbine for Vestas V80 2.0MW at 67-m Hub Height

Turbine ID	Net Energy (MWh/yr)
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Table 19. 12-Month by 24-Hour Percent of Energy Production (%) for Vestas V80 2.0 MW Turbines at 67-m Hub Height

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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Note that this matrix is an estimate of the pattern of average energy production. The energy production in any given hour or month may deviate significantly from this pattern.

Appendix A – Site Photos

Photo 1. View from Met 319 facing North

Photo 2. View from Met 319 facing East

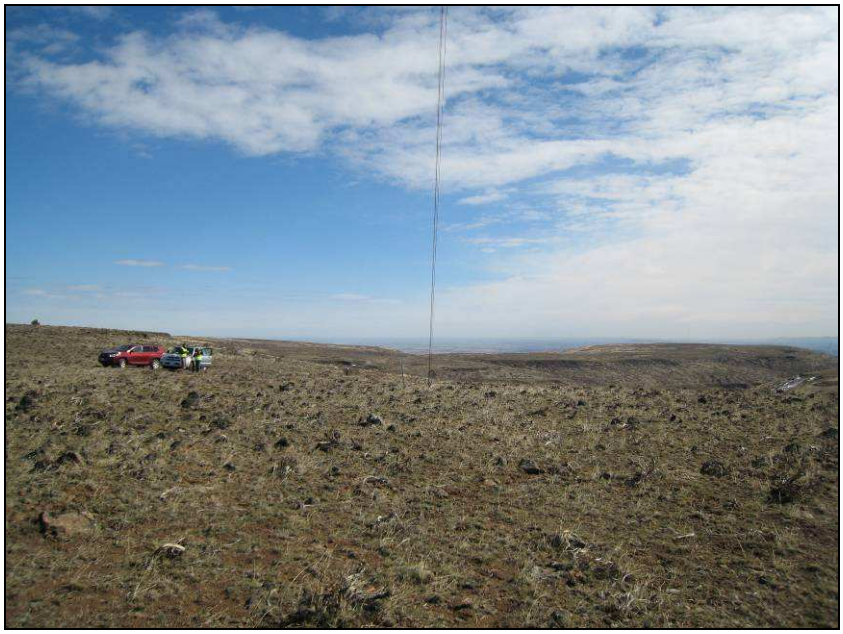

Photo 3. View from Met 319 facing South

Photo 4. View from Met 319 facing West

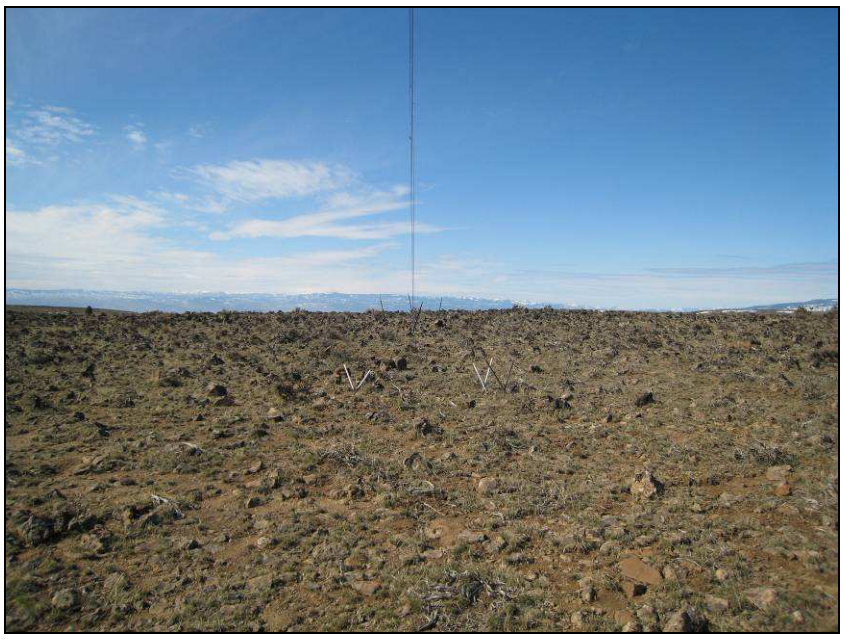

Photo 5. View from Met 320 facing North

Photo 6. View from Met 320 facing East

Photo 7. View from Met 320 facing South

Photo 8. View from Met 320 facing West

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DRAFT

Wind Resource and Energy Assessment Lower Snake River Phase I Wind Power Project

EARP0091

CONFIDENTIAL

March 3, 2010

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Approvals

Prepared by Date

Reviewed by Date

Version Block

Version	Release Date	Summary of Changes
DRAFT		

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Executive Summary

DNV Global Energy Concepts Inc. (DNV-GEC) has been retained by Puget Sound Energy to complete an energy assessment for the proposed Lower Snake River Phase I Wind Power Project located approximately 11 km (7 miles) northeast of Dayton, Washington. Table 1 presents a summary of the key features of the Project site and wind resource. Table 2 presents a summary of the estimated energy production. DNV-GEC's methodology, assumptions, analysis, uncertainties, and results are described in the main body of the report.

Table 1. Lower Snake River Phase I Project Executive Summary

Project Summary	
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Table 2. Lower Snake River Phase I Energy Production Executive Summary

Energy Assessment Summary, 20-Year Values				
Wake Loss Scenario	**Phase I Only**	**Phase I & II**	**Phase I & III**	**Phase I, II & III**
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Background and Project Description

DNV Global Energy Concepts Inc. (DNV-GEC) has been retained by Puget Sound Energy (PSE) to complete an energy assessment for the proposed Lower Snake River (LSR) Phase I Wind Power Project, located approximately 11 km (7 miles) northeast of Dayton, Washington. This report presents the methodology, assumptions, analysis, uncertainties, and results of the assessment. It first provides an overview of the wind resource and energy assessment process. It then discusses wind resource measurements and wind analysis results. Gross energy production is estimated based on wind speed frequency distributions and wind flow across the terrain. Finally, losses and uncertainties are considered to arrive at net energy estimates for the project with associated probability levels.

The location of the LSR Phase I Project is displayed in Figure 1. The LSR Phase I Project is planned to consist of 149 Siemens SWT-2.3-101 2.3 megawatt (MW) wind turbines installed at an 80-m hub height for a total installed project capacity of 342.7 MW. The principal features of the proposed turbine are shown in Table 3.

Analysis of the suitability of the proposed turbine model for the LSR Phase I Site is outside the scope of this assessment. Site suitability is commonly evaluated by wind turbine manufacturers or consultants and should be conducted as part of the project development process to confirm that site climatic conditions and the proposed turbine layout are within the design criteria of the turbine.

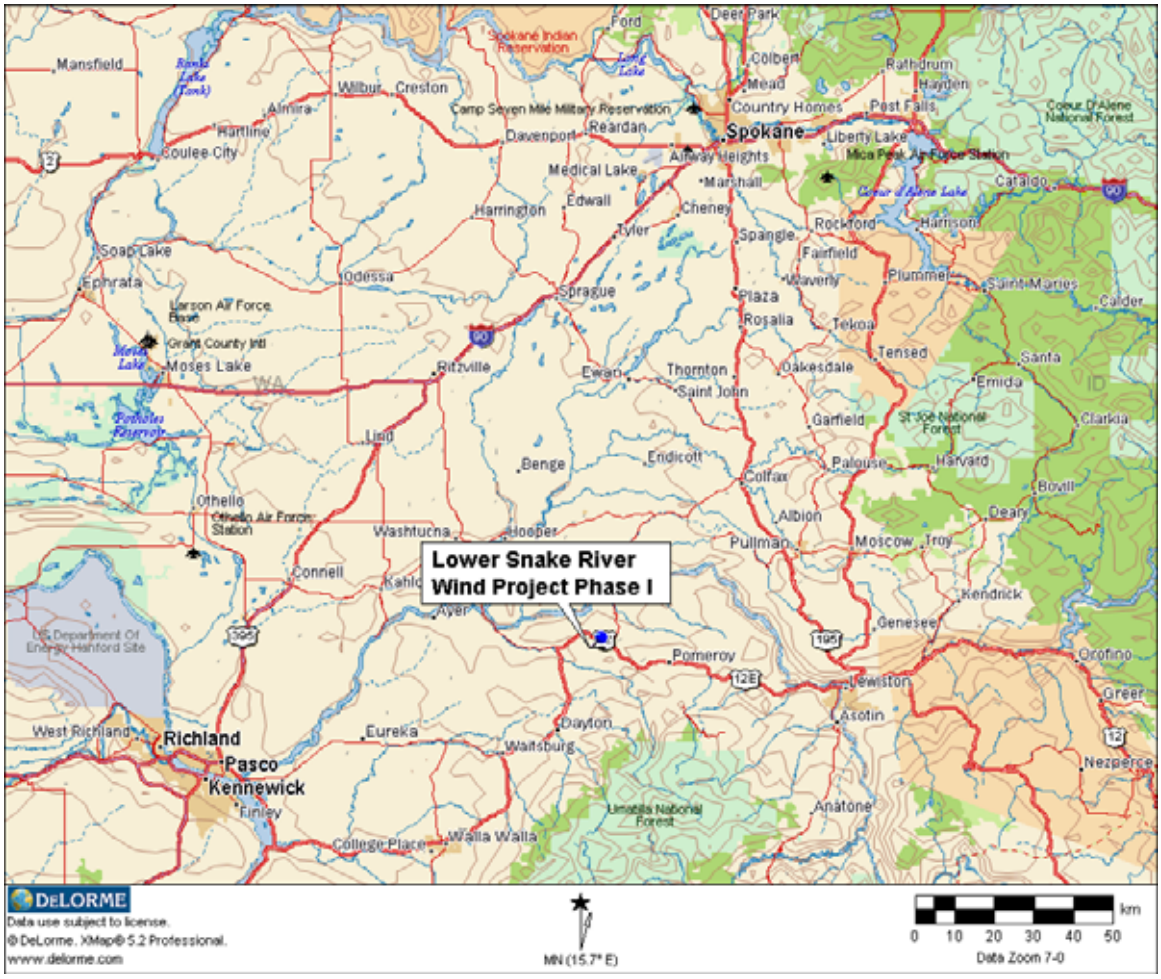

Figure 1. Location of the LSR Phase I Wind Power Project

Table 3. Proposed Wind Turbine Specifications

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1. Ambient operating temperature -25°C to +35°C

PSE provided the LSR Phase I Project layout. Wind data were collected at 21 meteorological (met) towers associated with the Project. Seven met towers are located within the LSR Phase I Project boundary; however, three of these towers (Met M540, Met M541, and Met M542) were installed in July 2009 and do not have a sufficient data record for inclusion in this analysis. Data from these

towers were used qualitatively to estimate the changes in wind speed over the Project area. Four longer-term Phase I met towers (Met M370, Met M437, Met M440, Met M438) make up the primary data set used in this analysis. Three nearby met towers (Met M252, Met M371 and Met M399) were also evaluated but do not significantly impact the results. LSR Phase I Project met tower and turbine locations are presented in Figure 2. The turbine and met tower coordinates are given in Appendix A. Figure 3 presents the proposed turbine locations for all phases of the LSR Project and the existing turbine locations of the Hopkins Ridge and Marengo wind power projects.

The energy assessment provides the net energy estimates for only the LSR Phase I wind turbines. However, the assessment includes four wake loss scenarios that estimate the impact of the Phase II and II turbines on the Phase I energy production. The four scenarios:

1. Phase I without the impact of later development
2. Impact of Phase II
3. Impact of Phase III
4. Impact of both Phase II and III

DNV-GEC conducted a site visit to the LSR Phase I Project region on September 15, 2009. Information obtained from this visit was incorporated into the analysis. The LSR Project is sited in a large agricultural area in rural Washington. The terrain consists of multiple ridges that are aligned east to west or northwest to southeast. The average proposed turbine elevation is 543 meters above sea level (masl) and the proposed turbine locations cover a 290-m range in elevation. There are roads and off-road-vehicle trails throughout the Project area; however, not all turbine locations are currently accessible by vehicle.

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Wind Resource and Energy Assessment Overview

This section presents an overview of the methodology used to process the data, evaluate the wind characteristics, and estimate energy production. A schematic of the wind resource and energy assessment process is shown in Figure 4. Details of the analysis and results are provided in following sections.

DNV-GEC processed raw data from seven met towers were processed and removed any invalid data. Wind speeds measured by anemometers at different heights were used to calculate the wind shear, which is a measure of how the wind speed changes according to height. The shear calculations were used to extrapolate wind speeds at the measurement heights to the turbine hub height. DNV-GEC consulted nearby long-term reference stations to determine how well the on-site data represent the long-term average wind speeds. DNV-GEC adjusted the on-site wind speeds to reflect the long-term average based on the reference data. The long-term hub-height wind speeds were normalized to one year (8,760 hours) so that annual wind speed frequency distributions could be created representing the met tower locations. DNV-GEC calculated the turbulence intensity (TI) for each measurement level at each met tower. TI is used in modeling turbine wake effects.

DNV-GEC estimated individual turbine hub-height wind speeds based on long-term adjusted hub-height met tower wind speeds, wind-flow modeling results, elevation and exposure, and our professional judgment regarding wind flow across the terrain. DNV-GEC estimated the annual gross energy production for each turbine location using the annual wind speed frequency distributions from the met towers, the estimated turbine wind speeds, and the turbine power curve. We estimated the Project's net energy based on the gross annual energy and the technical losses and uncertainties estimated for the Project.

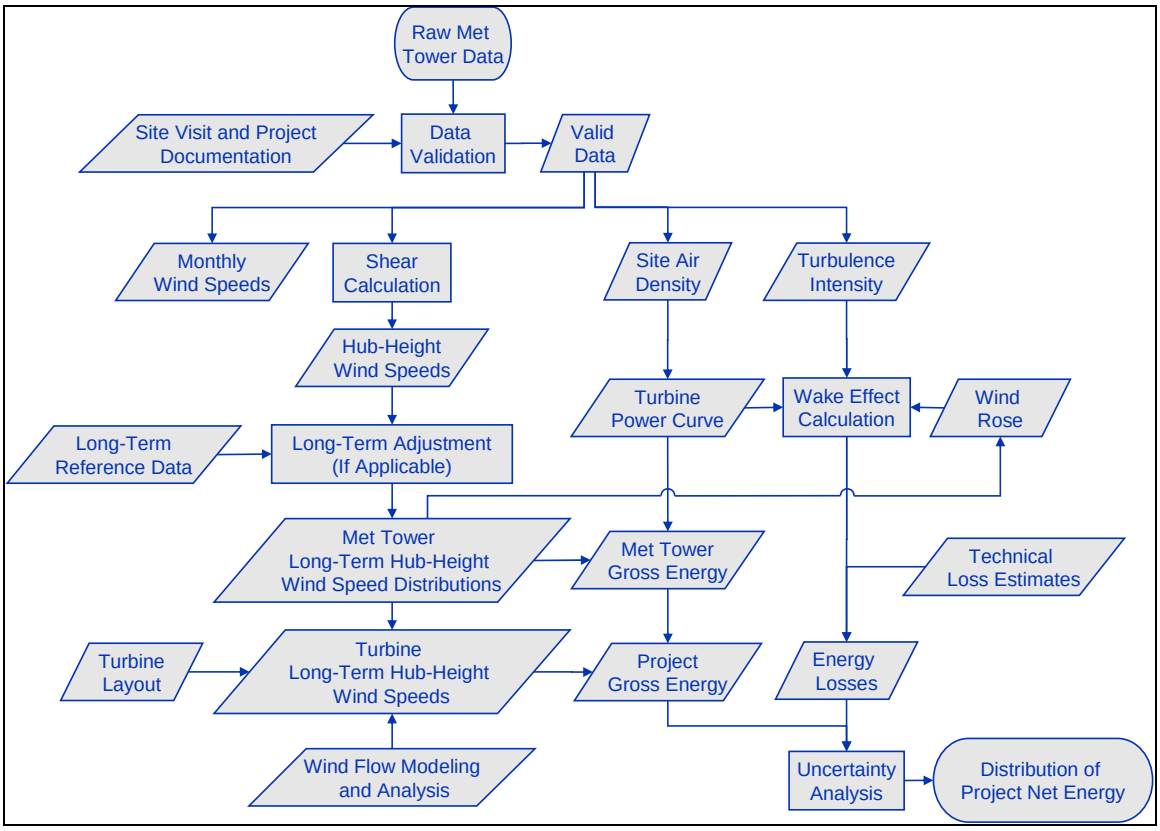

Figure 4. Wind Resource and Energy Assessment Process Overview

Wind Resource Measurements

DNV-GEC evaluated data from four on-site met towers and three nearby met towers. These towers were erected specifically for wind resource measurements. Three other met towers have been installed in and around the LSR Phase I Project area, but these met towers do not have a sufficient data record to be included in this analysis. Data from these three towers were only used qualitatively to estimate the changes in wind speed over the Project area. This section describes the met tower configurations, the data validation process, and the data recovery.

Meteorological Tower Configurations

A summary of the met tower configurations is presented in Table 4, including data start and end dates, anemometer heights and orientations, and data sampling rate. The anemometer heights were provided with the tower documentation. DNV-GEC confirmed these heights during the site visit using a Laser Technology Inc. TruPulse 200 Laser Rangefinder with an accuracy of approximately 1 m. All anemometer heights measured during the site visit were within 1 m of the documented height. Representative photos of the met towers are presented in Appendix B. The commissioning sheets for all seven met towers are included in Appendix C.

Table 4. Met Tower Summary

Met Tower	Tower Type	Ground Elevation (masl)	Period of Record	Years of Data	Anemometer Heights (m) [1]	Anemometer Orientations (º)
M252	Rohn 25G	687	03/08/05 – 08/31/09	4.2	56.3, 35.3	288
M370	Rohn 25G	612	05/03/07 – 08/31/09	2.3	60.4, 56.1, 35.1	135
M371	Rohn 25G	547	05/03/07 – 08/31/09	2.3	60.4, 56.1, 35.1	135, 131[2]
M399	Sabre 1200 TLWD	634	09/11/07 – 08/31/09	2.0	60.2, 58.0, 35.1	151
M437	Sabre 1800 TLWD	595	06/16/08 – 08/31/09	1.2	58.1 (2), 53.1, 38.2, 23.1	138, 320
M438	Sabre 1800 TLWD	598	06/17/08 – 08/31/09	1.2	58.1 (2), 53.1, 38.5, 23.1	130, 300
M440	Sabre 1800 TLWD	509	06/16/08 – 08/31/09	1.2	58.1 (2), 53.1, 38.2, 23.1	139, 319

1. (2) indicates that two anemometers are mounted at or very near that level.
2. The top anemometer is oriented to 135º and the lower anemometers are oriented to 131º

For all sites, measurements were recorded every 10 minutes throughout the collection period. All met towers are lattice towers and utilize Campbell Scientific Data Loggers. The side-mounted anemometers are mounted on booms at least 2.0 m long. With the exception of M252, the top anemometer(s) on each tower met tower are on goalpost-type booms and elevated above the top of the tower. All anemometers at the site are A1002L cup anemometers manufactured by Vector Instruments and calibrated by Svend Ole Hansen ApS. PSE provided calibration certificates for each anemometer to DNV-GEC. Raw wind speed data were processed using the respective calibration transfer parameters for each sensor.

According to the maintenance records provided by PSE, the Met M252 logger was replaced on September 5, 2008. The 35.3-m anemometer on Met M252 was replaced on April 11, 2007, due to a malfunction. Both wind vanes on Met M252 were replaced on July 17, 2009. For Met M370 and Met M371, the boom length of the side-mounted anemometers was changed from 2.87 m to 2.23 m on July 13, 2007.

Met M252, Met M371, and Met M399 are not located in the immediate project area, but were included in this analysis to increase the overall data-collection period and provide additional information about the wind speed variability across the site.

Data Validation

The available met tower data were compiled, validated, and incorporated into the analysis. DNV-GEC followed a standard validation process to identify and remove erroneous data (e.g., due to icing or tower shadow).

In cases where there are two anemometers at the same level, DNV-GEC designated one primary anemometer and one secondary anemometer. Wind speeds from the primary anemometer are used in this analysis except when the data are invalid, in which case valid data from the secondary anemometer are used. Met M437, Met M438, and M440 are the only met towers that have two anemometers at the same level. For these anemometers, DNV-GEC designated the southeast-oriented anemometers as primary and the northeast-oriented anemometers as secondary. Wind shear is only calculated from anemometers that share the same orientation.

Wind speed data were considered erroneous due to icing if the temperature was near or below freezing and an additional criterion was met, such as the wind vane or anemometer standard deviation equaling zero for consecutive records or the average wind speed being lower than expected, relative to the wind speeds at other levels. Wind vane data were considered erroneous due to icing if the standard deviation was zero for several consecutive records when temperatures were near or below freezing.

Data were also considered erroneous when the anemometers were affected by tower shadow (waked data). Tower shadow occurs when the wind direction is opposite to the anemometer orientation and places the tower between the wind and anemometer. For example, an anemometer oriented south of the tower will record invalid wind speed data when the winds are from the north. Data corresponding to the tower-waked sector (50º wide) were removed for all anemometers except those mounted on goalpost booms. We determined the wind direction for each data record using the upper-level wind vane whenever possible; otherwise the lower-level wind vane was used.

Met M370, Met M437, and Met M438 had malfunctioning wind vanes at the 54.6-m, 49.6-m, and 49.6-m levels, respectively. In all cases, the malfunction was reported to be caused by a manufacturing defect. The malfunctioning wind vanes were replaced on January 24, 2009. Analysis of the data from these wind vanes showed occasional deviation from the actual wind direction (as recorded by the other wind vanes at the Project site). For Met M370, we primarily used the upper-level wind vane (at 60.1 m) in this analysis so the malfunction of the 54.6-m wind

vane had little effect on the analysis. For Met M437, there was no significant deviation between the direction data of the two wind vanes, so we used data from the 49.6-m wind vane in the analysis. For M438, data from the 49.6-m wind vane deviated from the other wind vane on that tower and on other towers. During that time, we used the direction data from the lower-level wind vane.

The lower anemometer of Met M252 (35.3 m) measured intermittently erroneous data from April 2005 to April 2007, when it was replaced. Data from this time period were removed from the analysis so that the wind shear calculation would not be affected.

Data Recovery

Data recovery rates indicating the percent of data records with valid upper wind speed and direction measurements are presented by month and year in Table 5. The low data recovery rates for the winter months were due to anemometer and wind vane icing. Lower recovery rates for Met M252 are due to the removal of tower-waked data. There is no secondary anemometer at the upper level to replace the tower-waked data. There is a missing period of data at Met M252, from June 1, 2006, to July 31, 2006. Additionally, low data recovery for Met M252 in November 2006 and December 2006 is due to incomplete data transmittals. For the other towers, the data recovery is sufficient and data from the top-mounted anemometer were not affected by tower shadow because these anemometers are mounted above the tower top on goalpost booms.

Table 5. Valid Data Recovery

Month	Met M252	Met M370	Met M371	Met M399	Met M437	Met M438	Met M440
2005 March	71%	N/A	N/A	N/A	N/A	N/A	N/A
2005 April	86%	N/A	N/A	N/A	N/A	N/A	N/A
2005 May	92%	N/A	N/A	N/A	N/A	N/A	N/A
2005 June	96%	N/A	N/A	N/A	N/A	N/A	N/A
2005 July	98%	N/A	N/A	N/A	N/A	N/A	N/A
2005 August	98%	N/A	N/A	N/A	N/A	N/A	N/A
2005 September	98%	N/A	N/A	N/A	N/A	N/A	N/A
2005 October	95%	N/A	N/A	N/A	N/A	N/A	N/A
2005 November	74%	N/A	N/A	N/A	N/A	N/A	N/A
2005 December	84%	N/A	N/A	N/A	N/A	N/A	N/A
2006 January	96%	N/A	N/A	N/A	N/A	N/A	N/A
2006 February	91%	N/A	N/A	N/A	N/A	N/A	N/A
2006 March	87%	N/A	N/A	N/A	N/A	N/A	N/A
2006 April	90%	N/A	N/A	N/A	N/A	N/A	N/A
2006 May	92%	N/A	N/A	N/A	N/A	N/A	N/A
2006 June	2%	N/A	N/A	N/A	N/A	N/A	N/A
2006 July	1%	N/A	N/A	N/A	N/A	N/A	N/A
2006 August	96%	N/A	N/A	N/A	N/A	N/A	N/A
2006 September	93%	N/A	N/A	N/A	N/A	N/A	N/A

Month	Met M252	Met M370	Met M371	Met M399	Met M437	Met M438	Met M440
2006 October	95%	N/A	N/A	N/A	N/A	N/A	N/A
2006 November	46%	N/A	N/A	N/A	N/A	N/A	N/A
2006 December	37%	N/A	N/A	N/A	N/A	N/A	N/A
2007 January	72%	N/A	N/A	N/A	N/A	N/A	N/A
2007 February	84%	N/A	N/A	N/A	N/A	N/A	N/A
2007 March	94%	N/A	N/A	N/A	N/A	N/A	N/A
2007 April	95%	N/A	N/A	N/A	N/A	N/A	N/A
2007 May	95%	92%	92%	N/A	N/A	N/A	N/A
2007 June	95%	100%	100%	N/A	N/A	N/A	N/A
2007 July	98%	100%	100%	N/A	N/A	N/A	N/A
2007 August	97%	100%	100%	N/A	N/A	N/A	N/A
2007 September	98%	100%	100%	65%	N/A	N/A	N/A
2007 October	93%	100%	100%	100%	N/A	N/A	N/A
2007 November	88%	98%	95%	100%	N/A	N/A	N/A
2007 December	78%	81%	88%	84%	N/A	N/A	N/A
2008 January	89%	96%	99%	99%	N/A	N/A	N/A
2008 February	92%	100%	100%	100%	N/A	N/A	N/A
2008 March	97%	100%	100%	100%	N/A	N/A	N/A
2008 April	98%	100%	100%	100%	N/A	N/A	N/A
2008 May	93%	100%	100%	100%	N/A	N/A	N/A
2008 June	96%	100%	100%	100%	48%	45%	48%
2008 July	96%	100%	100%	100%	100%	100%	100%
2008 August	94%	100%	100%	100%	100%	100%	100%
2008 September	92%	100%	100%	100%	100%	100%	100%
2008 October	92%	100%	100%	100%	100%	100%	100%
2008 November	88%	100%	100%	99%	98%	100%	100%
2008 December	92%	99%	100%	99%	100%	100%	100%
2009 January	57%	59%	59%	59%	66%	62%	61%
2009 February	81%	93%	94%	93%	92%	94%	94%
2009 March	96%	100%	100%	100%	100%	100%	100%
2009 April	95%	98%	100%	100%	100%	100%	100%
2009 May	94%	100%	100%	100%	100%	100%	100%
2009 June	94%	100%	100%	100%	100%	100%	100%
2009 July	93%	100%	100%	100%	100%	100%	100%
2009 August	96%	100%	100%	100%	100%	100%	100%
Overall[(1)]	**86%**	**97%**	**98%**	**97%**	**97%**	**97%**	**97%**

1. Excludes partial months at beginning of the period of record.

Wind Analysis Results

This section discusses our evaluation of the wind data, including on-site wind speed correlations, monthly wind speeds, wind shear, turbulence, long-term wind speeds, and wind rose.

On-Site Correlations and Monthly Wind Speeds

In order to bring the met towers to a consistent period of record, DNV-GEC synthesized data at Met M399, Met M437, Met M438 and Met M440 from Met M370. We used the Variance Measure-Correlate-Predict (MCP) method[1] to establish a statistical relationship between Met M370 and the other met towers over simultaneous periods at each. We generated slope and intercept parameters using hourly average wind speeds greater than 3 m/s. We established the directional basis using 30° wind direction sectors to capture potential differences in relationships resulting from variations in the terrain surrounding the towers. These comparisons were made between the upper-measurement levels on each tower.

DNV-GEC evaluated the strength of the linear associations between the on-site met towers and found no apparent problems with the relationships between the data sets. The overall R-squared values associated with the linear relationships between Met M252 and the other met towers exceeded 0.80. When correlated to Met M370, the overall R-squared values exceeded 0.88, indicating a stronger correlation. Because of the stronger relationship, the Met M370 data set was used to synthesize data at Met M399, Met M437, Met M438 and Met M440.

DNV-GEC used directional correlation parameters based on 30º direction sectors to synthesize the data. For direction sectors with low average wind speeds or low data counts the correlation was often poor, with R-squared values between 0.42 and 0.70. In these cases, we used the non-directional relationship rather than the directional relationship. Summary statistics describing the observed relationships by direction are presented in Table 6 through Table 9. The slopes and intercepts shown in these tables were applied to the measured upper-level wind speeds at Met M370 to synthesize upper-level data at the other met towers. Data were only synthesized for periods when no measured data were available.

Monthly averages of upper-level measured and synthesized wind speeds for each met tower are presented in Table 10. The annual averages are listed at the bottom of the table.

[1] The Variance MCP model determines the slope and offset of a linear fit based on the standard deviations of the data from each tower and on the mean wind speeds at each tower over the period of concurrent data collection. This model is described in this reference: Rogers, A. L., Rogers, J. W., Manwell, J. F., Comparison of the Performance of Four Measure-Correlate-Predict Algorithms, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 93/3, pp. 243-264, 2005.

Table 6. Summary of Correlation Statistics between Met M399 and Met M370

Direction Sector (º)	Slope	Intercept (m/s)	R^2	# of Data Points
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

*Due to poor correlation or low data count the slope and offset for this sector were taken from the overall relationship.

Table 7. Summary of Correlation Statistics between Met M437 and Met M370

Direction Sector (º)	Slope	Intercept (m/s)	R^2	# of Data Points
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

*Due to poor correlation or low data count the slope and offset for this sector were taken from the overall relationship.

Table 8. Summary of Correlation Statistics between Met M438 and Met M370

Direction Sector (º)	Slope	Intercept (m/s)	R^2	# of Data Points
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

*Due to poor correlation or low data count the slope and offset for this sector were taken from the overall relationship.

Table 9. Summary of Correlation Statistics between Met M440 and Met M370

Direction Sector (º)	Slope	Intercept (m/s)	R^2	# of Data Points
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

*Due to poor correlation or low data count the slope and offset for this sector were taken from the overall relationship.

Table 10. Monthly Average Wind Speeds (m/s)

Month	Met M252	Met M370	Met M371	Met M399	Met M437	Met M438	Met M440
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Month	Met M252	Met M370	Met M371	Met M399	Met M437	Met M438	Met M440
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Note: Data in ***Bold Italics*** include synthesized values.

[redacted]

[2] Wind shear describes the typical increase in wind speed at greater heights above the ground. The wind shear exponent (alpha or α) is one method of describing the extent to which wind speeds vary with increasing height above ground level. The equation that uses the exponent is $(V_1 / V_2) = (H_1 / H_2)^{\alpha}$, where V_1 and V_2 are wind speeds at heights H_1 and H_2, respectively (measured from the ground level), and α is the dimensionless wind shear exponent.

[redacted]

[redacted]

[redacted]

[redacted]

Table 11. Average Shear Exponents by Hour

Hour	Met M252	Met M370	Met M371	Met M399	Met M437	Met M438	Met M440
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Average (>4m/s)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 12. Average Shear Exponents by Direction

Direction Sector (°)	Met M252	Met M370	Met M371	Met M399	Met M437	Met M438	Met M440
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Note: Shear averages corresponding to tower-waked direction sectors were removed from this table due to the low number of valid shear values in that sector.

Turbulence

DNV-GEC calculated turbulence intensity (TI) as the ratio of the wind speed standard deviation to the wind speed. TI is used in modeling wake losses and can be used to inform turbine site-suitability studies. Average TI was calculated for all wind speeds, and TI at wind speeds greater than 4 m/s was calculated by direction. Turbulence decreases with height above ground level; consequently, TI at the upper measurement levels on each tower was extrapolated to the 80-m turbine hub height by applying wind shear to calculate a hub-height wind speed while keeping the standard deviation constant.

The measured TI at all heights and estimated TI at hub height (80 m) are presented in Table 13 for all met towers. The average measured TI by direction at the upper measurement level and the extrapolated TI at hub height are presented in Table 14. These hub-height directional TI values are inputs for the Project wake effect modeling, discussed in the Gross Energy Estimates and Wake Effects section of this report. Overall turbulence levels are moderate for all met towers, with annual weighted averages for wind speeds greater than 4 m/s between 10% and 13% at hub height. This is consistent with DNV-GEC's expectations based on experience with similar sites and knowledge of the region. Figure 13 illustrates TI by wind speed for each met tower.

Table 13. Average Turbulence Intensity at for Wind Speeds > 4 m/s (%)

Met Tower	Nominal Measurement Height							Extrapolated Height
	23-m	35-m	38-m	53-m	56-m	58-m	60-m	80-m
Met M252	N/A	13	N/A	N/A	13	N/A	N/A	12
Met M370	N/A	11	N/A	N/A	11	N/A	11	10
Met M371	N/A	12	N/A	N/A	11	N/A	11	10
Met M399	N/A	12	N/A	N/A	N/A	12	12	11
Met M437	12	N/A	11	10	N/A	10	N/A	10
Met M438	14	N/A	14	13	N/A	13	N/A	13
Met M440	12	N/A	11	10	N/A	10	N/A	10

Table 14. Average Turbulence Intensity by Direction Sector (%)

Direction Sector (°)	Met M252		Met M370		Met M371		Met M399		Met M437		Met M438		Met M440	
	56-m	80-m	60-m	80-m	60-m	80-m	60-m	80-m	58-m	80-m	58-m	80-m	58-m	80-m
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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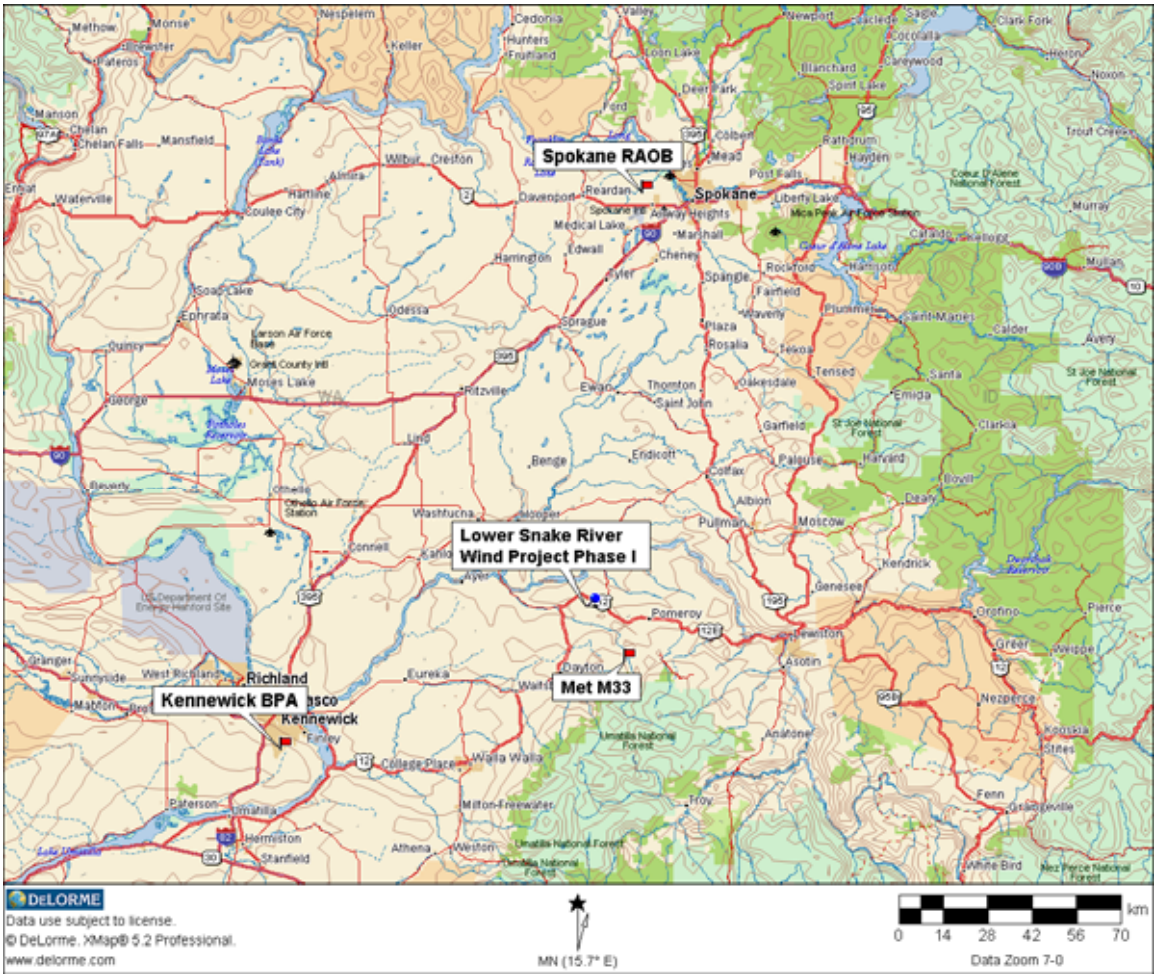

Figure 14. Location of Lower Snake River Phase I and Long-Term Reference Stations

Details of the correlation between average monthly wind speeds at the site and each long-term station considered are shown in Table 15. The table also presents other considerations for determining the suitability of the long-term reference stations. With the exception of Met M33 and the Kennewick BPA station, the stations in Table 15 were not used quantitatively in calculating the long-term adjustment at the site.

Table 15. Investigated Long-Term Reference Station Summary

Reference Station	Sensor Height (m)	R-Squared Correlation to On-Site Data (Monthly)	Period of Record	Distance from Site (km)	Notes
Met M33	56	0.74	2001-2009	22	Poor data recovery
Kennewick BPA	26	0.68	1994-2009	111	
Spokane RAOB	1050	0.44	1995-2009	120	Poor correlation

[redacted]

[redacted]

[redacted]

Long-Term Hub-Height Wind Speeds

Based on the estimated met tower wind speeds and the diurnal monthly wind shear pattern at each met tower, DNV-GEC developed a wind speed frequency distribution representing the long-term, hub-height (80-m) wind speed and wind direction at each met tower location. To generate frequency distributions, data from each tower over its entire period of record were binned by wind speed and direction. To normalize the data set to 8,760 hours, DNV-GEC developed a monthly record-length correction factor by counting the number of records with valid upper-level sensor wind speed and wind direction observations available in each month. We then categorized data according to wind direction sector (20° sectors centered on 0°, 20°, etc.) and wind speed bin (intervals of 0.5 m/s centered on 0.5 m/s, 1.0 m/s, etc.) to generate the hub-height annual frequency distribution showing the number of observations in each wind speed bin and for each wind direction sector. Wind speed frequency distributions were generated for each tower from this data set. Annual long-term hub-height (80-m) wind speeds computed from the frequency distributions are presented in Table 18.

Table 18. Annual Average Long-Term Adjusted 80-m Wind Speeds

Met Tower	Wind Speed (m/s)
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Wind Rose

A wind rose depicts the frequency and energy content of wind by direction. An annualized wind rose estimated at 80 m for Met M370 is presented in Figure 17. The other met towers show a similar wind direction distribution, with significant energy-producing winds coming from the southwest.

[redacted]

Figure 17. Met M370 Annual Wind Rose at 80 m

Gross Energy Estimates and Wake Effects

The turbine power curve, met tower wind speed distributions and the estimated turbine hub-height wind speeds used to determine the Project gross energy production are presented below. The methodology for estimating the Project gross energy production and wake effects is also discussed.

Gross Energy Estimates

DNV-GEC estimated the average air density of 1.15 kg/m^3 for the Project based on measured temperature data (an annual average of approximately 11.7ºC) from Met M33 and the average turbine hub-height elevation (623 m). PSE provided a density-specific power curve for the SWT-2.3-101 turbine at 1.16 kg/m^3. DNV-GEC adjusted the power curve to the site density (1.15 kg/m^3) and used it to calculate energy production.

The power curve and wind speed distributions from the met towers were used to estimate annual gross energy production for each turbine location. Table 19 presents the long-term annual wind speed frequency distributions, the power curve, and the gross energy production for a single SWT-2.3-101 turbine at the met tower locations.

Table 19. Long-Term Hub-Height Average Wind Speed Frequency Distributions and SWT-2.3-101 Power Curve at 1.15 kg/m^3 Air Density

Wind Speed (m/s)	SWT-2.3-101 Power (kW)	Met M252 (hours/yr)	Met M370 (hours/yr)	Met M371 (hours/yr)	Met M399 (hours/yr)	Met M437 (hours/yr)	Met M438 (hours/yr)	Met M440 (hours/yr)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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Wind Speed (m/s)	SWT-2.3-101 Power (kW)	Met M252 (hours/yr)	Met M370 (hours/yr)	Met M371 (hours/yr)	Met M399 (hours/yr)	Met M437 (hours/yr)	Met M438 (hours/yr)	Met M440 (hours/yr)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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DNV-GEC estimated individual turbine average hub-height wind speeds based on hub-height met tower wind speeds, the MS-Micro/3 software package wind flow model results, turbine distance from met towers, elevation and exposure, and DNV-GEC's judgment about wind flow across the terrain. DNV-GEC also considered the relative wind speeds at Met M540, Met M541, and Met M542 and Met M440 from July through September 2009 when estimating the wind speeds in the northern section of the LSR Phase I Project area. We calculated the individual turbine gross energy based on the assigned turbine wind speeds and the wind speed to energy relationship derived from the met tower frequency distribution and the power curve. The assigned turbine wind speeds and estimated gross energy are presented in Table 19.

Wake Effects

When a turbine extracts energy from the wind it causes an energy deficit in the form of lower wind speeds behind the turbine. The wake effect category accounts for the corresponding reduction in energy production at downwind turbines due to this phenomenon. DNV-GEC estimated this wake effect using four calculation methods in the WindFarm software package. The four methods utilize combinations of two wake models (Ainslie and Park) that predict the deficit behind single turbines and two wake combination models (square root of the sum of squares of velocity deficit, and energy balance) that combine the single wakes when they overlap. Detailed investigations have shown wake model performance is sensitive to terrain type, atmospheric stability, turbulence intensity, and inter-turbine spacing. DNV-GEC took the average of the four models as a best approximation of the expected wake losses. The spread of the four model results was also used to quantify the expected uncertainty of the calculations.

The proposed Phase II and Phase III projects are upwind (southwest) of the Phase I Project area as shown in Figure 3. Four wake loss scenarios were estimated for the Phase I project:

1. The wake loss of the Phase I project assuming no further development
2. The wake loss impact of Phase II
3. The impact of Phase III
4. The impact of Phase II and III combined.

The Hopkins Ridge Wind Project is located south of the proposed LSR Phase I Project area and will cause wake-induced energy loss at some turbines downwind. However, the Hopkins Ridge Project was constructed and online by November 2005[3], so the period of record at the met towers captures the wake effects of the Project. Consequently, the Hopkins Ridge turbines were not added to the wake analysis. The potential difference in wake effects at the turbine locations relative to the met tower locations was not assessed in this analysis.

The neighboring Marengo I and Marengo II projects are located to the southeast of the proposed Phase I Project area. Both projects were constructed and online in 2008, after data collection had commenced at the Phase I met towers. The Marengo I and Marengo II Projects are not located directly upwind of the proposed LSR Phase I Project area, and DNV-GEC expects that wake

[3] Puget Sound Energy webpage. http://www.pse.com/energyEnvironment/energysupply/pages/EnergySupply_ElectricityWind.aspx?tab=2&chapter= Accessed December 2009.

effects on the collected data are minimal. DNV-GEC also expects that the wake effects on the proposed LSR Phase I turbine locations will be similarly minimal. Consequently, for this analysis, the Marengo turbines were not included in the wake analysis.

To incorporate the differences between the measured wind speed and direction distributions into the wake analysis, DNV-GEC created wake calculations using distributions from all met towers. The distributions are based on 20º direction sectors, in order to have sufficient directional resolution for this unidirectional site.

DNV-GEC's estimates of wind speed, energy, and wake effects (for each of the four wake loss scenarios) for each of the turbines in the project is included in Appendix D.

A 12-month by 24-hour percent of gross energy production matrix is presented in Table 20. The energy production matrix is an estimate of the long-term pattern of average gross energy production by month and by hour. The energy production in any given hour or month of a specific year may deviate significantly from the pattern presented in the matrix.

Table 20. 12-Month by 24-Hour Gross Energy Production

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
[redacted]	[redacted]											
[redacted]	[redacted]											
[redacted]	[redacted]											
[redacted]	[redacted]											
[redacted]	[redacted]											
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[redacted]	[redacted]											

Losses and Uncertainties

Based on the gross annual energy estimated above, DNV-GEC generated a probability distribution for 20-year annual project net energy production using the following procedure:

- Probability distributions were assigned to each loss and uncertainty category.
- The distributions were parameterized using project-specific data.
- The loss and uncertainty model was then run in 100,000 iterations with each parameter changed randomly and independently to describe the distribution of potential net energy production. The individual results were combined to generate a distribution of net energy outcomes at several probability levels.

The results of these simulations are summarized in Table 21, which provides the net average energy production; and Table 22 which provides a summary of the long-term P50 losses.

Note that many of the losses and uncertainties are estimated based on DNV-GEC's current knowledge of the project and experiences with other wind projects. For example, the mechanical availability assumptions used are based on DNV-GEC's experiences monitoring performance of modern megawatt-scale wind turbines of similar design, but the availability at this particular site may be higher or lower for a variety of reasons. To some extent, low availability or performance may be mitigated through turbine warranties, insurance, or other factors; these issues are not considered explicitly in this analysis.

Losses

DNV-GEC estimated losses for the Project. For the purpose of uncertainty modeling, the following losses are normally distributed with uncertainty values listed at one standard deviation, unless otherwise noted. The P50 project losses are summarized by category in Table 26.

Availability

The availability loss category includes events that cause the turbine or any balance of plant component to be unavailable for power production. This category is subdivided into turbine availability and balance of plant. Weather-related events are addressed separately.

Turbine Availability

Turbine availability is lost energy production associated with:

- Routine maintenance downtime
- Fault downtime
- Minor component failures
- Major component failures

[redacted]

DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

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Net Energy Estimate

Based on the estimated gross annual energy, DNV-GEC estimated net energy production using a stochastic model to evaluate each source of loss or uncertainty identified above. Distributions appropriate for each loss or uncertainty were determined and a probabilistic description of the annual net energy was built, integrating each source. The model was then run in 100,000 iterations with each parameter changed randomly and independently to describe the distribution of potential net energy production. Table 22, Table 23, Table 24 and Table 25 summarize the results showing the probability of exceedance of various levels of annual energy production for each of the four wake loss scenarios. A summary of the long-term P50 losses are presented in Table 26 for each of the wake loss scenarios. The estimated net annual energy production for each turbine for each of the wake loss scenarios is presented in Appendix E.

Table 22. Summary of Project Net Average Energy Production Including Impact of Phase I Wakes Only

Probability of Exceedance	20-Year Average	10-Year Average (First 10 Years)	1-Year (Entire Project Life)	1-Year (During First 10 Years)
Net Annual Energy Production (GWh/yr)				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Net Annual Capacity Factor				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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Table 23. Summary of Project Net Average Energy Production Including Impact of Phase II Wakes

Probability of Exceedance	20-Year Average	10-Year Average (First 10 Years)	1-Year (Entire Project Life)	1-Year (During First 10 Years)
Net Annual Energy Production (GWh/yr)				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Net Annual Capacity Factor				
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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Table 24. Summary of Project Net Average Energy Production Including Impact of Phase III Wakes

Probability of Exceedance	20-Year Average	10-Year Average (First 10 Years)	1-Year (Entire Project Life)	1-Year (During First 10 Years)
Net Annual Energy Production (GWh/yr)				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Net Annual Capacity Factor				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 25. Summary of Project Net Average Energy Production Including Impact of Phase II and III Wakes

Probability of Exceedance	20-Year Average	10-Year Average (First 10 Years)	1-Year (Entire Project Life)	1-Year (During First 10 Years)
Net Annual Energy Production (GWh/yr)				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Net Annual Capacity Factor				
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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Table 26. Summary of Long-Term P50 Losses

Wake Loss Scenario	Phase I Only	Phases I & II	Phases I & III	Phases I, II & III
Gross Energy (GWh/year)	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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1. Values are long-term averages over a 20-year project life and are lower in initial years of operation.

PSE provided information[4] regarding the Siemens availability warranty of 96% (a 4% loss). This availability loss is a percentage of downtime and therefore is not directly comparable to our availability loss estimate of 5.8% which is a percentage of the energy. Additionally, Siemens availability warranty excludes balance-of-plant outages, which are included in our estimate, as well as any force majeure losses, which DNV-GEC includes separately as weather losses.

In order to provide an approximation of the Siemens availability warranty as a percent of energy lost due to unavailability, DNV-GEC applied a time-to-energy multiplier of 1.3 to the 4% downtime. Based on DNV-GEC's experience with operating projects, downtime due to turbine

[4] Siemens Turbine Supply Agreement, Exhibit R1, Availability Test Procedure, Document ID: PG-R4-40-0000-0014-05, September 1, 2009.

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Appendix A – Turbine and Met Tower Coordinates

ID	WGS84 UTM11	
	Easting (m)	Northing (m)
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ID	WGS84 UTM11	
	Easting (m)	Northing (m)
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Appendix B – Site Photos

Photo 1. View of Met M252 facing Northeast

Photo 2. View of Met M370 facing Northeast

Photo 3. View of Met M371 facing Northeast

Photo 4. View of Met M399 facing Northeast

Photo 5. View of Met M3437 facing Northeast

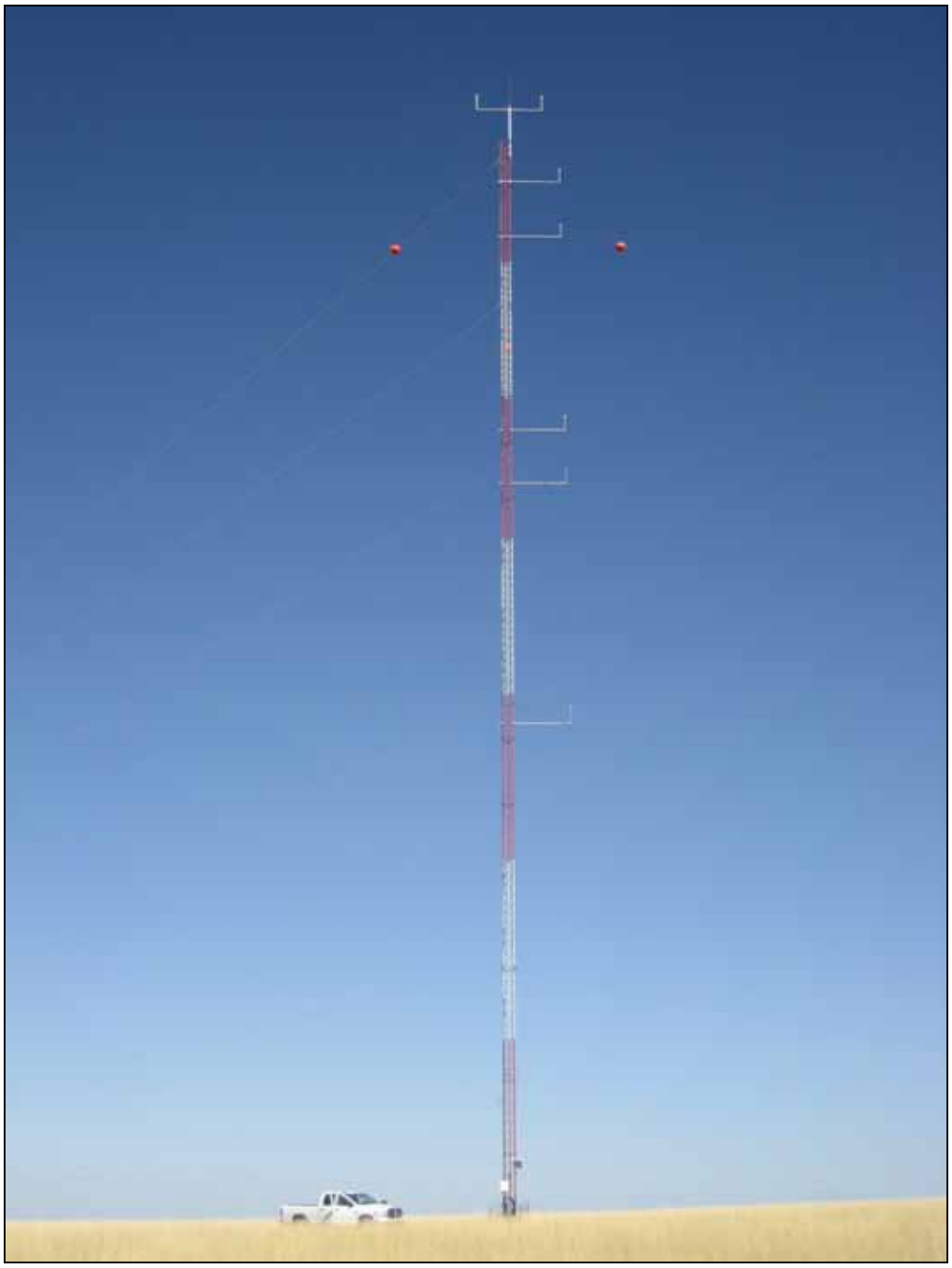

Photo 6. View of Met M438 facing Northeast

Photo 7. View of Met M440 facing Northeast

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DESIGNATED INFORMATION is CONFIDENTIAL per Protective Order in Dockets UE-170033 & UE-170034

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Appendix D – Wind Speed, Gross Energy Estimate, and Wake Loss for Each Turbine

Table D-1. Average Wind Speed, Gross Energy Estimate, and Wake Loss for Each Turbine Including Impact of Phase I Wakes Only

Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Table D-2. Average Wind Speed, Gross Energy Estimate, and Wake Loss for Each Turbine Including Impact of Phase I and II Wakes

Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Table D-3. Average Wind Speed, Gross Energy Estimate, and Wake Loss for Each Turbine Including Impact of Phase I and III Wakes

Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Table D-4. Average Wind Speed, Gross Energy Estimate, and Wake Loss for Each Turbine Including Impact of Phase I, II and III Wakes

Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Turbine ID	Assigned 80-m Wind Speed (m/s)	Gross Energy (MWh/yr)	Wake Effect (%)	Gross Energy minus Wakes (MWh/yr)
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Appendix E – Net Turbine Energy for Four Wake Loss Scenarios

Table E-1. Average Annual Net Energy Production Estimate for Each Turbine Including Impact of Phase I Wakes Only

Turbine ID	Net Energy (MWh/yr)	Turbine ID	Net Energy (MWh/yr)	Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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Table E-2. Average Annual Net Energy Production Estimate for Each Turbine Including Impact of Phase I and II Wakes

Turbine ID	Net Energy (MWh/yr)	Turbine ID	Net Energy (MWh/yr)	Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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Table E-3. Average Annual Net Energy Production Estimate for Each Turbine Including Impact of Phase I and III Wakes

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Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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Table E-4. Average Annual Net Energy Production Estimate for Each Turbine Including Impact of Phase I, II and III Wakes

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Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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Turbine ID	Net Energy (MWh/yr)
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