DNV KEMA Energy & Sustainability

Wind Resource Data Summary
Cotal Area, Guam
Data Summary and Transmittal for
September 2012

Prepared for:

GHD Inc.
194 Hernan Cortez Avenue
2nd Floor, Ste. 203
Hagatna, Guam 96910

March 2013

DNV Renewables (USA) Inc.
1809 7th Avenue, Suite 900, Seattle, WA 98101
Phone: (206) 387-4200 Fax: (206) 387-4201
www.dnv.com/windenergy

BACKGROUND

The Guam Power Authority (GPA) is performing an assessment of the wind resource potential on Guam with support from GHD Inc. and their subcontractor DNV Renewables (USA) Inc. (DNV KEMA). A preliminary site assessment was performed by DNV KEMA to evaluate potentially viable wind energy development areas on Guam and identifiy meteorological (met) tower locations. This report summarizes the monthly monitoring results and activities at the Cotal Area in central Guam.

GHD Inc. has subcontracted with DNV KEMA to collect, quality control (QC), validate, summarize, and transmit data for a 60-m meteorological tower located along the Cross Island Road in central Guam. This 60-m XHD tower, provided by NRG Systems, is identified as Site 0001. Black Construction Corporation installed the tower on July 29, 2011.

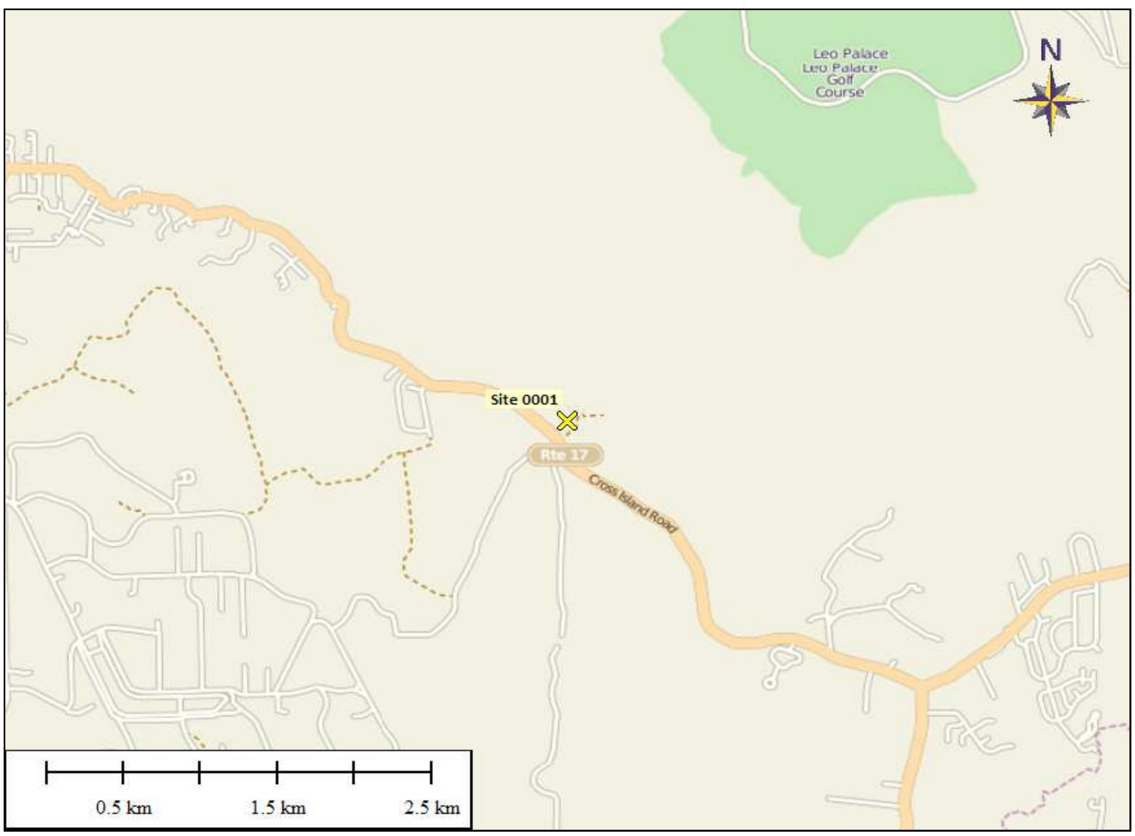
Location Summary

Site Number	Tower Type	Installation Date	Tower Coordinates (WGS 84)		Elevation
			Latitude	Longitude	
0001	**NRG 60-m XHD**	July 29, 2011	N 13° 23.361'	E 144° 43.359'	166 m (545 ft)

Sensor Summary

	Quantity	Nominal Sensor Height (m)	Actual Sensor Height (m)	Sensor Orientation (°)*	Boom Length (m)
NRG #40C Anem.	2	60	58	44, 134	2.4
NRG #40C Anem.	1	50	50	44	2.4
NRG #40C Anem.	2	40	40	44, 134	2.4
NRG #40C Anem.	1	25	25	44	2.4
NRG #200P Vanes	2	50, 45	52, 47.5	1, 1	2.4
NRG #110S Temp.	1	3	3		

*** An orientation of 180° means the sensor is due south of the tower.**



Location of GPA Wind Monitoring Station in Guam

OBJECTIVE AND DESCRIPTION

The monthly data summary is not a detailed analysis intended for use in making long-term energy estimates. The monthly activities provide a general validation and summarization of the 10-minute data, presented in a cumulative format. This includes elimination of data associated with tower shadow, icing, intermittent sensors, and failed sensors. The data summary does not include the detailed analysis of the data that is needed to address relatively small tower and boom effects, small sensor discrepancies, and other anomalies that may occur. While the validated data provided in the monthly processing provide a building block for evaluating a site's wind resource, they are not being delivered as a final wind resource assessment.

The information provided in this monthly data summary is based on the validated data but does not include detailed analysis and should be considered preliminary. For example, invalid data have not been replaced, and no consideration has been given to the long-term representativeness of the data that have been collected and reported in this summary. Additional analysis is required to establish a representative long-term data set.

Data Recovery

	Hours	Hours Lost				Recovery Rate	
	In Period	60 m	50 m	40 m	25 m	All Heights	Upper Level
August 2011	744	125	259	125	259	74.2%	83.2%
September	720	0	181	0	181	87.4%	100.0%
October	744	0	13	0	13	99.1%	100.0%
November	720	0	0	0	0	100.0%	100.0%
December	744	0	0	0	0	100.0%	100.0%
January 2012	744	0	0	0	0	100.0%	100.0%
February	696	0	0	0	0	100.0%	100.0%
March	744	0	0	0	0	100.0%	100.0%
April	720	0	0	0	0	100.0%	100.0%
May	744	0	14	0	14	99.0%	100.0%
June	720	0	3	0	3	99.8%	100.0%
July	744	0	35	0	35	97.7%	100.0%
August	744	0	181	0	181	87.8%	100.0%
September	720	0	38	0	38	97.4%	100.0%
Overall	**10,248**	**125**	**725**	**125**	**725**	**95.9%**	**98.8%**

O&M Summary

	Site 0001 NRG 60-m XHD Installed 7/29/11
August 2011	Tower installed on 7/29. Incomplete data transmittals 8/1-8/12; transmittal issues resolved via remote patch file from DNV to the iPack 8/12.
September	No issues
October	No issues
November	No issues
December	No issues
January 2012	No issues
February	No issues
March	No issues
April	No issues
May	No issues
June	No issues
July	No issues
August	No issues
September	No issues

Green shading indicates greater than 70% data recovery at 60 m.

Cause of Hours Lost (60m)

	Missing	Mal.	Tower[1]
August 2011	125	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
January 2012	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
Overall	**125**	**0**	**0**

[1] Hours lost due to tower shadow are expected and occur under normal conditions where there is only one anemometer per measuring height.

Cause of Hours Lost (50 m)

	Missing	Mal.	Tower[1]
August 2011	125	0	0
September	0	0	181
October	0	0	13
November	0	0	0
December	0	0	0
January 2012	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	14
June	0	0	3
July	0	0	35
August	0	0	181
September	0	0	38
Overall	**125**	**0**	**466**

[1] Hours lost due to tower shadow are expected and occur under normal conditions where there is only one anemometer per measuring height.

Cause of Hours Lost (40 m)

	Missing	Mal.	Tower[1]
August 2011	125	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
January 2012	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
Overall	**125**	**0**	**0**

[1] Hours lost due to tower shadow are expected and occur under normal conditions where there is only one anemometer per measuring height.

Cause of Hours Lost (25 m)

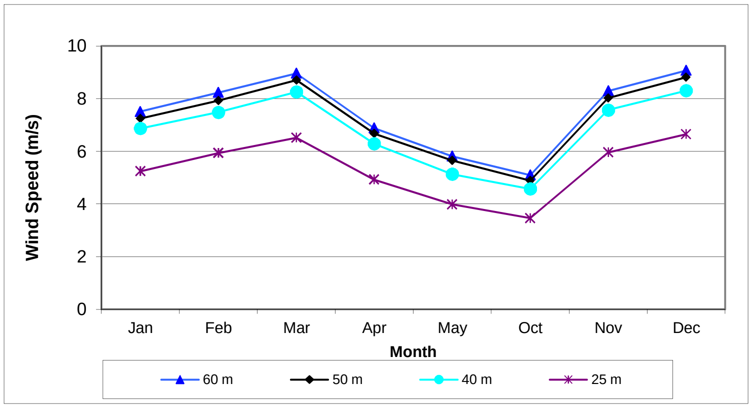
	Missing	Mal.	Tower[1]
August 2011	125	0	0
September	0	0	181
October	0	0	13
November	0	0	0
December	0	0	0
January 2012	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	14
June	0	0	3
July	0	0	35
August	0	0	181
September	0	0	38
Overall	**125**	**0**	**466**

[1] Hours lost due to tower shadow are expected and occur under normal conditions where there is only one anemometer per measuring height.

Monthly Average Wind Speeds (m/s)

	60 m	50 m	40 m	25 m
August 2011	4.7	4.4	4.2	3.0
September	4.8	4.4	4.3	3.1
October	5.1	4.9	4.6	3.5
November	8.3	8.0	7.6	6.0
December	9.1	8.8	8.3	6.7
January 2012	7.5	7.2	6.9	5.2
February	8.2	7.9	7.5	5.9
March	9.0	8.7	8.2	6.5
April	6.9	6.7	6.3	4.9
May	5.8	5.6	5.1	4.0
June	5.7	5.5	5.1	3.8
July	4.4	4.1	3.8	2.8
August	4.2	3.7	3.7	2.5
September	4.3	4.2	3.8	2.8
Weighted Average [1]	**6.6**	**6.3**	**5.9**	**4.6**

[1] The weighted annual average accounts for a period longer than 12 months by averaging duplicate calendar months.



Monthly Wind Speeds Graph

Maximum Wind Speed Gust (m/s)

	60 m	50 m	40 m	25 m
August 2011	25.6	26.0	24.1	22.5
September	18.7	18.3	18.7	16.0
October	19.5	19.5	18.0	15.7
November	22.5	22.9	23.3	19.9
December	21.4	21.8	22.2	21.4
January 2012	22.9	21.4	21.4	21.0
February	23.7	23.3	22.9	21.8
March	23.3	23.3	23.7	21.8
April	17.2	17.2	16.4	15.7
May	22.5	22.5	23.3	18.7
June	20.2	19.9	19.5	17.2
July	16.8	16.0	16.8	14.5
August	21.4	20.6	21.0	18.3
September	18.3	17.6	17.6	15.7
Period of Record [1]	**25.6**	**26.0**	**24.1**	**22.5**

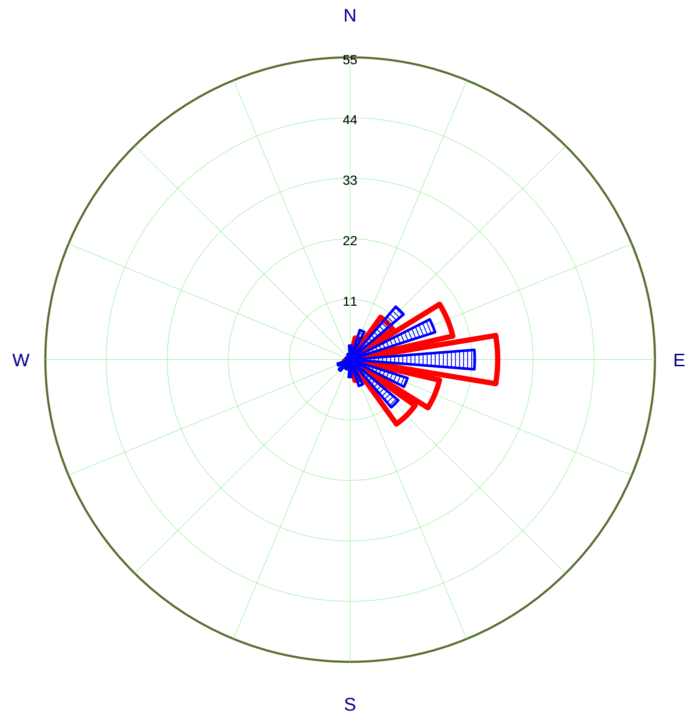
[1] Period of Record is the maximum wind speed from August 1, 2011, through the current month.

N/A indicates less than 50% data recovery.

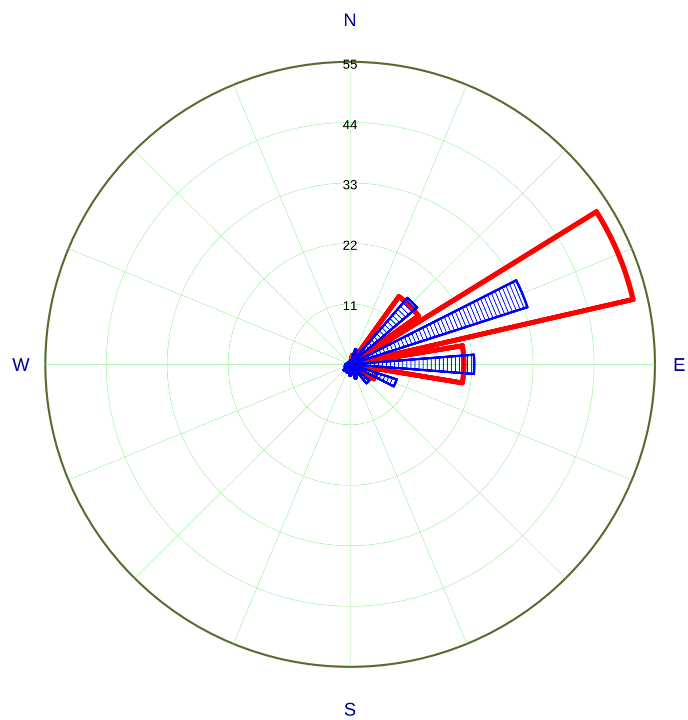
Temperature Ranges (°C)

	Average	Minimum	Maximum
August 2011	26.6	22.6	32.9
September	26.5	22.7	32.6
October	26.3	21.8	33.0
November	26.7	22.8	31.9
December	26.7	22.5	31.7
January 2012	25.5	20.6	31.7
February	26.2	21.1	32.0
March	26.2	22.2	33.5
April	27.1	22.8	33.0
May	27.4	23.4	34.1
June	27.7	23.2	33.7
July	27.0	23.0	32.8
August	26.2	22.3	33.0
September	27.0	22.9	33.5
Period of Record [1]	**26.7**	**20.6**	**34.1**

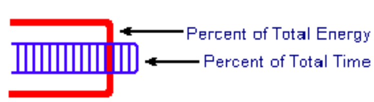
[1] The weighted annual average accounts for a period longer than 12 months by averaging duplicate calendar months.



Monthly Wind Rose (60 m)



Annual Wind Rose (60 m)

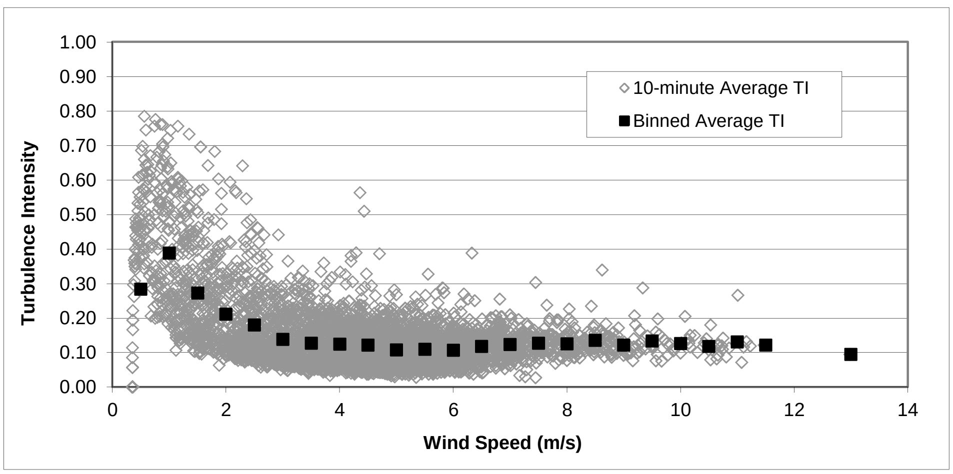


Wind Shear Exponent

	40-60 m	25-50 m
August 2011	0.32	N/A
September	0.28	N/A
October	0.29	0.42
November	0.26	0.42
December	0.25	0.41
January 2012	0.25	0.43
February	0.27	0.41
March	0.24	0.42
April	0.25	0.40
May	0.30	0.46
June	0.29	0.45
July	0.30	N/A
August	0.32	N/A
September	0.31	0.43
Weighted Average [1]	**0.28**	**0.43**

[1] The weighted annual average accounts for a period longer than 12 months by averaging duplicate calendar months.

N/A indicates less than 200 hours of wind speed recovery greater than 4 m/s for both anemometers used to calculate shear.



Average Turbulence Intensity by Wind Speed - Site 0001 (60 m)

PRELIMINARY DATA QUALITY CHECKING AND VALIDATION

Data are considered invalid if they do not appear to represent the actual wind conditions at the site. Typical causes of invalid data include tower wake influences, sensor icing, and equipment damage due to lightning, electrostatic discharge, failed components, or vandalism. The data validation process used to generate this report is generally automated and DNV is continuing to implement further automation. However, some manual review is required to assure the quality of the validated data. The data processing and validation are completed on 10-minute average data unless only hourly averages are available. The following provides a description of the data processing and validation activities completed prior to generating the data summaries.

Quality Checking

Data are quality checked on a weekly basis to verify normal operation of the logger and sensors. This process identifies failed sensors or other malfunctions that require immediate corrective action to maximize data recovery rates. During freezing conditions, this may require a determination as to whether a sensor has failed or is operating abnormally due to icing.

Validation

On a monthly basis, the 10-minute data are compiled into a monthly data set and data are validated to identify and remove data affected by tower wake influences, icing, intermittent operation, and other anomalies.

Tower Wake Influence - Wind speeds collected from an anemometer directly downwind of the tower are shadowed by the tower and consequently invalid. These invalid winds are removed from the data set. For example, an anemometer mounted to the south of the tower will record invalid wind speed data when the winds are from the north. The orientation of the anemometers is reported on the met tower commissioning sheets and can be verified by comparing two sensors on the tower that are oriented in different directions. For NRG tubular towers, the significant tower wake influence is approximately 50°. The exclusion sector may be wider for lattice towers which have a wider tower face than the tubular towers.

Icing - During freezing conditions, sensor icing can result in a significant amount of invalid data. The initial screening used to flag suspect data identifies periods where the standard deviation of the direction data is zero (direction is constant) and temperatures are 35°F or lower. This is used as the primary criteria because vanes are typically affected by icing several hours before an anemometer at the same height is affected. These flagged data are reviewed to determine if the sensors are being affected by icing or if the winds are just low. Typically, upper level sensors are affected before the lower level sensors because the temperatures are colder at the upper levels than at the lower. Upper level anemometers recording wind speeds lower than the lower level anemometers is another indicator of icing.

Similarly, the lower level sensors commonly return to operation before the upper level sensors. Heated anemometers and Risø anemometers are less affected by icing (typically slow down less than #40s in light to moderate icing) and when available are used to help identify icing on the standard NRG anemometers. When an icing event (longer than an hour) is identified, the data are removed from the data set.

Intermittent Operation - When a sensor is operating intermittently, all data from the sensor are considered suspect and are removed from the validated data set. An anemometer that has failed will record the sensor offset. Vane failures are identified when the sensors on the same tower do not agree. These invalid values are all removed from the validated data set.

Other Issues - While the above process identifies the majority of invalid data, DNV also plots time series of wind speed, wind direction, and temperature for the month. This process provides another verification that all significant anomalies have been removed.

Most Representative Data Set

From the validated data, DNV generates a data set for each height at which data are available that are most representative of the wind speeds at that height. The factor considered in developing this data set is wind direction. When two sensors are installed at the same height, the valid wind speed data from the sensor that is least influenced by the tower is used. For example, where anemometers are oriented to the west and south, when the wind direction is between 45° and 225°, the winds from the south anemometer are selected, when the wind direction is between 225° and 360° or 0° to 45°, the winds from the west anemometer are selected. These criteria are applied to each 10-minute record. While all valid data are saved, this most representative data set is used to develop the data summary.

DATA SUMMARY

A data summary is generated from the most representative data set. The information included in the summary is described below.

Data Recovery, O&M Summary, and Reason for Hours Lost - The data recovery rates are provided for valid wind speed data collected at all heights. The "Hours Lost" column indicates the number of hourly data points that were missing or removed during the data validation process for each monitoring height. The "Recovery Rate" represents the remaining data expressed as a percentage of total sensor hours in the period. A summary of O&M events is provided as well as a table that indicates the reason for missing or invalid data.

Monthly Average Wind Speed and Maximum Wind Speed Gust - The average monthly wind speeds are summarized and include data for the entire period of record. When a period of record (POR) is longer than 12 months, the weighted average calculation weights the additional months of data to estimate an annual average. For example, if a POR begins November 1 and ends 14 months later at the end of December, the two Novembers would be averaged, and the two Decembers would be averaged, and these two averages would be included with the remaining ten monthly averages, resulting in a weighted annual average wind speed. A graphical illustration of the individual monthly wind speeds (weighted when there are more than 12 months of data) is also provided. The maximum 2-second wind speeds are summarized on a monthly basis.

Temperature Ranges - A summary of the monthly average, minimum, and maximum temperature data is provided for the period of record.

Monthly and Cumulative Wind Roses - Wind rose graphs are provided on a monthly and cumulative basis. The cumulative wind rose is based on all data collected to date, or the most recent 12 months if more than a year of data has been collected. The graphs consist of two bars in each of the 16 wind direction sectors that represent the percent of total time and the percent of total wind energy. The calculated wind energy in the wind rose is based on a cube of the wind speed. Total wind energy from a project will be somewhat different. The winds above rated wind speed of a wind turbine have a non-cubic relationship to the energy. However, the wind roses provide a clear indication of the direction of the energy-producing winds.

Wind Shear Exponent - Monthly wind shear exponent values are summarized for the period of record. The wind shear exponent represents the degree to which wind speed increases with height. The wind shear exponent is only calculated from sensors with the same orientation and when the wind speed is higher than 4 m/s (operable winds). Calculation of the wind shear exponent is based on the following equation:

$$\left(\frac{H_1}{H_2}\right)^{\alpha} = \left(\frac{V_1}{V_2}\right)$$

where H_1 and H_2 are measurement heights, V_1 and V_2 are wind speeds, and α is the wind shear.

Turbulence Intensity - Turbulence intensity (TI) is a relative indicator of turbulence and not an absolute value. The average turbulence intensity at the upper monitoring level is summarized. The TI values are calculated by dividing the 10-minute standard deviation of the wind speed by the 10-minute average wind speed. The plot illustrates the average TI for all wind speeds as well as the average TI for each wind speed bin.