WIND RESOURCE ASSESSMENT

PIERRE-DE-SAUREL WIND FARM

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Document Information

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Approvals

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Revision History

Issue Date	Version	Overview
March 31, 2015	V1	Meteorological data analysis, yields, losses and confidence intervals for the proposed 12 x Senvion MM92 2.05MW turbine wind farm with a 100 m hub height. The calculations were based on measurements made at Met Masts 0091, LIDAR and 0092.
April 27, 2015	V2	Added Section 12: Temporal profiling and Appendix I. Minor text edits to the executive summary.

Disclaimer

Table of Contents

List of Tables

List of Figures

1 Executive Summary

WSP performed an independent analysis of the long-term energy resource for the Pierre-de-Saurel Wind Power Project on behalf of Parc Éolien Pierre-De Saurel SEC.

The project is located in the south portion of Quebec, approximately 15 km from Sorel. Table 1 outlines the significant information for the project and the major findings of the analysis.

Turbine model	Senvion MM92
Hub height (m)	100
Rotor diameter (m)	92
Number of turbines	12
Turbine rated power (MW)	2.05
Facility rated power (MW)	24.6

	Start Date	End Date	Annual Long-term Average Wind Speed at Hub Height (m/s)
Met mast 0091	03-Oct-2009	22-Feb-2015	6.51
Met mast 0092	17-Dec-2014	19-Feb-2015	6.55
LIDAR	10-Apr-2013	19-Aug-2013	-
Reference station MERRA	01-Jan-2000	31-Jan-2015	-

Average air density (kg/m³)	1.246
Average turbulence intensity at hub height (% at 15 m/s)	9.5
Average shear exponent	0.269
Project mean wind speed (m/s)	6.52

	1-Year Value		20-Year Value	
	Energy (GWh/year)	Capacity Factor (%)	Energy (GWh/year)	Capacity Factor (%)
Gross energy yield	74.4	34.5	74.4	34.5
Losses (%)	17.5		17.5	

	1-Year Value		20-Year Value	
	Energy (GWh/year)	Capacity Factor (%)	Energy (GWh/year)	Capacity Factor (%)
P50 net energy yield	61.3	28.4	61.3	28.4
P90 net energy yield	51.2	23.8	53.8	24.9
Standard uncertainty (%)	12.8		9.5	

Table 1: Project summary

WSP has identified the following recommendations and considerations of this analysis:

Data Quality

- Met Mast 0091 provides more than 5 years of wind data, well documenting the site seasonal variations. It does not have heated instruments, which leads to sensor icing and lower recovery rates during the winter months.
- The LIDAR campaign does not show any particular issue and enables a good characterization of shear values for Met Mast 0091 during the summer months. This provides significant reductions in the yield uncertainty.
- Met Masts 0092 has been collecting for only two months in winter, months which are particularly affected by icing. The temporary power source installed on-site which provides the power to the heated instruments appear to not be sufficient and icing events are affecting the quality of the data. A permanent hook-up is planned and should improve this issue.
- The overall data quality is good and does not result in excessive uncertainty in the wind resource assessment.

Shear Extrapolation

- The shear value between 58.7 m and 39.3 m at Met Mast 0091 was chosen as it agrees with the collocated LIDAR shear value for the same period and heights and is consistent with the site roughness characteristics.
- The shear analysis with Met Mast 0092 was also carried out. Given the short period of record for this tower and the icing events it encountered during that period, it is difficult to rely on the shear values calculated for this tower. Additional data collected at this tower for a full year should confirm the shear conditions throughout the site.

Wind Flow Modeling

- The WAsP wind flow model was used at it is well adapted to model winds over this site simple terrain.

- Given the size and spread of the turbine layout, the number and positions of meteorological towers on site is deemed adequate to calibrate the wind flow model

Layout

- The turbine model used for this site is adequate. The turbines are equipped with a cold weather package. No de-icing equipment was selected for this project. The data collected at Met Mast 0091 over five consequent winters shows that average icing losses are low.
- The spacing in between turbines is small, leading to moderately high wake losses. They are nevertheless within the recommended values.

Uncertainty

- The total uncertainty is moderate. Yields could fluctuate greatly from year to year given the high production sensitivity (1% wind speed decrease will be translated in 2.07% yield decrease).
- Shear conditions have been well documented with the deployment of a LIDAR unit, which helps improve the overall uncertainty.

2 Introduction

This report presents an independent analysis of the long-term energy estimate for the Pierre-de-Saurel Wind Power Project. The methodology of the assessment is outlined in Table 2.

Task	Description	Section
Data Collection and Quality Control	The data collected from on-site met masts and nearby reference stations was put through a quality control process to prepare it for the analysis and evaluate its validity.	3
Vertical Shear Extrapolation	The measured and reference site wind speeds were extrapolated to hub height.	4
Long-Term Predictions	Long-term predicted data sets for wind speed, wind direction, temperature, and pressure were generated for each on-site met mast using the most suitable reference station.	6
Wind Flow Modeling	A WAsP wind flow model was used to calculate wind speeds across the project site. Inputs for the model include the predicted long-term data sets at hub height, topographical data, and surface roughness data.	7
Turbine Layout	The turbine layout was provided by Parc Éolien Pierre-de-Saurel SEC	8
Gross Yield Calculation	Gross energy yields were calculated at each turbine location using the wind flow model results.	9
Losses	Losses were quantified in order to calculate the net energy yield for the project. Each loss category was characterized as a beta-pert probability distribution with a variability component for the confidence interval calculation.	10
Uncertainty and Confidence Intervals	Uncertainties and variations associated with the long-term prediction of yield for the wind power project were quantified. The energy yield was estimated for various averaging periods and probabilities of exceedance levels.	11
Wind Resource Temporal Profiling	A matrix of month by hour (12 x 24) P50 Net yields were generated for the project (long-term average), based on measured on-site data and scaled to reflect the long-term expected annual average yield of the project. A record-by-record air density correction is made using the air density dependent power curves. Shear is applied on seasonal, diurnal and directional basis to capture these dependencies.	12

Table 2: Summary of the Wind Resource Assessment Methodology

2.1 Project Description

Photographs of the project site are found in Appendix A.

The wind turbine layout is located approximately 15 km south-east of Sorel and covers an area of approximately 1.5 km in width and 4 km in length (6 km2). The wind turbines are located in flat orography with elevation differences reaching approximately 4 m. The surrounding vegetation is composed of fields with few hedges and wood lots. Rural-type of housing is present along farm roads surrounding the project. Hog farm buildings are located near the Met tower 0091 and LIDAR locations.

A map of the project site and the surrounding area is shown in Figure 1.

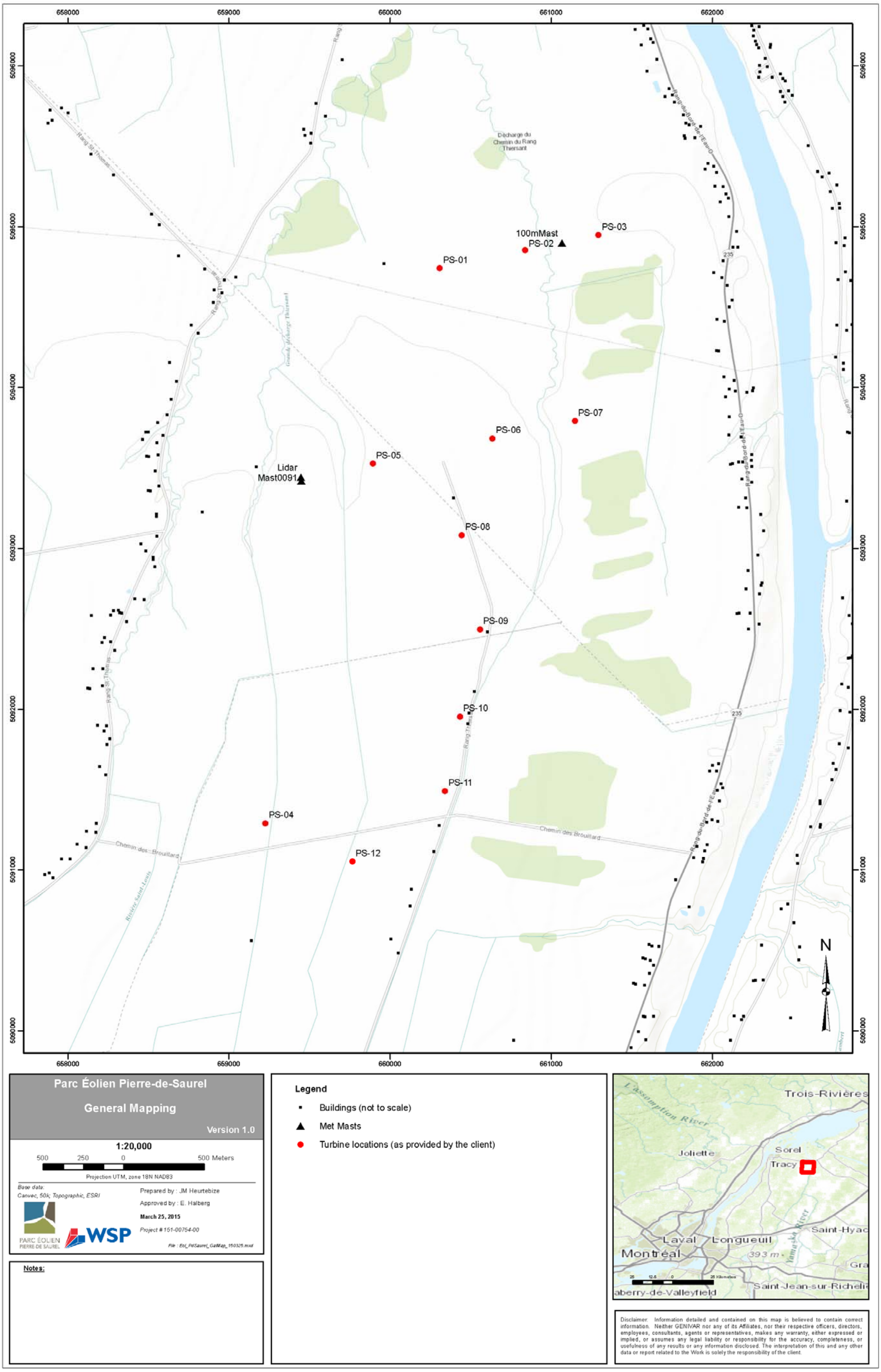


Figure 1: Project site and surrounding area

3 Data Collection and Quality Control

3.1 Meteorological Campaign Summary

Wind data has continuously been collected from the project lands from October 3, 2009 to February 22, 2009. The MERRA reference monitoring station is located approximately 20 km east of the project lands.

As discussed in Section 6.2, MERRA reanalysis data was selected as the long-term reference.

Table 3 describes the on-site met masts and the reference monitoring station.

Name	Location (UTM Zone 18, NAD83)		Elevation (m)	Monitoring Period		Monitoring Heights (m)
	Easting	Northing		Start	End	
0091	659449	5093442	20	03-Oct-2009	22-Feb-2015	58.7, 49.7, 39.3
0092	661069	5094899	19	17-Dec-2014	19-Feb-2015	100,98,79,59
LIDAR	659450	5093422	20	10-Apr-2013	19-Aug-2013	99,79,58,48,38
MERRA	680671	5096694	N/A	01-Jan-2000	31-Jan-2015	50

Table 3: On-site Met Masts and Reference Stations

3.2 Data Collection Instrumentation

The data logger recorded time-stamped meteorological data over a 10-minute sampling period. Instrumentation details for the on-site met masts are summarized in Table 4 and Table 5.

Tower configuration details can be found in Appendix B.

The sensor heights remained the same at the two met masts. The NRG Symphonie logger was replaced by a new one on Met Mast 0091 on June 30, 2010.

The LIDAR is a ZephIR 300 unit installed 20 m away from Met Mast 0091.

Monitoring Height (m)	Type of Instrumentation	Manufacturer/Model
58.7	Anemometer (2)	NRG / #40C Max
49.7	Anemometer (2)	NRG / #40C Max
39.3	Anemometer (1)	NRG / #40C Max
57	Wind Vane	NRG / #200P
47	Wind Vane	NRG / #200P
3	Temperature sensor	NRG / 110S
1.5	Logger	NRG / Symphonie

Table 4: Instrument Configuration, Met Mast 0091

Monitoring Height (m)	Type of Instrumentation	Manufacturer/Model
100	Anemometer (1)	RMY Ultrasonic
100	Anemometer (1)	Thies 1stClass
98	Anemometer (1)	NRG IceFree3
98	Anemometer (1)	Thies 1stClass
79	Anemometer (1)	NRG IceFree3
79	Anemometer (1)	Thies 1stClass
59	Anemometer (1)	NRG IceFree3
59	Anemometer (1)	Thies 1stClass
96	Wind Vane	Thies Classic
77	Wind Vane	NRG IceFree3
57	Wind Vane	Thies 1stClass
96	Temperature sensor	Campbell Sc. 109
3	Temperature sensor	Campbell Sc. 109
3	Pressure sensor	NRG / BP20
3	Humidity sensor	NRG / RH5X
1.5	Logger	Campbell Sc. CR3000

Table 5: Instrument Configuration, Met Mast 0092

3.3 Quality Control Results

Met Mast 0091 provides more than 5 years of wind data, well documenting the site seasonal variations. It does not have heated instruments which leads to sensor icing and lower recovery rates during the winter months. A corrective offset of -190 and -194 degrees were applied to the 57 m and 47 m respectively to align the vanes with reference to local reference stations. No pressure or relative humidity sensor data was recorded during the period of record as these sensors were likely never mounted contrary to what is mentioned in the site notes. Both Met mast 0091 and the LIDAR unit are located near farm buildings (the closest one is 20 m away south-east of the base of the mast), which introduce a flow distortion. Nevertheless, this distortion was is expected to be negligible at 0.23% based upon obstruction calculations based upon the IEC Standard 61400-12-1[1].

A description of the quality control methodology can be found in Appendix C.

The data validity is measured by the percentage of records that were deemed reasonable and of suitable accuracy during the quality control process.

The LIDAR campaign does not show any particular issue and enables a good characterization of shear values for Met Mast 0091 during the summer months.

[1] International Electrotechnical Commission, Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines, 61400-12-1 Ed. 1, 2005.

Met Masts 0092 has been collecting for the two months in winter, months which are particularly affected by icing. The wind speed sensor calibrations provided in the site notes did not correspond with what was programmed in the logger, and transfer functions were applied in WindServer to compensate for the discrepancy. The temporary power source installed on-site which provides the power to the heated instruments appear to not be sufficient and icing events are affecting the quality of the data. A permanent hook-up is planned and should improve this issue. Also, the 100 m instruments are mounted on 3.66 m side booms. For hub-height measurements, WSP recommends to follow the IEC 61400-12-1 standard on power performance measurements of wind turbines, which calls for goal-post booms to be used for the top measurement height as lattice towers tend to create a significant flow distortion affecting the quality of the data. Finally, the calibration parameters provided for the three NRG Ice Free 3 anemometers mounted at 59 m, 79 m and 98 m are questionable (the tower shadow plots presented in Figure 3 reveals an important difference with the wind speeds measured by the Thies anemometers at these levels) and cannot be completed with the same level redundant anemometers at this time given the lack of adequate data (temperatures must be above 5 °C).

The overall data quality is good and does not result in excessive uncertainty in the wind resource assessment.

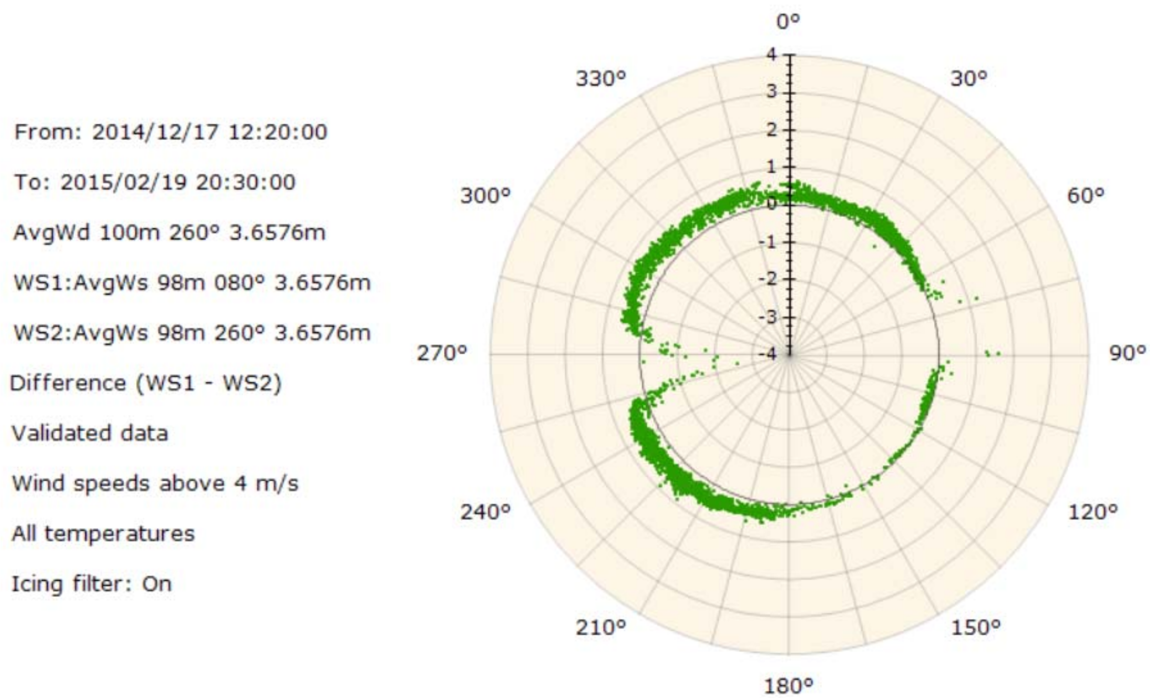


Figure 2: Tower shadow plot at 98 m showing the difference between the wind speeds measured with the NRG Ice Free 3 (80°) and the Thies (260°) anemometers for Met Mast 0092

Table 6 shows the significant data gaps in the measured data.

Met Mast	Gap Start	Gap End	Gap Length (days)
0091	2010/06/29 23:50:00	2010/06/30 23:50:00	1.0
0091	2010/06/29 23:50:00	2010/06/30 23:50:00	1.0
0091	2010/07/30 23:50:00	2010/07/31 23:50:00	1.0
0091	2013/11/27 21:50:00	2013/11/30 23:50:00	3.1
0091	2014/12/12 21:50:00	2014/12/15 23:50:00	3.1
0091	2015/01/01 23:50:00	2015/01/04 23:50:00	3.0
0091	2015/01/17 21:50:00	2015/01/20 23:50:00	3.1
		Subtotal	15.3
0092	2014/12/29 07:20:00	2014/12/30 15:20:00	1.3
0092	2015/01/01 20:00:00	2015/01/02 08:10:00	0.5
0092	2015/01/03 09:20:00	2015/01/05 08:40:00	2.0
0092	2015/01/07 06:10:00	2015/01/08 11:00:00	1.2
0092	2015/01/19 04:20:00	2015/01/19 20:40:00	0.7
0092	2015/01/21 01:30:00	2015/01/21 11:50:00	0.4
0092	2015/01/21 19:10:00	2015/01/22 10:40:00	0.6
		Subtotal	6.7

Table 6: Data Gaps

Table 7 summarizes the data identified as invalid during the quality control process.

Met Mast	Reason	Invalid Data (days)
0091	Flagged invalid due to missing value or WindServer quality controlled.	171.3
0092	Flagged invalid due to missing value or WindServer quality controlled.	8.8

Table 7: Data removed during the quality control process

3.4 Measured Data Statistics

3.4.1 Data Validity

Table 8 through Table 11 summarize the monthly data availability at the top measurement height of the on-site met masts and the nearby reference station.

Year	Month												Annual Average
	1	2	3	4	5	6	7	8	9	10	11	12	
1999	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%
2000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2001	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2002	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2003	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2004	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2005	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2006	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2007	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2008	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2009	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2010	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2011	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2012	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2013	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2014	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2015	99%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%
Summary	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	94%	100%

Table 8: Data Validity Summary for MERRA

Year	Month												Annual Average
	1	2	3	4	5	6	7	8	9	10	11	12	
2009	0%	0%	0%	0%	0%	0%	0%	0%	0%	91%	97%	82%	23%
2010	85%	91%	95%	99%	100%	98%	97%	100%	100%	99%	92%	62%	93%
2011	95%	92%	82%	95%	100%	100%	100%	100%	100%	98%	96%	69%	94%
2012	91%	77%	89%	98%	100%	100%	100%	100%	100%	100%	94%	81%	94%
2013	98%	86%	94%	96%	100%	100%	100%	100%	98%	96%	85%	61%	93%
2014	91%	87%	96%	97%	100%	100%	100%	100%	100%	100%	98%	59%	94%
2015	44%	54%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%
Summary	84%	81%	91%	97%	100%	100%	99%	100%	100%	97%	94%	69%	93%

Table 9: Data Validity Summary for 0091

Year	Month												Annual Average
	1	2	3	4	5	6	7	8	9	10	11	12	
2014	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	35%	3%
2015	80%	66%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	12%
Summary	80%	66%										35%	87%

Table 10: Data Validity Summary for 0092

Year	Month												Annual Average
	1	2	3	4	5	6	7	8	9	10	11	12	
2013	0%	0%	0%	57%	79%	78%	83%	51%	0%	0%	0%	0%	29%
Summary				57%	79%	78%	83%	51%					81%

Table 11: Data Validity Summary for LIDAR

3.4.2 Wind Speed

Table 12 through Table 15 summarize the wind speeds measured at the top monitoring height of the on-site met masts and the nearby reference station.

Year	Month												Annual Average
	1	2	3	4	5	6	7	8	9	10	11	12	
1999												2.7	2.7
2000	6.6	6.4	5.9	5.9	5.0	4.6	4.1	4.3	5.3	5.5	4.5	5.8	5.3
2001	4.9	6.3	6.0	6.2	4.8	4.6	4.6	4.7	5.1	6.0	5.7	5.6	5.4
2002	5.6	6.4	6.8	5.7	6.1	4.4	5.1	4.8	5.3	5.0	5.6	6.1	5.6
2003	5.6	6.1	5.7	5.4	4.0	4.6	4.9	4.4	5.0	5.5	6.2	6.0	5.3
2004	6.0	5.7	6.0	6.1	5.5	5.4	4.0	4.6	5.1	5.4	5.3	5.9	5.4
2005	6.0	5.4	6.2	5.9	5.1	4.9	4.3	4.4	5.4	5.5	6.8	6.0	5.5
2006	6.2	6.7	5.8	5.7	5.0	4.8	4.7	4.5	4.8	5.8	5.3	6.2	5.4
2007	6.2	6.9	6.8	5.8	5.2	4.7	4.0	4.3	5.3	5.1	5.8	5.8	5.5
2008	6.8	6.2	6.4	5.6	5.1	4.2	4.5	3.6	4.4	5.0	5.6	6.6	5.3
2009	5.1	6.6	5.7	6.2	5.6	4.1	4.2	4.5	4.5	4.9	4.6	5.6	5.1
2010	6.0	6.3	6.3	5.6	4.9	4.1	4.4	4.5	5.3	5.6	5.7	5.9	5.4
2011	4.9	6.4	6.3	6.1	5.2	4.6	4.3	4.4	4.2	5.7	5.9	5.5	5.3
2012	5.9	5.6	5.8	5.9	4.5	4.7	4.1	4.4	5.2	5.4	4.5	5.6	5.1
2013	6.5	5.6	5.8	6.4	5.1	4.4	4.1	4.4	4.8	5.4	6.6	4.9	5.3
2014	7.2	6.1	6.4	6.5	5.2	4.4	5.3	4.0	5.1	5.8	6.9	5.4	5.7
2015	6.8												6.8
Summary	6.0	6.2	6.1	5.9	5.1	4.6	4.4	4.4	5.0	5.4	5.7	5.6	5.4

Table 12: Wind Speed (m/s) Summary for MERRA at 50 m

Year	Month												Annual Average
	1	2	3	4	5	6	7	8	9	10	11	12	
2009										5.3	4.9	5.8	5.3
2010	6.0	6.2	6.2	5.8	5.4	4.6	5.0	5.0	5.5	5.9	5.5	6.4	5.6
2011	5.1	6.3	6.0	6.3	6.1	5.3	4.8	5.3	4.5	6.2	6.6	6.1	5.7
2012	5.8	5.9	6.2	6.3	5.1	5.5	4.7	5.1	5.5	5.4	5.0	6.0	5.5
2013	6.1	5.9	5.6	6.9	5.8	5.1	4.9	5.0	5.2	5.7	7.0	5.9	5.7
2014	7.0	6.2	6.2	6.4	5.8	4.8	5.9	4.2	5.5	6.0	6.9	6.3	5.9
2015	6.9	6.3											6.6
Summary	6.1	6.1	6.1	6.3	5.6	5.0	5.0	4.9	5.2	5.8	6.0	6.1	5.7

Table 13: Wind Speed (m/s) Summary for 0091 at 58.7 m

Year	Month												Annual Average
	1	2	3	4	5	6	7	8	9	10	11	12	
2014												6.9	6.9
2015	7.1	6.1											6.7
Summary	7.1	6.1										6.9	6.8

Table 14: Wind Speed (m/s) Summary for 0092 at 100 m

Year	Month												Annual Average
	1	2	3	4	5	6	7	8	9	10	11	12	
2013				7.5	6.9	6.2	6.1	6.8					6.7
Summary				7.5	6.9	6.2	6.1	6.8					6.7

Table 15: Wind Speed (m/s) Summary for LIDAR at 99 m

Figure 3 and Figure 4 show representative examples of the wind speed frequency distributions for the measured data.

The on-site measured data at Met Mast 0091 has an average wind speed of 5.68 m/s and a maximum wind speed of 24.80 m/s. The reference data has an average wind speed of 5.39 m/s and a maximum wind speed of 18.19 m/s.

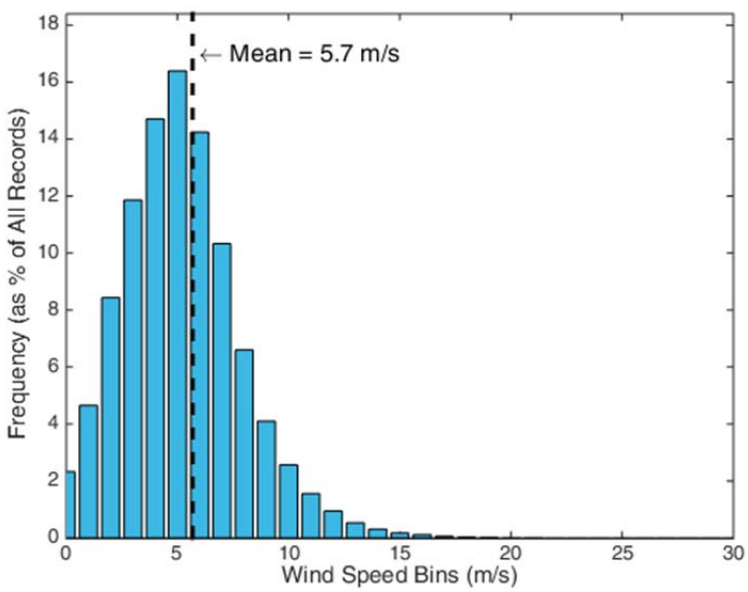


Figure 3: Wind Speed Distribution for Met Mast 0091 at the Top Measurement Height

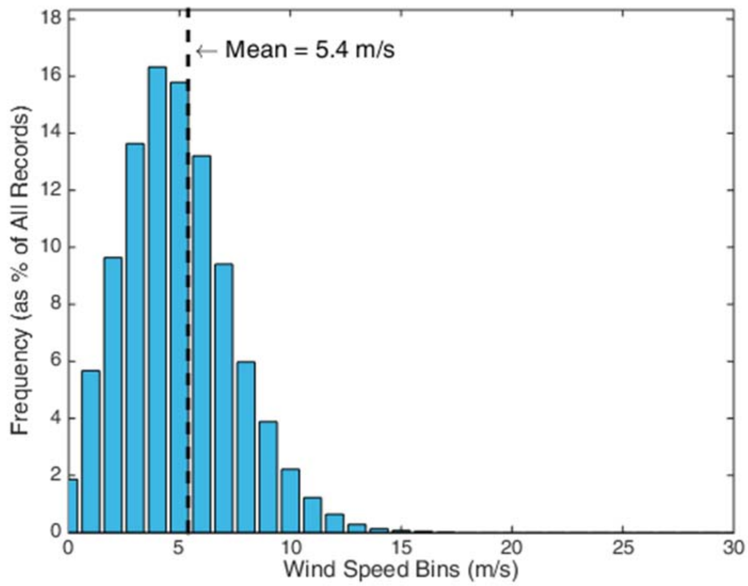


Figure 4: Wind Speed Distribution for MERRA at the Top Measurement Height

3.4.3 Wind Direction Frequency Distribution

Figure 5 and Figure 6 display the wind direction frequency distribution at Met Mast 0091 and MERRA. The frequency is presented as a percentage of all valid records. The wind directions are divided into 16 bins, each 22.5° wide.

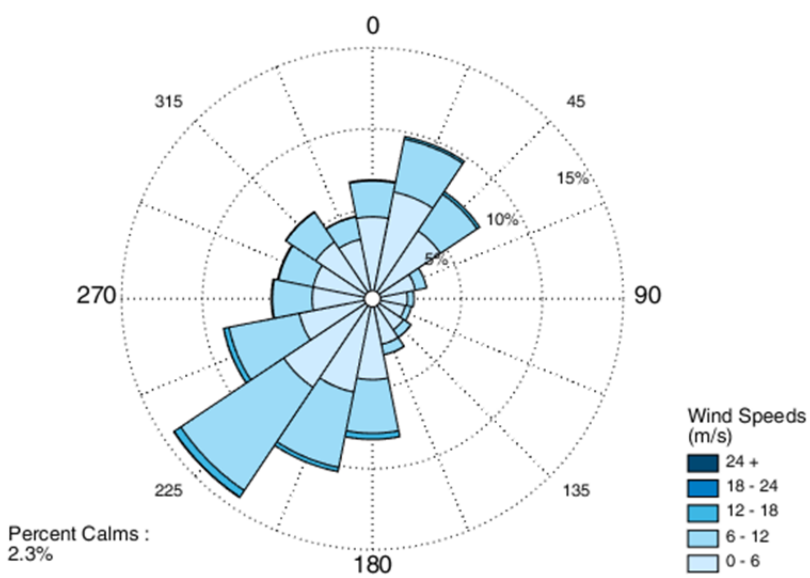


Figure 5: Wind Direction Distribution at Met Mast 0091 at the Top Measurement Height

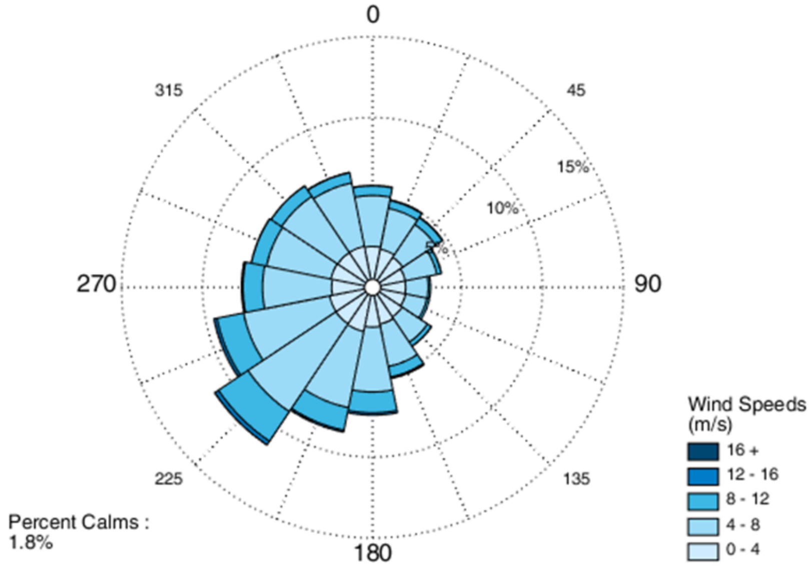


Figure 6: Wind Direction Distribution for MERRA at the Top Measurement Height

4 Vertical Shear Extrapolation

4.1 Extrapolation to Hub Height

Detailed methodology for the shear calculation can be found in Appendix D.

Table 16 shows the vertical shear calculated for each monitoring height pair. Displacements heights were applied at Met Mast 0091 and the LIDAR location to account for the effect of the farm buildings located nearby. Based on a comparison between the multiple monitoring heights, the power law is assumed to accurately represent vertical shear conditions between the top monitoring height and hub height. Shear exponents were binned by season, wind direction and record timestamp. These bins were then used to extrapolate the top monitoring height wind speeds to hub height.

The shear value between 58.7 m and 39.3 m was chosen as it agrees with the LIDAR shear value for the same period and heights (0.288 for Met Mast 0091 vs 0.285 for the LIDAR). The shear value at the LIDAR was found to decrease with height up to 99 m. The shear between 99 m and 58 m is lower than the shear between 58.7 m and 39.3 m by a factor of 0.954. This adjustment factor was applied to the shear used to extrapolate to 100 m hub height at Met Mast 0091.

Table 16 shows both measured and corrected shear values and extrapolated wind speeds at Met Mast 0091.

The shear analysis with Met Mast 0092 was also carried out. Given the short period of record for this tower, the icing events it encountered during that period and the doubts on the NRG Ice Free 3 sensors explained in Section 3.3, it is difficult to rely on the shear values calculated for this tower. The 100m wind speeds are therefore used directly for the remaining of the analysis.

The shear profiles selected to extrapolate wind speeds were based on the measured heights indicated in grey in Table 16.

Site	Measurement Heights (m)	Effective Shear	Average Applied Shear	Top Wind Speed (m/s)	Extrapolated Wind Speed (m/s)
0091	49.7 - 39.3	0.296	0.294	5.44	6.70
	58.7 - 39.3	0.282	0.279	5.68	6.60
	58.7 - 49.7	0.267	0.264	5.68	6.55
LIDAR	99 - 79	0.261	0.254	6.67	6.68
	99 - 58	0.275	0.267	6.67	6.68
	99 - 48	0.279	0.270	6.67	6.68
	99 - 38	0.278	0.269	6.67	6.68
	79 - 58	0.282	0.275	6.29	6.73
	79 - 48	0.285	0.277	6.29	6.73
	79 - 38	0.283	0.275	6.29	6.73
	58 - 48	0.289	0.283	5.79	6.77
	58 - 38	0.285	0.278	5.79	6.76
	48 - 38	0.283	0.277	5.49	6.76
0091 synchronized with LIDAR measurements	58.7 - 39.3	0.288	0.284	5.63	6.57
LIDAR measurements synchronized with 0091	99 - 58	0.275	0.267	6.67	6.68
0091_Corrected	60 - 40	0.269	0.266	5.68	6.55

Table 16: Wind Shear Characteristics at the Met Mast 0091 and LIDAR

Photographs of the project site are found in Appendix A.

Figure 7 and Figure 8 show the diurnal and seasonal shear profile measured at Met Mast 0091 and show the strong diurnal dependency in the shear profile. Photographs of the project site show that the calculated shear is reasonable given the surface roughness surrounding the towers.

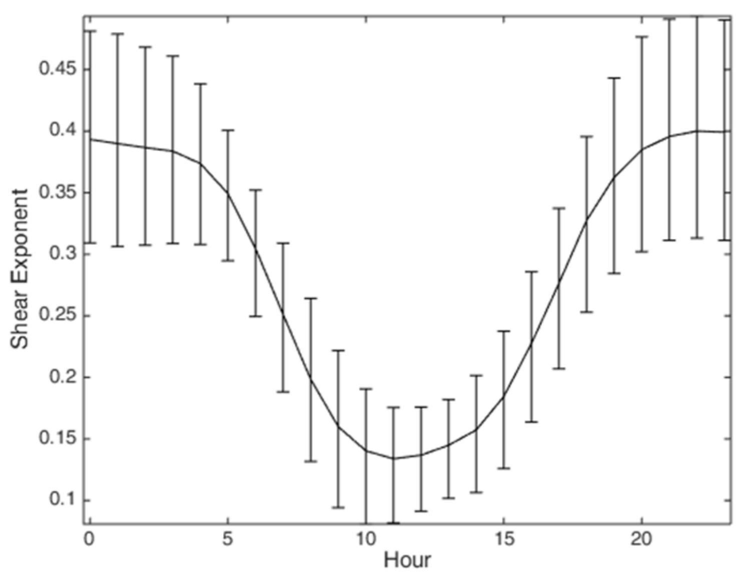
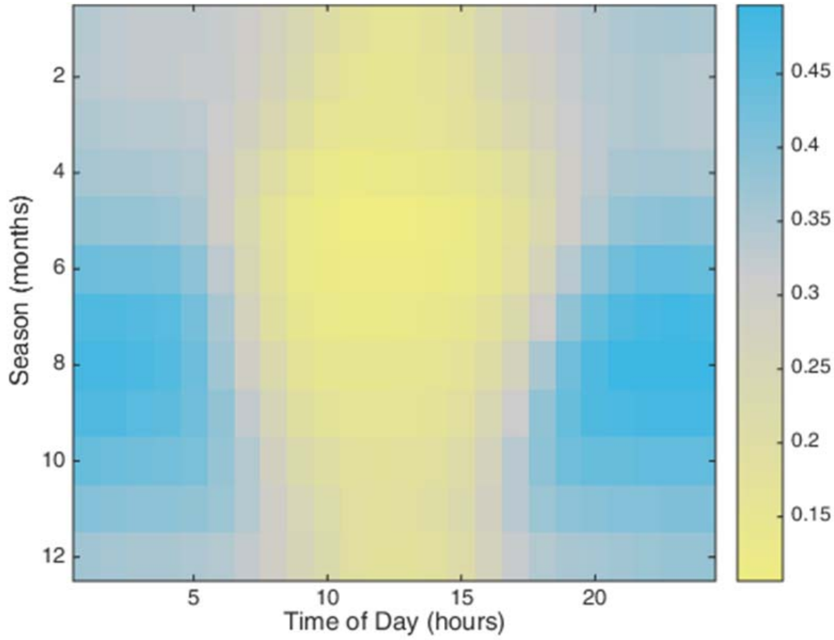


Figure 7: Diurnal Shear Profile between 39.3 m and 58.7 m at Met Mast 0091



Periods of high shear are indicative of lower turbulence and higher thermal stability. Thermal stability has implications for the wind flow model and turbine efficiency.

Figure 8: Diurnal and Seasonal Shear between 39.3 m and 58.7 m at Met Mast 0091

5 Ambient Turbulence Intensity

Table 17 summarizes the turbulence intensity for Met Mast 0091 during its measurement period. Turbulence intensity is defined as the ratio of the standard deviation of wind speeds to the mean wind speed. The turbulence intensity was extrapolated to hub height by assuming that the wind speed standard deviation is invariant with height[2]. Therefore, the turbulence intensity can be calculated by dividing the wind speed standard deviation measured at the top measurement height by the hub height wind speed.

The characteristic turbulence intensity at 15 m/s is used in turbine design load calculations.

Based on the characteristic turbulence intensity, the project site falls within the limits of IEC Turbine Class C.

Ambient turbulence conditions are used in calculating turbine efficiency and power curve losses, as discussed in Section 10.

Wind Speed Range (m/s)	Frequency	Mean TI	Standard Deviation of TI	Characteristic TI
0 to 0.5	0.7%	13.3%	17.9%	31.3%
0.5 to 1.5	2.7%	42.8%	15.3%	58.1%
1.5 to 2.5	4.9%	23.4%	12.4%	35.8%
2.5 to 3.5	7.7%	15.2%	8.3%	23.6%
3.5 to 4.5	10.0%	11.6%	6.3%	17.8%
4.5 to 5.5	12.1%	9.7%	5.2%	14.8%
5.5 to 6.5	13.5%	8.7%	4.5%	13.1%
6.5 to 7.5	13.2%	8.1%	4.1%	12.2%
7.5 to 8.5	11.3%	8.0%	3.8%	11.9%
8.5 to 9.5	8.5%	8.3%	3.7%	12.0%
9.5 to 10.5	5.6%	8.7%	3.5%	12.3%
10.5 to 11.5	3.6%	9.3%	3.4%	12.7%
11.5 to 12.5	2.3%	9.6%	3.0%	12.6%
12.5 to 13.5	1.4%	9.7%	3.0%	12.7%
13.5 to 14.5	0.9%	9.7%	2.9%	12.6%
14.5 to 15.5	0.6%	9.5%	2.8%	12.4%
15.5 to 16.5	0.4%	9.7%	2.8%	12.5%
16.5 to 17.5	0.2%	9.7%	2.6%	12.3%
17.5 to 18.5	0.1%	10.3%	3.1%	13.4%
18.5 to 19.5	0.1%	10.1%	2.8%	12.9%

[2] International Electrotechnical Commission (IEC), Wind turbines – Part 1: Design requirements third edition, 61400-1, 2005.

Wind Speed Range (m/s)	Frequency	Mean TI	Standard Deviation of TI	Characteristic TI
19.5 to 20.5	0.1%	10.4%	2.5%	12.9%
20.5 to 21.5	0.0%	10.7%	2.5%	13.2%
21.5 to 22.5	0.0%	11.6%	2.6%	14.2%
22.5 to 23.5	0.0%	11.5%	2.2%	13.7%
23.5 to 24.5	0.0%	12.3%	2.1%	14.4%
24.5 to 25.5	0.0%	11.3%	1.6%	12.9%

Table 17: Measured Turbulence Intensity for Met Mast 0091 at Hub Height

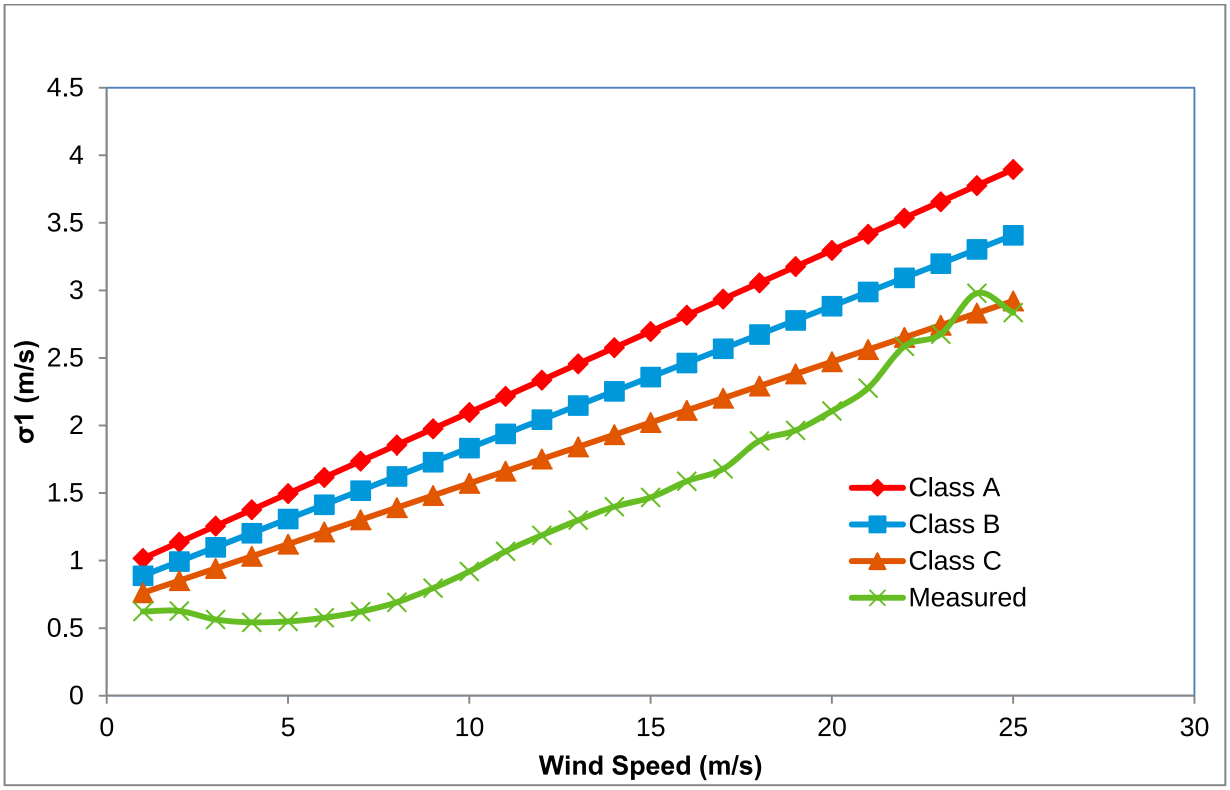


Figure 9: IEC (rev 3) Representative Turbulence Intensity at 0091 at 100 m

6 Long-Term Predictions

6.1 Filling and Extension of On-site Data Sets

The uncertainty in the on-site data is impacted by its validity and length of record. In order to minimize this uncertainty, the wind speed, wind direction, and temperature data sets from the on-site masts were filled and extended in a round-robin fashion. The resulting filled and extended data sets have the same period of record and maximized validity.

The methodology for the non-linear correlation process is described in Appendix E.

The wind speed and wind direction data sets were correlated using a non-linear process, while the temperature data sets were correlated using a linear process.

Met Mast 0091 has the longest measured period of record and is used as a reference site for the other onsite met masts. Linear correlations between the onsite towers were calculated for the daily rolling average wind speed and direction to provide an indicator of the strength of relationship between onsite towers. The respective coefficients of determination are shown in Table 18.

The wind direction correlations are based on the vector rolling average.

Met Mast	Coefficient of Determination (r^2)		
	Wind Speed	Wind Direction	Temperature
0092	0.97	0.95	0.98

Table 18: Coefficients of determination for correlations between Met Mast 0091 and Met Mast 0092

The period of record, data validity, and hub-height wind speed for each of the filled and extended data sets are presented in Table 19.

Met Mast	Start Date	End Date	Wind Speed at Hub Height (m/s)	Data Validity (%)
0091	03-Oct-2009	25-Jan-2015	6.54	92.8
0092	03-Oct-2009	22-Feb-2015	6.59	93.6

Table 19: Statistics for Filled and Extended On-site Data Sets

6.2 Evaluation of Reference Stations

Environment Canada has a number of monitoring stations located near the project lands that could be selected as the long-term reference station. Also, MERRA reanalysis data has been considered as a long-term reference dataset. A summary of the characteristics of potential reference stations and their data is shown in Table 20.

Reference Station	Start Date	End Date	Distance to Project (km)	Annual Wind Speed (m/s)	Validity (%)	Height (m)
GRANBY	07-Oct-2003	19-Feb-2015	67.8	2.35	67.5	10
LAC ST PIERRE	01-Jan-1999	19-Feb-2015	23.8	6.08	92.3	10
MONTREAL INTL A	01-Jan-1994	19-Feb-2015	84.3	4.81	99.3	10
MONTREAL PIERRE ELLIOT TRUDEAU INTL A	01-Jan-1994	14-Feb-2013	85.1	4.75	99.5	10
MONTREAL ST HUBERT	10-Dec-2009	19-Feb-2015	62.8	5.18	93.6	10
NICOLET	01-Jan-1994	19-Feb-2015	36.7	3.58	96.4	10
SHAWINIGAN	25-Jan-1999	19-Feb-2015	68.2	3.10	89.2	10
TROIS RIVIERES	01-Feb-1994	19-Feb-2015	54.9	4.13	94.6	10
VARENNES	16-Aug-1994	19-Feb-2015	44.0	4.27	96.9	10
L'ASSOMPTION	07-Sep-1994	22-Feb-2015	43.0	3.22	96.7	10
MERRA[3]	01-Jan-2000	31-Jan-2015	21.6	6.06	100	50

Table 20: Details of Nearby Reference Stations

The suitability of these monitoring stations for use as references is determined by three factors:

1. The validity of their measured data
2. The strength of the correlation between their measured data and the data measured on site
3. The absence of trends in the data set

The wind speed and wind direction data sets were correlated using a non-linear process as described in Appendix E.

Linear correlations between 0091 and the potential reference sites were calculated for the daily rolling average wind speed and direction to provide an indicator of the strength of relationship. The respective coefficients of determination are shown in Table 21.

[3] The GEOS-5 data used in this study/project have been provided by the Global Modeling and Assimilation Office (GMAO) at NASA Goddard Space Flight Center through the online data portal in the NASA Center for Climate Simulation"

Reference Station	Coefficient of Determination (r^2)	
	Wind Speed	Wind Direction
GRANBY	0.06	0.30
LAC ST PIERRE	0.73	0.78
MONTREAL INTL A	0.72	0.79
MONTREAL PIERRE ELLIOT TRUDEAU INTL A	0.70	0.80
MONTREAL ST HUBERT	0.73	0.90
NICOLET	0.66	0.87
SHAWINIGAN	0.38	0.76
TROIS RIVIERES	0.63	0.77
VARENNES	0.75	0.91
L'ASSOMPTION	0.78	0.90
MERRA	0.75	0.72

Table 21: Coefficient of Determination (r^2) Between Met Mast 0091 and Reference Stations

It is important that any trends in reference stations are identified to avoid bias in the long-term prediction process.

All of the above reference sites were evaluated as potential long-term reference datasets to be used to generate the long-term prediction. Measurements from every site were truncated to remove earlier periods of incompatibility between reference sites and suspected periods of possible inconsistencies in the data.

A plot of annual average wind speeds all of the reference stations is shown in Figure 10.

- GRANBY and SHAWINIGAN were eliminated as potential reference given the low coefficient of determination (r^2) with Met Mast 0091.
- L'ASSOMPTION was eliminated due to a downward trend appearing through the years.
- VARENNES was excluded due to an apparent configuration change in 2007. As illustrated in Figure 10, 2007 was an aberration in average annual wind speeds. Figure 11 and Figure 12 show a comparison of the VARENNES and MERRA data. The differences in wind direction and wind speed values before 2007 vary substantially from year to year, and then become consistent after 2007. In addition, there was a step change in wind speeds before and after 2007 that is not present in any other reference station: 2006 was the lowest on record in VARENNES and 2007 was one of the highest which disagrees with all other available reference stations.

- LACSTPIERRE and MERRA provided the best fit when comparing predicted and measured data for the synchronized period of records. LACSTPIERRE data had a gap of 4 months during the winter 2008-2009 which matches with a step in the measured wind speed and a possible change in instrumentation. MERRA was therefore selected as the reference station.

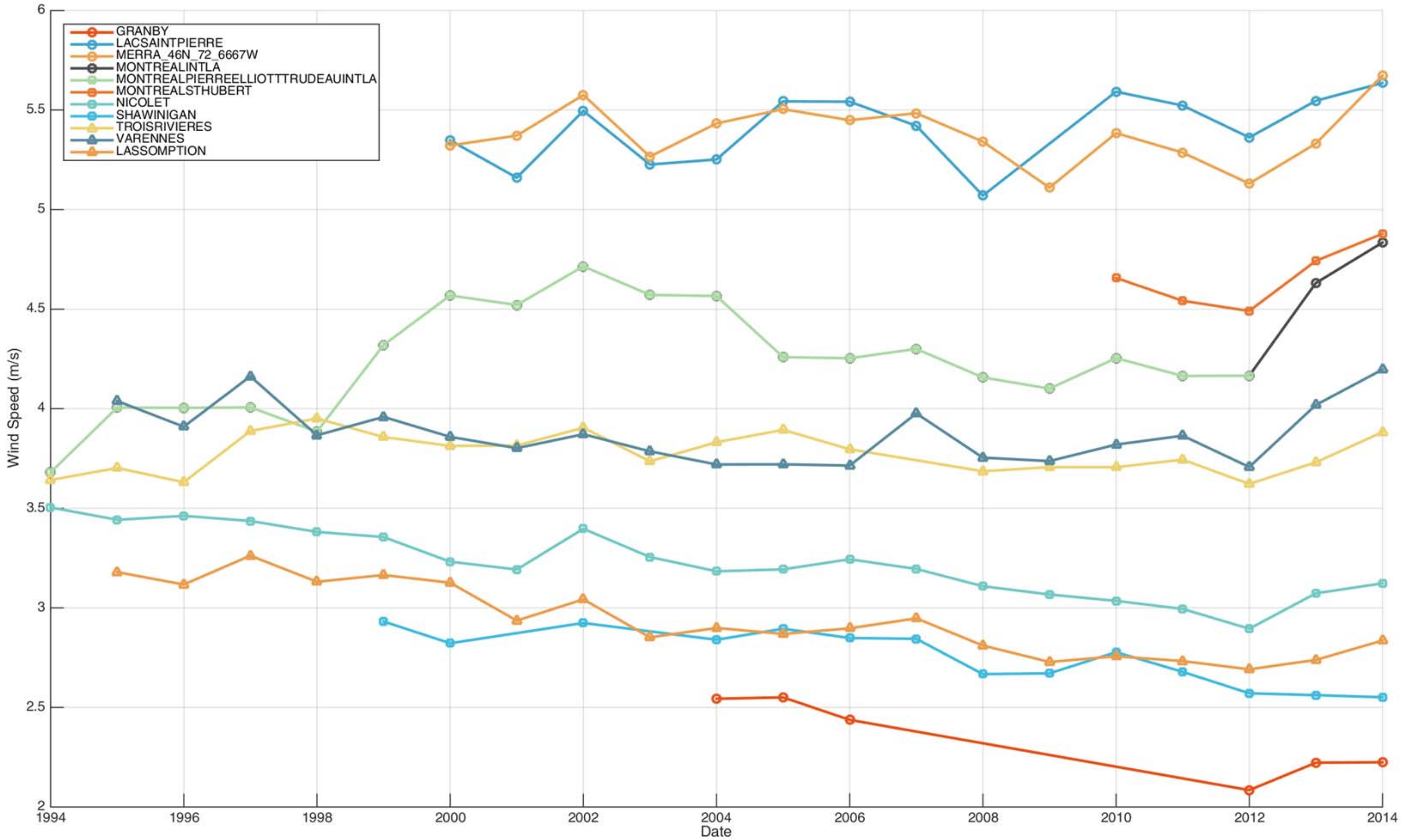


Figure 10: Annual Average Wind Speeds Measured at the Potential Reference Stations

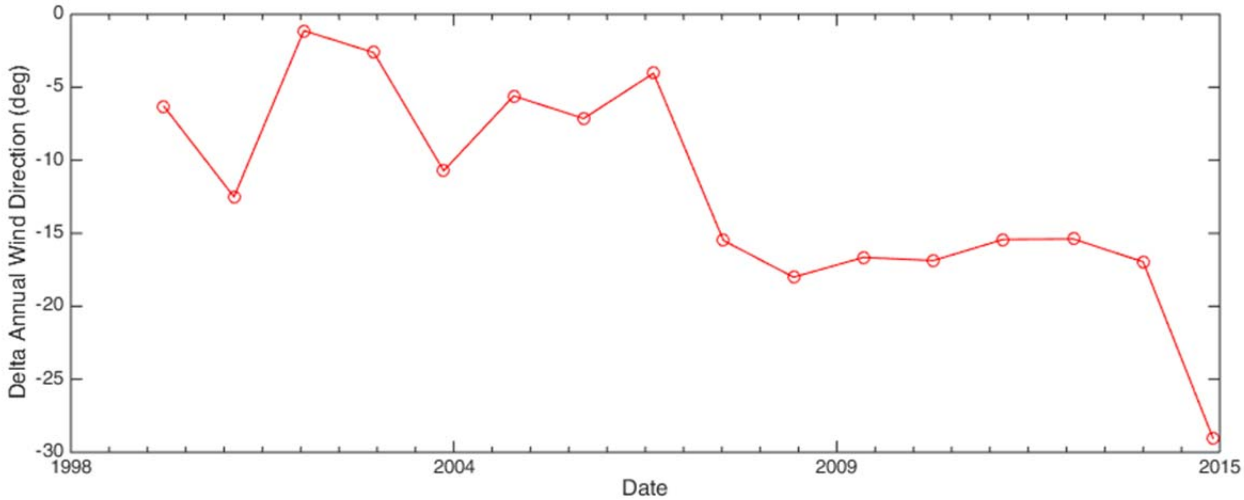


Figure 11: Comparison between MERRA and VARENNES Reference Stations annual wind directions

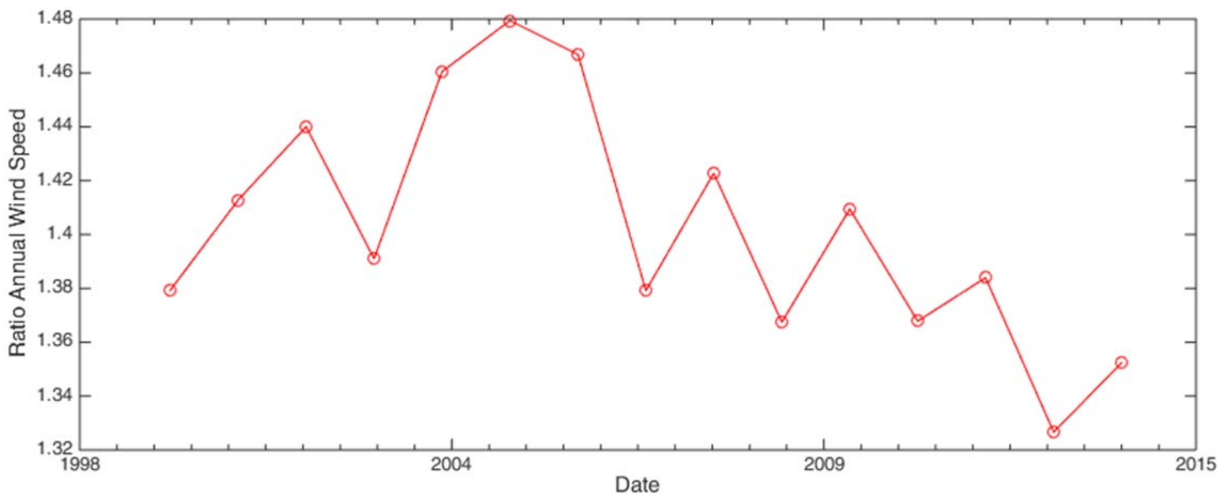


Figure 12: Comparison between MERRA and VARENNES Reference Stations annual wind speeds

6.3 Generation and Validation of Long-Term Predictions

After the filling and extension process, the data sets collected on site were correlated to the reference station to generate a predicted data sets representative of the on-site locations for the long-term period. The results of the prediction process are summarized in Table 22.

Period	Data Set	0091	0092
Short-Term	Hub Height Wind Speeds	6.55	6.75
Long-Term	Hub Height Synthesized Predicted	6.51	6.55

Table 22: Wind Speeds (m/s) for the Met Mast Locations at Hub Height

Relative to the measured period of record, the long-term prediction process resulted in a 0.7% decrease (from 6.55 m/s to 6.51 m/s) for met mast 0091, and a 3.0% decrease (from 6.75 m/s to 6.55 m/s) for met mast 0092..

The synchronized predicted and measured data sets were compared to validate the accuracy of the prediction and demonstrate that, when applied to the turbine power curve, the energy content of the two data sets is consistent.

The synchronized period is determined by the records that intersect between the reference and measured data sets.

Gross capacity factors were calculated at each met mast location using the synchronized measured and predicted wind speed data sets and the power curve described in Section 9.

Period	Data Set	0091	0092
Synchronized Short-Term	Measurements	6.54	6.59
	Synthesized Prediction	6.54	6.59
Long-Term	Synthesized Predicted	6.51	6.55

Table 23: Gross Capacity Factors (%) for the Met Mast Locations at Hub Height

For the synchronized period, the average gross capacity factors calculated from predicted and measured data sets differ by 0.3%. The yield correction factor, described in Equation 1, was used to correct the average yield at each turbine, as calculated in Section 9.

$$Yield\ correction\ factor = \frac{Mean\ gross\ capacity\ factor\ from\ \ synchronized\ measured\ data}{Mean\ gross\ capacity\ factor\ from\ \ synchronized\ predicted\ data}$$

Equation 1: Yield correction factor

Figure 13 shows a comparison of monthly average capacity factors of measured and predicted datasets for Met Mast 0091. The capacity factors were calculated using the power curve shown in Section 9. These figures show that the predicted values follow the pattern of the on-site measured data set. Moreover, the difference in measured and predicted values does not show any consistent seasonal bias.

For demonstration purposes, this validation is presented for Met Mast 0091. All on-site met masts were equivalently validated.

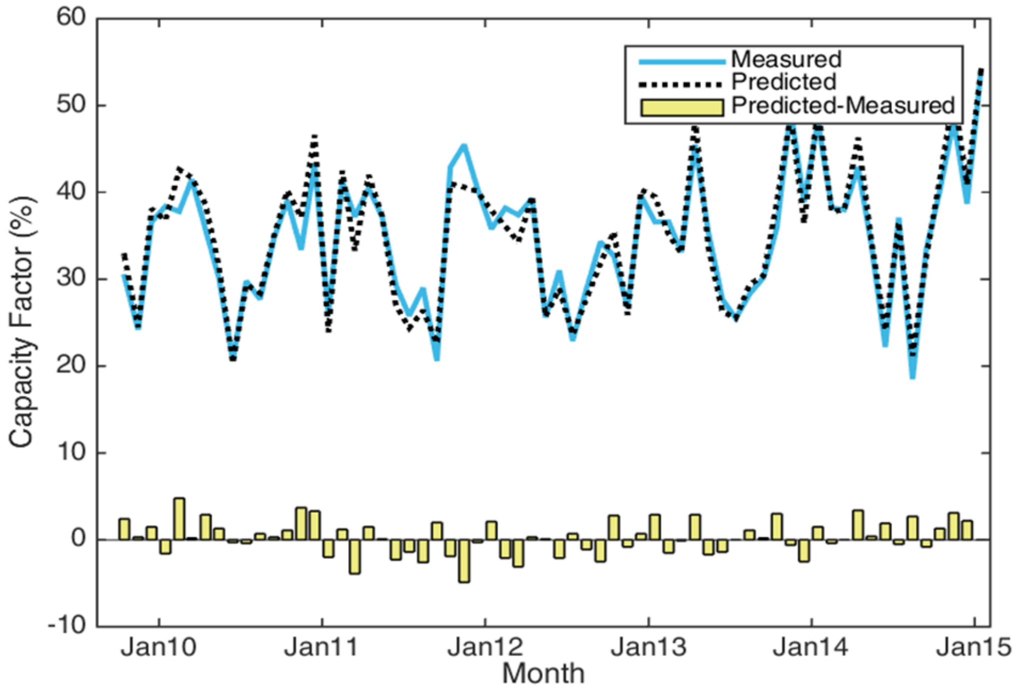


Figure 13: Comparison of Monthly Measured and Predicted Capacity Factors for Met Mast 0091 at Hub Height

The distribution of 4-day capacity factor errors is shown in Figure 14. The mean of the capacity factor errors is 0.27% absolute, which demonstrates that the overall bias in the prediction is small and that the predicted data set is representative of the measured data.

The standard deviation of these errors is 6.0% absolute, which is used in the cross-validation process described in Section 11 for empirically quantifying the correlation uncertainty.

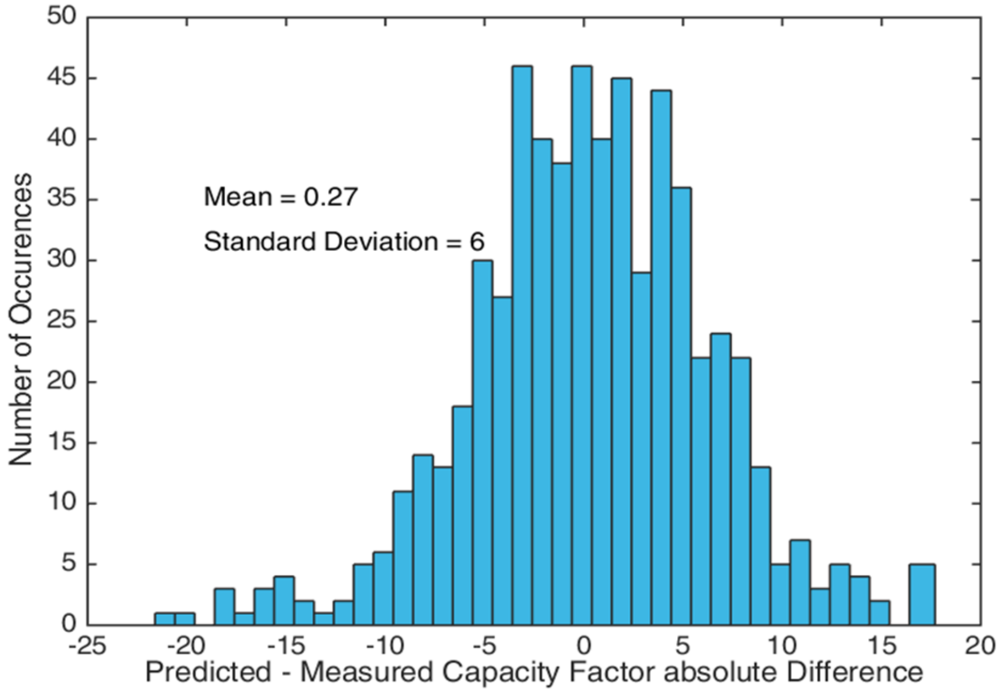


Figure 14: Distribution of 4-day Average Capacity Factor Prediction Errors during the Synchronized Period of Record

Figure 15 shows the wind speed distributions of the measured and predicted data sets.

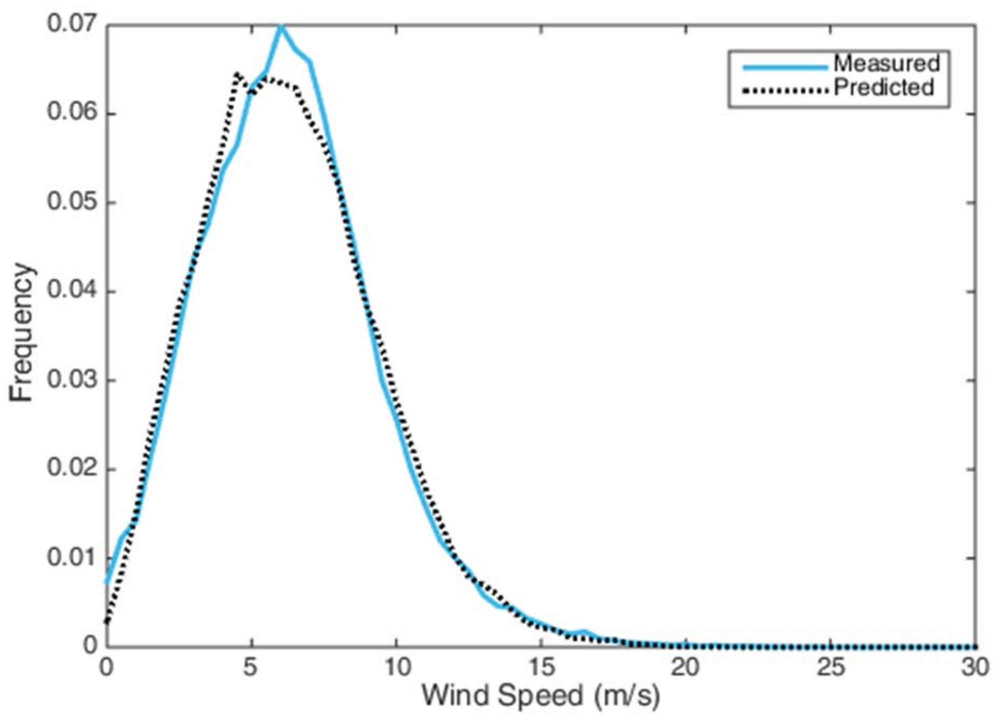


Figure 15: Comparison of Measured and Predicted Wind Speed Distributions

6.4 Long-Term Temperature and Air Density

A linear regression between the on-site measurement at Met Mast 0092 and the long-term reference L'ASSOMPTION was calculated for temperature (T) and pressure (P) measurements using Equation 2 and Equation 3. The correlation coefficients were then applied to the long-term reference data to predict long-term temperature and pressure data sets for the on-site towers.

$$T_{on-site} = 0.95 \cdot T_{reference} + 0.2$$

Equation 2: Temperature regression equation

$$P_{on-site} = 0.92 \cdot P_{reference} + 7.6$$

Equation 3: Pressure regression equation

Air density was then calculated for the site using the predicted long-term temperature and pressure based on the ideal gas law. The air density was calculated at Met Mast 0092 since it was the only tower with pressure measurements.

Table 24 shows the outcome of these calculations. The effects of hysteresis and wind speed distribution during times of extreme temperature are considered in the loss calculations in Section 10.

Mean Temperature (°C)	6.29
First Percentile Temperature (°C)	-21.07
99th Percentile Temperature (°C)	27.47
Percent of time below low-temperature cut-out (-30°C)	0
Percent of time above high-temperature cut-out (40°C)	0
Hub height average air density at Met Mast 0092 (kg/m^3)	1.246

Table 24: Long-Term Temperature Statistics at Met Mast 0092

7 Wind Flow Modeling

7.1 Model and Model Inputs

Modeled wind speeds were applied to the turbine power curve to generate gross yield estimates as discussed further in Section 9.

The WAsP wind flow model was used to extrapolate wind speeds at the met mast locations across project lands and at turbine locations. Inputs for the wind flow model include 16.5 m elevation grid derived from the CDED[4] digital elevation model, roughness features derived from the CanVec Feature Catalogue[5], obstacles derived from satellite imagery available on Google Earth as shown in Appendix A, and the predicted dataset for Met Mast 0091. It was decided not use the predicted dataset for Met Mast 0092 due to the short period of record and the uncertainty linked to the icing events during that period and described in Section 3. Moreover, given the size of the project area and the similar environment in which met Mast 0091 and the turbines are located, Met Mast 0091 is deemed sufficiently representative of the wind flow conditions at the turbine locations. Each type of feature was assigned a roughness length, as shown in Table 25.

Feature	Roughness Length (m)
Cleared areas (farm land)	0.1
Vegetation	0.5
Built areas (along rural roads)	0.3
Water bodies	0.001

Table 25: Roughness lengths

7.2 Validation

Modeling validation results are used as inputs for the modeling uncertainty assumptions described in Section 11.

As explained previously, only Met Mast 0091 was used to seed the wind flow model. Therefore the model yields estimates for Met Mast 0091 and 0092 cannot be validated. Nevertheless, the generated wind flow provides a reading for the hub height wind speed at Met Mast 0092 at 6.55 m/s, which indicates that the model captures adequately of the wind flow conditions at Met Mast 0092, where the long-term predicted wind speed at hub height was calculated to be 6.55 m/s in Section 6.

[4] GeoBase, Canadian Digital Elevation Data, Natural Resources Canada, Government of Canada, accessed February 2015.
[5] CanVec, Natural Resources Canada, Government of Canada, accessed February 2015.

8 Turbine Layout

The turbine layout is configured for the turbine model[6] shown in Table 26.

Manufacturer	Senvion
Model	MM92 CCV
Rotor diameter (m)	92.5
Hub height (m)	100
Rated capacity of each turbine (kW)	2050
Number of turbines	12

Table 26: Turbine Model Information

The coordinates of each turbine location can be found in Appendix H.

The project layout was provided by Parc Éolien Pierre-De Saurel SEC[7]. WSP has not evaluated the optimization of the layout, turbine spacing, validity of the project lands, sound level restrictions, topography, and general setbacks from roads, residences, water bodies, etc. with respect to the layout as part of the scope of this project.

Figure 1 shows a map of the turbine layout.

[6] Doc.-ID: PD-2.12-WT.WT.01-A-F-EN, Senvion 2014
[7] 063-P-0002046-5500-CI-D-0001-S00[1].pdf, Parc éolien Pierre-de-Saurel S.E.C., 2015

9 Gross Yield Calculation

Long-term gross yields were estimated for the turbine layout described in Section 6, using the wind flow model described in Section 7 and the power curve[8] shown in Table 27. The site average air density was adjusted at each turbine location using standardized adjustment[9] to consider the location-specific elevation.

The turbine-specific yield estimates are tabulated in Appendix H.

Wind Speed (m/s)	Power (kW)	Thrust Coefficient
3	20.0	0.98
4	94.0	0.87
5	205.0	0.79
6	391.0	0.79
7	645.0	0.79
8	979.0	0.79
9	1375.0	0.74
10	1795.0	0.69
11	2000.0	0.54
12	2040.0	0.39
13	2050.0	0.29
14	2050.0	0.23
15	2050.0	0.19
16	2050.0	0.15
17	2050.0	0.13
18	2050.0	0.11
19	2050.0	0.09
20	2050.0	0.08
21	2050.0	0.07
22	2050.0	0.06
23	2050.0	0.06
24	2050.0	0.05

Table 27: Power curve used in the analysis

[8] Extracted from report 800437-CAMO-R-01 provided by Parc éolien Pierre de Saurel S.E.C.
[9] EMD International: Modelling of the Variation of Air Density with Altitude through Pressure, Humidity and Temperature, 2005.

Wind flow models typically give the most accurate results when the seed met masts are within reasonable proximity of the turbine locations and are located in representative terrain. Met Mast 0091 is well representative of the overall site terrain conditions and elevation. Based on the site survey[10], the lowest wind turbine is located at 18 m elevation, the highest wind turbine is located at 22 m while Met Mast 0091 is located at about 20 m.

The gross energy yield estimated for the project is estimated at 74.36 GWh/yr.

[10] Extracted from drawing 063-P-0002046-6000-SR-D-0001-S01.pdf provided by Parc éolien Pierre de Saurel S.E.C.

10 Losses

10.1 Loss Definitions

Details of the losses, including parameters for each beta-PERT distribution, are provided in Appendix F.

The loss definitions used in the analysis are based on industry-standard categories[11] and assigned as beta-PERT distributions specified according to minimum, most-likely, and maximum values. The beta-PERT distribution allows for either symmetrical or skewed probability about the mean loss value. This characterization is helpful for situations where there is greater downside potential than upside potential relative to the most likely value. This is applicable to loss categories such as turbine availability. As discussed further in Section 11, individual loss categories are also assigned an annual variability component to account for changing operational or environmental conditions over time.

10.2 Wake Losses

The turbine-specific wake loss estimates are tabulated in Appendix H.

Wake losses have been calculated in WindPRO using the N.O. Jensen model[12] with the wake decay constant adjusted according to site-specific turbulence. The individual turbine wakes are combined using the root-sum-square combination method.

10.3 Icing Losses

Two predominant icing mechanisms have been identified by current research: in-cloud icing which occurs due to super-cooled droplets in low level clouds and freezing precipitation icing which is a result of rain drops in below zero temperatures[13]. Freezing precipitation and in-cloud icing result in the formation of rime or glaze ice. The temperature and size of the droplets as well as the rate at which they strike a surface governs the form of the ice. Glaze icing is predominantly the result of freezing precipitation. Rime icing occurs when structures are exposed to cold fogs or clouds[14].

Sophisticated models such as TURBICE, LEWICE, and CANICE estimate ice accretion based on a number of input parameters such as spectrum of particle size, mass of particles and their thermodynamic state, and a description of the airflow. However, according to Laakso et al.[15], “in general, due to its complexity

[11] Jones, Stephen, Standard Loss Definitions for Wind Resource/Energy Assessment, American Wind Energy Association WINDPOWER Conference, Houston Texas, June 2008.

12 I. Katic, J. Højstrup, N.O.Jensen, A simple model for cluster efficiency, European wind energy association conference and exhibition, 1986.

[13] Marjaniemi, M., Laakso, T., Makkonen, L., Wright, J., 2001. Results of Pori Wind Farm Measurements. (VTT Energy Reports 42/2001). Finland: VTT Energy, Energy Systems.

[14] Koleychuk, R., Silis, A., 1987. Preliminary Investigation of the Potential Effects of Icing on Wind Energy System Performance. (DSS File No. 54SZ-23216-6-6119) Ottawa: Energy, Mines and Resources Canada.

[15] Laakso, T., Holttinen, H., Ronsten, G., Tallhaug, L., Horbaty, R., Baring-Gould, I., Lacroix, A., Peltola, E., Tammelin, B., April, 2003. State-of-the-art of wind energy in cold climates. International Energy Agency, IEA R&D.

and the many process parameters a physical icing model that would apply to all icing processes still needs to be developed.”

For the purpose of identifying periods of potential glaze or rime icing, a number of indicators may be used. In ice loading estimation performed by Sundin et al.[16] meteorological parameters were used to estimate ice accretion. Specifically, glaze icing conditions are identified by the occurrence of freezing rain or freezing drizzle or the combination of rain or drizzle that occurs while the dew point temperature is below 0ºC. The second set of icing criteria identifies conditions for rime icing: where the cloud height is lower than the height of interest and the temperature is between –15ºC and 0ºC.

Icing losses are manifested through a combination of turbine shutdown and blade aerodynamic inefficiencies.

Icing losses near the site have been evaluated by WSP and the percentage of time in a year where the conditions are favorable for icing. Icing was calculated using the Canadian Weather Energy and Engineering Dataset (CWEEDS) for the St-Hubert Airport site between 1953 to 2005[17]. The CWEEDS data was used to calculate the frequency of rime and clear icing, corrected for the difference in elevation at the reference station and hub height. The total icing loss based on CWEEDS was then compared to the icing frequency detected at Met Mast 0091 from the quality control to confirm the seasonal profile. Based on an empirical fit of icing frequency to production loss[18], the production loss due to icing was calculated to be 1.5% of total production for the standard turbine model. Icing losses are adjusted based upon specifications of the turbine technology selected.

[16] Sundin, E., Makkonen, L., 1997. Ice Loads on a Lattice Tower Estimated by Weather Station Data (Journal of Applied Meteorology 37/1998) American Meteorology Society.

[17] Environment Canada, ‘http://climate.weather.gc.ca/prods_servs/engineering_e.html

[18] Barry Turner, Jean-Marie Heurtebize, ”Linking Icing Estimates to Operational Losses” CanWEA 2013

Category	Subcategory	Assumption	Mean Loss
Availability	Turbine (guaranteed)	Warranted availability based on 10-year production period (time based). An increase in O&M budgets is recommended after 10 years.	3.0%
	Turbine (other)	Items excluded from warranted availability (maintenance factors, manual stops, turbine de-rating, production based losses)	1.9%
	Balance of plant	Values assumed based on typical facility outages	0.3%
	Grid	Values assumed based on typical grid outages	0.3%
	Other		0.0%
	Subtotal		5.3%
Wake Effects	Internal wake effects	Wake effects within the facility	5.5%
	External wake effects	Not applicable: there are no wind facilities within 20 km of any turbine	0.0%
	Future wake effects	Estimated based on planned project expansion.	0.0%
	Subtotal		5.5%
Turbine Performance	Power curve	Power curve underperformance based upon historical experience of the turbine model	1.5%
	High wind hysteresis	Calculated from measured wind data, based upon the frequency of wind speeds above the turbine recut-in threshold proceeding a high wind event (> cut-out)	0.0%
	Wind flow	Power curve losses based on mismatches between the warranted operational envelope of the turbine and the expected wind flow conditions	0.4%
	Other		0.0%
	Subtotal		1.9%

Category	Subcategory	Assumption	Mean Loss
Electrical	Electrical losses	Based on targeted electrical loss calculations provided by Parc Éolien Pierre-de-Saurel S.E.C.	2.0%
	Facility consumption	Estimated based on site conditions.	0.3%
	Subtotal		2.3%
Environmental	Performance degradation not due to icing	Based on standard blade cleaning and maintenance routine	2.0%
	Performance degradation due to icing	Based upon icing rates quantified from automated WindServer algorithms and a detailed assessment of icing frequency based upon CWEEDS and applicable reference data	0.8%
	Shutdown due to icing, lightning, hail, etc.	Based upon icing rates quantified from automated WindServer algorithms and a detailed assessment of icing frequency based upon CWEEDS and applicable reference data	0.7%
	High and low temperature	Calculated from on-site temperature statistics and the operational envelope of the turbine technology.	0.1%
	Site access and other force majeure events	Site access is good with few access issues.	0.2%
	Tree growth or felling	Not applicable	0.0%
	Subtotal		3.8%
Curtailment	Wind sector management	Not applicable	0.0%
	Grid curtailment and ramp-rate	Not applicable	0.0%
	Power purchase agreement curtailment	Not applicable	0.0%

Category	Subcategory	Assumption	Mean Loss
	Environmental (noise, visual, bird/bat)	Not applicable	0.0%
	Subtotal		0.0%
Other	Other	Not applicable	0.0%
	Subtotal		0.0%
Total			17.5%

Table 28: Project losses

11 Uncertainty and Confidence Intervals

Uncertainty definitions are based on industry-standard categories [19] and assigned as either normal or beta-PERT distributions. A Monte Carlo simulation was performed in order to evaluate the propagation of uncertainty and determine confidence levels for both the net and gross energy production. This stochastic simulation was performed using 1,000,000 iterations of the model.

Table 29 provides a description of all uncertainty categories, the standard uncertainty values in units of m/s where applicable, and percent energy. Wind speed uncertainties are converted to percent production by applying them to the turbine power curve. In a sensitivity test, it was found that a decrease in average wind speed by 1% corresponded to a 2.07% reduction in yield. The contribution of each uncertainty category is summarized in Figure 16.

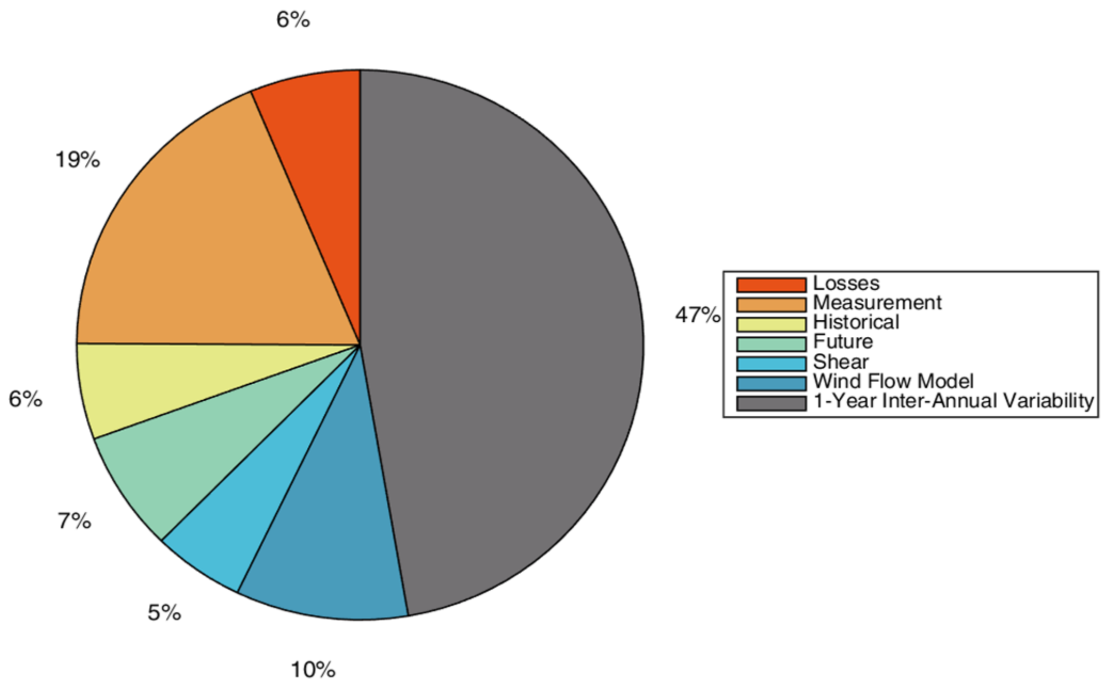


Figure 16: Uncertainty Contributions for the 1-Year Return Period

[19] Framework for the Categorisation of Losses and Uncertainty for Wind Energy Assessments, February 5, 2013

Category	Sub Category	Assumption	Uncertainty (% of Wind Speed)	Uncertainty (% of Production)
Measurement Uncertainty	Anemometer Accuracy	Wind speed measurement uncertainty associated with certified anemometer classification (Class 2.4A accuracy of the NRG Max #40C anemometer).	2.4%	3.96%
	Calibration	Wind tunnel and anemometer calibration uncertainty from the calibration certificate.	0.70%	1.46%
	Measurement Interference	Tilted anemometers, mast flow distortion, mounting effects.	0.2%	0.41%
	Data Quality and Metadata	Periods of missing or poor data/metadata quality that may results in potential overestimation of under-estimation of wind speeds.	1.76%	3.65%
Historic Climate	Long-Term Representativeness	There is uncertainty associated with the assumption that the historical period is representative of the long-term. The value assigned considers both the calculated annual variability of the long-term prediction as well as regional studies of a large number of reference stations. The assigned uncertainty assumes a Gaussian distribution and considers the length of the predicted historical period of record.	1.0%	2.14%
	Wind Speed Distribution	For a given average wind speed, the energy density depends on the shape of the wind speed distribution. There is uncertainty in the representativeness of the predicted dataset distribution relative to the long-term.	0.26%	0.50%
	Reference Site	Uncertainty associated with the data quality and consistency of instrumentation at the reference station.	0.78%	1.65%
	On-site data synthesis	A cross-validation process was used to empirically quantify the uncertainty in long-term prediction. The on-site measured dataset was broken into six data sets and five of the datasets were used to predict the sixth in a round-robin fashion. By comparing to the original measured data, a distribution of daily prediction error was generated for the period of record to calculate the uncertainty of the prediction.	0.68%	1.41%

Future Variability	Inter-annual Variability of Wind Speed	Future variability is based upon the inter-annual variability defined in the Historic Climate category. The magnitude of this variability is dependent upon the length of the averaging period. Therefore, this uncertainty was assessed for the 1-, 10-, and 20-year periods. The 1-year inter-annual variability is presented.	4.00%	8.29%
	Inter-annual Variability of Wind Speed Distribution	Future variability in the wind speed distribution is based upon the wind speed distribution uncertainty defined in the Historic Climate category. The magnitude of this variability is dependent upon the length of the averaging period. Therefore, this uncertainty was assessed for the 1-, 10-, and 20-year periods. The 1-year inter-annual variability is presented.	0.52%	2.1%
	Climate Change	Changes in climate patterns in the long- and medium-term.	1.25%	2.6%
Vertical Shear Extrapolation	Extrapolation to hub height	A sensitivity test has been performed using a shear exponent evaluated at 2/3 of the assigned values for the on-site meteorological towers.	1.44%	2.98%
Spatial Variation	Model Inputs	Quality of terrain and land cover data, and uncertainty associated with changes in the roughness over time (forest growth or deforestation)	0.24%	0.50%
	Horizontal Extrapolation	Representativeness of meteorological masts relative to the turbine locations (elevation, roughness, exposure). Uncertainty of the accuracy of the model to represent wind flow over project terrain (considering terrain complexity and complex wind flow conditions).	1.93%	4.0%
	Other	Model Bias, model quality and error, complexity of terrain and quality of Weibull fit used in the model.	0.24%	0.5%
Plant Performance And Losses	Distribution of Losses	Beta-PERT parameters and standard uncertainties defined in Appendix G.	1.64%	3.41%
	Inter-annual Variability of Losses	Variability of losses from year to year (Availability, Icing, Balance of Plant)	1.06%	2.19%

Table 29: Descriptions and the assigned magnitude of uncertainty categories

Table 30 shows the standard uncertainty for various return periods. Standard uncertainty is equal to one standard deviation of the uncertainty distribution.

Return Period	Standard Uncertainty (%)
1 Year	12.8
10 Years	9.7
20 Years	9.5

Table 30: Standard Uncertainties for Various Return Periods

Table 31 shows the Net Yield and Capacity Factor for the 12 turbines Senvion MM92 layout.

Net Yield (GWh/year)	Confidence level (%)				
	50	75	90	95	99
1-Yr Average Production	61.3	56.0	51.2	48.4	43.2
10-Yr Average Production	61.3	57.3	53.6	51.5	47.5
20-Yr Average Production	61.3	57.3	53.8	51.7	47.8
Net Capacity Factor	Confidence level (%)				
	50	75	90	95	99
1-Yr Average Production	28.4%	26.0%	23.8%	22.5%	20.0%
10-Yr Average Production	28.4%	26.5%	24.9%	23.9%	22.0%
20-Yr Average Production	28.4%	26.6%	24.9%	24.0%	22.2%

Table 31: Production Probabilities of Exceedance

12 Wind Resource Temporal Profiling

WSP has generated a matrix of month by hour (12 x 24) P50 Net yields for the project. This is based on the measured on-site data and scaled to reflect the long-term expected annual average yield of the project. A record-by-record air density correction is made using the air density dependent power curves. Air pressure data is interpolated from the L'ASSOMPTION reference station. Shear is applied on seasonal, diurnal and directional basis to capture these dependencies. Table 32 shows the matrix for both Net Capacity factors and Net Yields.

Hourly Capacity Factor (%) as a Function of Month: Inclusive of All Losses

Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Monthly Average
1	33.6	32.0	33.1	32.4	32.9	32.8	32.0	31.8	32.0	28.5	27.5	26.5	26.4	26.8	26.6	29.1	29.1	32.5	33.8	34.1	34.7	36.9	36.0	33.9	31.5
2	31.6	32.4	33.2	33.1	33.7	33.7	33.4	32.5	31.3	27.6	26.2	26.6	28.4	30.8	32.1	33.8	33.6	35.2	34.4	35.9	33.4	33.2	31.6	31.3	32.0
3	35.6	35.1	35.5	33.9	33.1	32.9	31.9	27.7	24.4	22.6	24.3	25.8	26.7	28.9	28.7	30.1	30.0	32.2	32.0	36.6	36.7	37.0	35.0	34.8	31.3
4	36.7	33.5	33.8	32.5	32.6	30.5	32.0	29.7	30.4	28.0	28.5	30.1	32.3	34.2	34.7	34.9	35.0	36.1	33.5	37.3	38.3	39.4	39.3	38.4	33.8
5	30.3	29.2	28.8	28.7	28.1	25.5	23.4	20.4	21.2	19.7	20.8	21.8	22.8	23.9	24.6	25.6	25.8	28.1	28.3	32.3	34.1	35.7	34.5	33.6	26.9
6	27.6	25.1	24.7	24.6	24.6	18.9	17.2	15.5	15.9	15.1	16.0	16.8	17.2	20.0	22.7	24.4	23.7	25.3	21.5	25.1	26.5	30.1	28.9	28.6	22.3
7	28.8	26.7	25.1	25.6	26.1	19.9	16.7	12.6	13.0	14.1	16.5	18.2	20.4	22.4	22.6	23.8	21.4	22.0	18.2	24.4	27.7	31.7	32.3	32.5	22.6
8	28.3	26.7	23.6	23.9	23.4	21.4	16.5	9.9	11.4	11.9	13.4	15.0	16.9	19.6	20.6	21.1	17.5	19.3	19.4	26.7	30.5	31.9	30.1	28.9	21.2
9	27.2	28.8	30.4	29.5	28.1	26.2	24.4	16.8	18.4	18.8	19.7	21.0	21.6	22.3	22.9	23.8	21.0	23.3	25.9	31.3	32.3	32.2	29.0	28.3	25.1
10	34.0	33.5	33.0	32.6	32.2	31.4	31.1	23.2	22.5	22.7	25.0	27.3	27.6	29.6	29.2	28.9	26.2	32.0	34.8	36.9	36.7	36.4	35.4	35.0	30.7
11	32.9	32.7	31.6	33.2	33.9	34.4	33.5	29.7	28.9	26.9	27.4	26.2	25.5	27.3	26.0	28.7	28.6	32.7	34.9	35.3	34.8	36.1	35.3	34.3	31.3
12	36.3	34.7	34.7	34.2	34.0	34.6	35.7	34.1	32.5	29.4	28.1	28.1	27.8	27.6	27.9	28.4	28.2	32.1	35.0	34.2	34.8	35.3	36.7	36.9	32.6
																								Yearly Average	28.4

Hourly Production (MWh) as a Function of Month: Inclusive of All Losses

Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Monthly Total $x10^3$
1	8.3	7.9	8.1	8.0	8.1	8.1	7.9	7.8	7.9	7.0	6.8	6.5	6.5	6.6	6.5	7.2	7.2	8.0	8.3	8.4	8.5	9.1	8.9	8.4	5.8
2	7.8	8.0	8.2	8.1	8.3	8.3	8.2	8.0	7.7	6.8	6.4	6.5	7.0	7.6	7.9	8.3	8.3	8.7	8.5	8.8	8.2	8.2	7.8	7.7	5.3
3	8.7	8.6	8.7	8.3	8.1	8.1	7.8	6.8	6.0	5.5	6.0	6.4	6.6	7.1	7.1	7.4	7.4	7.9	7.9	9.0	9.0	9.1	8.6	8.6	5.7
4	9.0	8.2	8.3	8.0	8.0	7.5	7.9	7.3	7.5	6.9	7.0	7.4	7.9	8.4	8.5	8.6	8.6	8.9	8.2	9.2	9.4	9.7	9.7	9.5	6.0
5	7.4	7.2	7.1	7.1	6.9	6.3	5.8	5.0	5.2	4.8	5.1	5.4	5.6	5.9	6.1	6.3	6.4	6.9	7.0	7.9	8.4	8.8	8.5	8.3	4.9
6	6.8	6.2	6.1	6.1	6.0	4.7	4.2	3.8	3.9	3.7	3.9	4.1	4.2	4.9	5.6	6.0	5.8	6.2	5.3	6.2	6.5	7.4	7.1	7.0	4.0
7	7.1	6.6	6.2	6.3	6.4	4.9	4.1	3.1	3.2	3.5	4.1	4.5	5.0	5.5	5.6	5.9	5.3	5.4	4.5	6.0	6.8	7.8	7.9	8.0	4.1
8	7.0	6.6	5.8	5.9	5.8	5.3	4.1	2.4	2.8	2.9	3.3	3.7	4.2	4.8	5.1	5.2	4.3	4.7	4.8	6.6	7.5	7.8	7.4	7.1	3.9
9	6.7	7.1	7.5	7.3	6.9	6.4	6.0	4.1	4.5	4.6	4.8	5.2	5.3	5.5	5.6	5.9	5.2	5.7	6.4	7.7	7.9	7.9	7.1	7.0	4.5
10	8.4	8.2	8.1	8.0	7.9	7.7	7.7	5.7	5.5	5.6	6.1	6.7	6.8	7.3	7.2	7.1	6.4	7.9	8.6	9.1	9.0	8.9	8.7	8.6	5.6
11	8.1	8.1	7.8	8.2	8.3	8.5	8.2	7.3	7.1	6.6	6.7	6.5	6.3	6.7	6.4	7.1	7.0	8.1	8.6	8.7	8.6	8.9	8.7	8.4	5.5
12	8.9	8.5	8.5	8.4	8.4	8.5	8.8	8.4	8.0	7.2	6.9	6.9	6.8	6.8	6.9	7.0	6.9	7.9	8.6	8.4	8.6	8.7	9.0	9.1	6.0
																								Yearly Average	61.3

Table 32: Wind Resource Temporal Profiling - Net P50 yields

Appendix A Site Pictures

Satellite image for Met Mast 0091 extracted from Google Earth Pro, Digital Globe

Met Mast 0091 site pictures extracted from report 800437-CAMO-R-01 provided by Parc éolien Pierre de Saurel S.E.C.

Appendix B Additional Tower Configuration Details & History

Site Configuration History

Pierre-De Saurel: QC - Yamaska 0091 60m (0091)

Municipality: Le Bas Richelieu
Province/State: Quebec
Country/Region: Canada
Land Type Description: Corn field
Key: TBD
Magnetic Declination: -15
Fenced: True
Site Number: 0091
Time Zone: Eastern

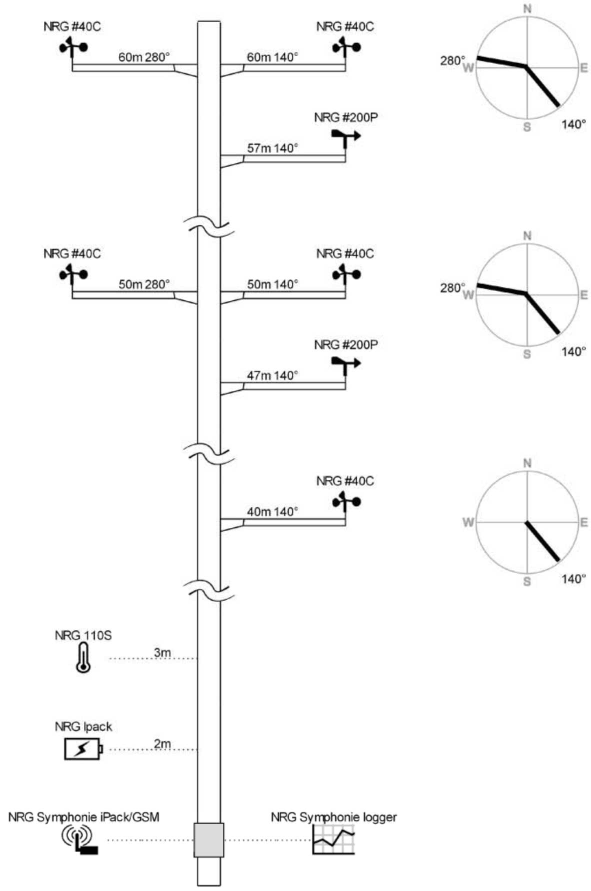
Installation date: 2009/08/31
Period of record: 2009/10/03-2015/01/25

UTM (NAD_83): Zone:18T E:659449 N:5093442
Latitude: 45.97602°
Longitude: -72.94167°
Elevation: 13m

Maintenance Timeline

2009/08/31: Site installed.

Configuration period: 2010/06/30 to Present (2015/02/26)



Layout is approximate, and may not be exactly as drawn.
Drawing is not to scale.
Boom directions are measured tower-to-tip in °True.

Tower

PE#	Model	Gin Pole Orientation	Lightning Protection	Anchors
50210	NRG 60m HD 10" - 8"	0		

Booms

PE#	Model	Length	Vertical	T-Boom	Mount Height	Dir (T)	Dir (M)	Post Height
50215	NRG 2.4m Boom (95")	2.4m	False	False	60m	140°	155°	0.4m
50214	NRG 2.4m Boom (95")	2.4m	False	False	60m	280°	295°	0.4m
50216	NRG 2.4m Boom (95")	2.4m	False	False	57m	140°	155°	0.4m

windserver | www.windserver.com QC - Yamaska 0091 60m (0091) | 2

50213	NRG 2.4m Boom (95")	2.4m	False	False	50m	140°	155°	0.4m
50212	NRG 2.4m Boom (95")	2.4m	False	False	50m	280°	295°	0.4m
50217	NRG 2.4m Boom (95")	2.4m	False	False	47m	140°	155°	0.4m
50211	NRG 2.4m Boom (95")	2.4m	False	False	40m	140°	155°	0.4m

Sensors

PE#	Model	S/N	Type	Height	Boom Dir (T)	Boom Len	Boom PE#	Dead-band
50222	NRG #40C Maximum Anemometer	179500114251	Anemometer	60m	140°	2.4m	50215	
50221	NRG #40C Maximum Anemometer	179500113896	Anemometer	60m	280°	2.4m	50214	
50223	NRG #200P Wind Vane 10K		Windvane	57m	140°	2.4m	50216	0°
50220	NRG #40C Maximum Anemometer	179500113864	Anemometer	50m	140°	2.4m	50213	
50219	NRG #40C Maximum Anemometer	179500113895	Anemometer	50m	280°	2.4m	50212	
50224	NRG #200P Wind Vane 10K		Windvane	47m	140°	2.4m	50217	0°
50218	NRG #40C Maximum Anemometer	179500113863	Anemometer	40m	140°	2.4m	50211	
50225	NRG 110S Temperature Sensor + Radiation Shield		Thermometer	3m				
50228	NRG Ipack Battery Voltage		Voltmeter	2m				

Cellular Modems

PE#	Model	S/N	ID Type	ID	Phone #/ IP Addr.	Network Type	Account Provider
50229	NRG Symphonie iPack/GSM	38604740	IMEI	137474			Unknown

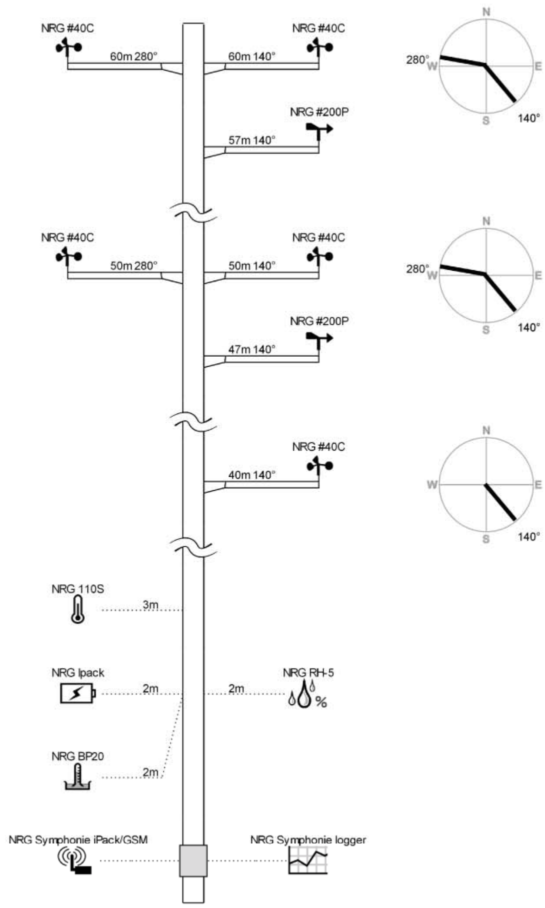
Loggers

PE#	Model	S/N	Channels Used
50231	NRG Symphonie logger	309015316	9

Logger Configuration (PE# 50231)

Ch	Model	S/N	PE#	Height	Boom Dir (T)	Boom Len	Dead-band	Logger Slope	Logger Offset	WS Slope	WS Offset	WindServer Data Set
C2	NRG #40C	179500113895	50219	50m	280°	2.4m		0.755	0.36	1	0	Ws 50m 280° 2.4m
C3	NRG #40C	179500113864	50220	50m	140°	2.4m		0.762	0.32	1	0	Ws 50m 140° 2.4m
C4	NRG #40C	179500113896	50221	60m	280°	2.4m		0.757	0.36	1	0	Ws 60m 280° 2.4m
C5	NRG #40C	179500114251	50222	60m	140°	2.4m		0.762	0.32	1	0	Ws 60m 140° 2.4m
C6	NRG #40C	179500113863	50218	40m	140°	2.4m		0.76	0.38	1	0	Ws 40m 140° 2.4m
C11	NRG Ipack		50228	2m				0.021	0	1	0	Bv 2m
A7	NRG #200P		50224	47m	140°	2.4m	0°	0.351	136	1	-194	Wd 47m 140° 2.4m
A8	NRG #200P		50223	57m	140°	2.4m	0°	0.351	136	1	-190	Wd 57m 140° 2.4m
A9	NRG 110S		50225	3m				0.136	-86.383	1	0	Te 3m

Configuration period: 2009/08/31 to 2010/06/30



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Tower

PE#	Model	Gin Pole Orientation	Lightning Protection	Anchors
50210	NRG 60m HD 10" - 8"	0		

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50213	NRG 2.4m Boom (95")	2.4m	False	False	50m	140°	155°	0.4m

50212	NRG 2.4m Boom (95")	2.4m	False	False	50m	280°	295°	0.4m
50217	NRG 2.4m Boom (95")	2.4m	False	False	47m	140°	155°	0.4m
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50221	NRG #40C Maximum Anemometer	179500113896	Anemometer	60m	280°	2.4m	50214	
50223	NRG #200P Wind Vane 10K		Windvane	57m	140°	2.4m	50216	0°
50220	NRG #40C Maximum Anemometer	179500113864	Anemometer	50m	140°	2.4m	50213	
50219	NRG #40C Maximum Anemometer	179500113895	Anemometer	50m	280°	2.4m	50212	
50224	NRG #200P Wind Vane 10K		Windvane	47m	140°	2.4m	50217	0°
50218	NRG #40C Maximum Anemometer	179500113863	Anemometer	40m	140°	2.4m	50211	
50225	NRG 110S Temperature Sensor + Radiation Shield		Thermometer	3m				
50228	NRG Ipack Battery Voltage		Voltmeter	2m				
50227	NRG RH-5 Humidity Sensor		Hygrometer	2m				
50226	NRG BP20 Barometric Pressure Sensor		Barometer	2m				

Cellular Modems

PE#	Model	S/N	ID Type	ID	Phone #/ IP Addr.	Network Type	Account Provider
50229	NRG Symphonie iPack/GSM	38604740	IMEI	137474			Unknown

Loggers

PE#	Model	S/N	Channels Used
50230	NRG Symphonie logger	30908623	9

Logger Configuration (PE# 50230)

Ch	Model	S/N	PE#	Height	Boom Dir (T)	Boom Len	Dead-band	Logger Slope	Logger Offset	WS Slope	WS Offset	WindServer Data Set
C1	NRG #40C	179500113863	50218	40m	140°	2.4m		0.76	0.38	1	0	Ws 40m 140° 2.4m
C2	NRG #40C	179500113895	50219	50m	280°	2.4m		0.755	0.36	1	0	Ws 50m 280° 2.4m
C3	NRG #40C	179500113864	50220	50m	140°	2.4m		0.762	0.32	1	0	Ws 50m 140° 2.4m
C4	NRG #40C	179500113896	50221	60m	280°	2.4m		0.757	0.36	1	0	Ws 60m 280° 2.4m
C5	NRG #40C	179500114251	50222	60m	140°	2.4m		0.762	0.32	1	0	Ws 60m 140° 2.4m
A7	NRG #200P		50223	57m	140°	2.4m	0°	0.351	0	1	-50	Wd 57m 140° 2.4m
A8	NRG #200P		50224	47m	140°	2.4m	0°	0.351	0	1	-50	Wd 47m 140° 2.4m
A9	NRG 110S		50225	3m				0.138	-86.383	1	0	Te 3m
A11	NRG Ipack		50228	2m				0.021	0	1	0	Bv 2m

- Highlighted rows and cells indicate items that have been added or changed from the previous period.
- Boom directions are measured tower-to-tip in °True.
- Wind vane deadband directions are measured clockwise relative to the boom heading.
- Configuration changes may take several days to complete. The period's start date indicates the date that changes began.

Site Configuration History

Pierre-De Saurel: QC - Yamaska 2-100m (0092)

Municipality: Yamaska
Province/State: Quebec
Country/Region: Canada
Land Type Description: Fields
Key:
Magnetic Declination: -15
Fenced: False
Site Number: 0092
Time Zone: Eastern

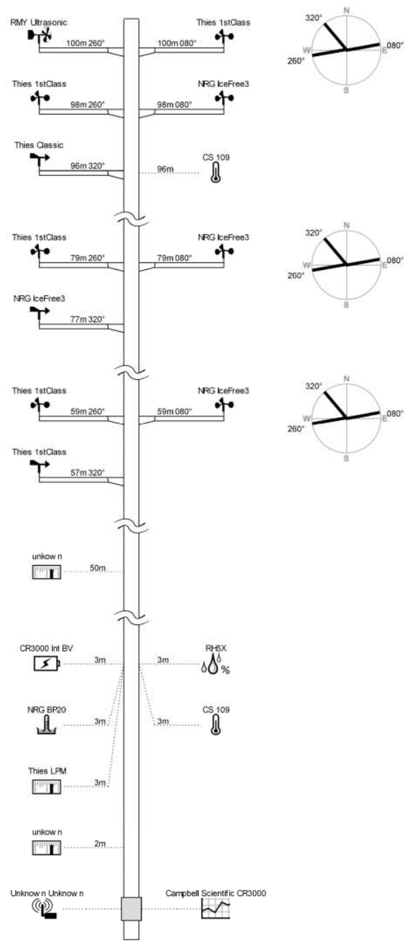
Installation date: 2014/12/13
Period of record: 2014/12/17-2015/02/19

UTM (NAD_83): Zone:18T E:661068.78 N:5094898.54
Latitude: 45.98873°
Longitude: -72.92028°
Elevation: 19m

Maintenance Timeline

2014/12/13: Site installed.

Configuration period: 2014/12/13 to Present (2015/02/25)



Layout is approximate, and may not be exactly as draw n.
Draw ing is not to scale.
Boom directions are measured tow er-to-tip in °True.

Tower

PE#	Model	Gin Pole Orientation	Lightning Protection	Anchors
50269	Veos #100-00122	0		

Booms

PE#	Model	Length	Vertical	T-Boom	Mount Height	Dir (T)	Dir (M)	Post Height
50271	Custom 3.66m Boom	3.7m	False	False	100m	080°	095°	0.5m
50270	Custom 3.66m Boom	3.7m	False	False	100m	260°	275°	0.5m
50280	Custom 3.66m Boom	3.7m	False	False	98m	080°	095°	0.5m

50272	Custom 3.66m Boom	3.7m	False	False	98m	260°	275°	0.5m
50273	Custom 3.66m Boom	3.7m	False	False	96m	320°	335°	0.5m
50275	Custom 3.66m Boom	3.7m	False	False	79m	080°	095°	0.5m
50274	Custom 3.66m Boom	3.7m	False	False	79m	260°	275°	0.5m
50276	Custom 3.66m Boom	3.7m	False	False	77m	320°	335°	0.5m
50278	Custom 3.66m Boom	3.7m	False	False	59m	080°	095°	0.5m
50277	Custom 3.66m Boom	3.7m	False	False	59m	260°	275°	0.5m
50279	Custom 3.66m Boom	3.7m	False	False	57m	320°	335°	0.5m

Sensors

PE#	Model	S/N	Type	Height	Boom Dir (T)	Boom Len	Boom PE#	Dead-band
50282	Thies First Class Anemometers	07141862	Anemometer	100m	080°	3.7m	50271	
50281	RM Young Ultrasonic	VC-1618	Vanemometer	100m	260°	3.7m	50270	0°
50284	NRG IceFree3 Anemometer	48457-3	Anemometer	98m	080°	3.7m	50280	
50283	Thies First Class Anemometers	07141864	Anemometer	98m	260°	3.7m	50272	
50293	Campbell Scientific 109 Temperature Probe		Thermometer	96m				
50285	Thies Classic Vanes	07140217	Windvane	96m	320°	3.7m	50273	0°
50287	NRG IceFree3 Anemometer	48458	Anemometer	79m	080°	3.7m	50275	
50286	Thies First Class Anemometers	07141863	Anemometer	79m	260°	3.7m	50274	
50288	NRG IceFree3 WindVane	32429	Windvane	77m	320°	3.7m	50276	0°
50290	NRG IceFree3 Anemometer	48459	Anemometer	59m	080°	3.7m	50278	
50289	Thies First Class Anemometers	07141861	Anemometer	59m	260°	3.7m	50277	
50291	Thies First Class Wind Vane	07140216	Windvane	57m	320°	3.7m	50279	0°
50297	unkown Lantern	MidLight	BaseType	50m				
50299	Campbell Scientific CR3000 Internal battery voltage sensor		Voltmeter	3m				
50296	NRG RH5X		Hygrometer	3m				
50295	NRG BP20 Barometric Pressure Sensor	180523186	Barometer	3m				
50294	Campbell Scientific 109 Temperature Probe		Thermometer	3m				
50292	Thies Laser Precipitation Monitor	0.7143099	BaseType	3m				
50298	unkown Lantern	Beacon	BaseType	2m				

Cellular Modems

PE#	Model	S/N	ID Type	ID	Phone #/ IP Addr.	Network Type	Account Provider
50300	Unknown Unknown						Unknown

Loggers

PE#	Model	S/N	Channels Used
50301	Campbell Scientific CR3000		20

Logger Configuration (PE# 50301)

Ch	Model	S/N	PE#	Height	Boom Dir (T)	Boom Len	Dead-band	Logger Slope	Logger Offset	WS Slope	WS Offset	WindServer Data Set
CH1	RMY Ultrasonic	VC-1618	50281	100m	260°	3.7m	0°	0.2	0	1	0	Ws 100m 260° 3.6576m
CH2	Thies 1stClass	07141862	50282	100m	080°	3.7m		0.0461	0.2352	0.99718 0043	0.021	Ws 100m 080° 3.6576m
CH3	Thies 1stClass	07141864	50283	98m	260°	3.7m		0.04606	0.2491	1	0	Ws 98m 260° 3.6576m
CH4	NRG IceFree3	48457-3	50284	98m	080°	3.7m		0.7635	0.35	0.76441 3883	0.6936	Ws 98m 080° 3.6576m
CH5	Thies Classic	07140217	50285	96m	320°	3.7m	0°	1	0	1	152	Wd 96m 320° 3.6576m
CH6	Thies 1stClass	07141863	50286	79m	260°	3.7m		0.04599	0.2496	1.00043 5066	-0.006	Ws 79m 260° 3.6576m
CH7	NRG IceFree3	48458	50287	79m	080°	3.7m		0.7635	0.35	0.75743 2875	0.7107	Ws 79m 080° 3.6576m
CH8	NRG IceFree3	32429	50288	77m	320°	3.7m	0°	1	0	1	144	Wd 77m 320° 3.6576m
CH9	Thies 1stClass	07141861	50289	59m	260°	3.7m		0.0461	0.2352	1.00239 1824	-0.015	Ws 59m 260° 3.6576m

CH10	NRG IceFree3	48459	50290	59m	080°	3.7m		0.7635	0.35	0.74918 1401	0.7378	Ws 59m 080° 3.6576m
CH11	Thies 1stClass	07140216	50291	57m	320°	3.7m	0°	1	0	1	143	Wd 57m 320° 3.6576m
CH12	Thies LPM	0.7143099	50292	3m				1	0	1	0	Pr 3m
CH13	CS 109		50293	96m				1	0	1	0	Te 96m
CH14	CS 109		50294	3m				1	0	1	0	Te 3m
CH15	NRG BP20	180523186	50295	3m				1	0	1	0	Bp 3m
CH16	RH5X		50296	3m				1	0	1	0	Rh 3m
CH17	unkown	MidLight	50297	50m				1	0	1	0	Un 50m
CH18	unkown	Beacon	50298	2m				1	0	1	0	Un 2m
CH19	CR3000 Int BV		50299	3m				1	0	1	0	Bv 3m
CH1A	RMY Ultrasonic	VC-1618	50281	100m	260°	3.7m	0°	1	0	1	81	Wd 100m 260° 3.6576m

- Highlighted rows and cells indicate items that have been added or changed from the previous period.
- Boom directions are measured tower-to-tip in °True.
- Wind vane deadband directions are measured clockwise relative to the boom heading.
- Configuration changes may take several days to complete. The period's start date indicates the date that changes began.

Appendix C Quality Control Summaries

Validity Summary

QC - Yamaska 0091 60m (0091), 2009/10/03 - 2015/02/22

Wind Speed	Valid (%)	Icing (%)	Flagged (%)	Filtered (%)	Missing (%)	Mean (m/s)	Std Dev (m/s)	Max Value (m/s)	Max Gust (m/s)
Ws 60m 140° 2.4m	92.56	4.54	2.20	0.00	0.70	5.62	2.69	25.63 (2012/01/18 02:50:00)	34.99 (2013/11/01 10:20:00)
Ws 60m 280° 2.4m	92.56	4.54	2.20	0.00	0.70	5.62	2.70	25.38 (2012/01/18 02:50:00)	34.80 (2013/11/01 10:20:00)
Ws 50m 140° 2.4m	92.48	4.54	2.20	0.08	0.70	5.40	2.60	25.00 (2012/01/18 02:50:00)	34.99 (2013/11/01 10:20:00)
Ws 50m 280° 2.4m	92.21	4.54	2.20	0.35	0.70	5.40	2.59	24.60 (2012/01/18 02:50:00)	34.71 (2013/11/01 10:20:00)
Ws 40m 140° 2.4m	83.86	4.30	10.85	0.29	0.70	5.07	2.53	24.00 (2012/01/18 02:50:00)	34.22 (2013/11/01 10:20:00)

Wind Direction	Valid (%)	Icing (%)	Flagged (%)	Filtered (%)	Missing (%)	Vector Average (°)	Average Standard Deviation (°)	Standard Deviation of Standard Deviation (°)
Wd 57m 140° 2.4m	92.56	4.54	2.20	0.01	0.70	253.40	7.28	6.84
Wd 47m 140° 2.4m	92.54	4.54	2.20	0.02	0.70	253.96	7.64	7.38

Other	Valid (%)	Flagged (%)	Filtered (%)	Missing (%)	Mean	Std Dev	Max	Min	Units
Temperature 3m	97.39	1.80	0.10	0.70	6.46	12.63	35.80	-34.90	°C
Battery Voltage 2m	99.30	0.00	0.00	0.70	13.57	0.71	15.30	6.70	V
Air Density 80m	-	-	-	-	1.25	0.06	1.47	1.13	kg/m³

Validity Summary

QC - Yamaska 2-100m (0092), 2014/12/17 - 2015/02/19

Wind Speed	Valid (%)	Icing (%)	Flagged (%)	Filtered (%)	Missing (%)	Mean (m/s)	Std Dev (m/s)	Max Value (m/s)	Max Gust (m/s)
Ws 100m 260° 3.6576m	84.74	0.58	3.73	0.00	10.95	6.72	3.49	20.66 (2014/12/25 10:40:00)	26.83 (2014/12/25 10:20:00)
Ws 100m 080° 3.6576m	62.43	14.58	12.03	0.00	10.95	7.32	3.12	21.32 (2014/12/25 10:40:00)	27.14 (2014/12/25 10:40:00)
Ws 98m 260° 3.6576m	63.76	14.58	10.64	0.06	10.95	7.32	3.09	20.96 (2014/12/25 10:40:00)	26.50 (2014/12/25 10:20:00)
Ws 98m 080° 3.6576m	54.53	14.39	20.13	0.00	10.95	8.02	3.13	21.75 (2014/12/25 10:40:00)	27.81 (2014/12/25 10:20:00)
Ws 79m 260° 3.6576m	70.50	14.58	3.96	0.00	10.95	7.08	2.97	20.33 (2014/12/25 10:40:00)	26.33 (2014/12/25 10:40:00)
Ws 79m 080° 3.6576m	54.53	14.39	20.13	0.00	10.95	7.72	2.94	20.80 (2014/12/25 10:40:00)	27.00 (2014/12/25 10:40:00)
Ws 59m 260° 3.6576m	70.26	14.58	4.20	0.00	10.95	6.45	2.89	19.44 (2014/12/25 10:40:00)	24.89 (2014/12/25 10:20:00)
Ws 59m 080° 3.6576m	54.53	14.39	20.13	0.00	10.95	7.03	2.83	19.64 (2014/12/25 10:40:00)	25.03 (2014/12/25 07:20:00)

Wind Direction	Valid (%)	Icing (%)	Flagged (%)	Filtered (%)	Missing (%)	Vector Average (°)	Average Standard Deviation (°)	Standard Deviation of Standard Deviation (°)
Wd 100m 260° 3.6576m	84.31	0.58	4.16	0.00	10.95	264.71	5.19	5.88
Wd 96m 320° 3.6576m	64.91	14.49	9.65	0.00	10.95	280.83	3.85	2.90
Wd 77m 320° 3.6576m	64.88	14.49	9.65	0.03	10.95	269.27	4.85	3.12
Wd 57m 320° 3.6576m	70.32	14.58	4.15	0.00	10.95	265.10	5.01	3.70

Other	Valid (%)	Flagged (%)	Filtered (%)	Missing (%)	Mean	Std Dev	Max	Min	Units
Temperature 96m	71.85	0.00	2.13	26.02	-11.15	7.59	7.91	-24.61	°C
Barometric Pressure 3m	89.05	0.00	0.00	10.95	100.81	0.83	103.30	98.30	kPa
Battery Voltage 3m	89.05	0.00	0.00	10.95	-1.25	0.35	10.31	-2.20	V
Relative Humidity 3m	89.05	0.00	0.00	10.95	75.22	12.73	94.10	28.82	%
Temperature 3m	89.01	0.00	0.03	10.95	-12.32	8.05	6.24	-34.39	°C
Air Density 80m	-	-	-	-	1.30	0.07	1.42	1.20	kg/m³

Appendix D Extrapolation of Wind Speed Data

Wind shear is a meteorological phenomenon in which the wind increases with height above ground. Wind speeds are typically measured at lower heights than the hub height of turbines. Therefore, the data must be extrapolated to various heights before assessing the power production in an area.

An estimated wind speed at a higher height is found using the following equation:

$$V_u = V_l \cdot \left(\frac{H_u}{H_l}\right)^{\alpha}$$

Equation D-1

where:

V_u = Estimated upper height wind velocity

V_l = Measured wind speed at the lower height

H_l = Lower height where V_l is measured

H_u = Upper height where V_u is defined (typically turbine hub height)

α = Wind shear coefficient

The wind shear coefficient, α, is calculated based on the local measured wind speed at the top and middle heights. It is defined by the following equation:

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

Equation D-2

The average shear exponents are calculated for a set of wind direction, time-of-day bins, and season bins. These binned shear values are calculated using the measured met mast data at the top and middle wind speed heights. The average shear exponent values are then applied to the measured data according to the appropriate bin for each local met mast to extrapolate the top measured wind speed to hub height. This method of extrapolation takes into consideration temporal and directional variations in the shear profile.

In order to capture the characteristics of the local site shear profile in the predicted data set, the binned shear values calculated using the on-site local data are applied to the reference data set. At 10 m, which is the typical height of the reference met masts, the average wind speed is greatest during the middle of the day; however, due to the strength of the shear profile, at higher heights the average wind speed peaks in the evening. Since the hub height on-site wind speeds are predicted from the reference data set it is necessary to adjust the 10 m wind speeds to account for the diurnal variation in the shear profile. To do this, the binned shear method is used to extrapolate the reference wind speeds to hub height. Performing this adjustment ensures that the long-term predicted and on-site measured data sets have similar diurnal wind speed profiles.

Appendix E Derivation of Non-Linear Correlation Method

The long-term prediction is produced by performing a non-linear correlation between synchronized on-site and reference wind speeds using a sector-wise regression (30 degree bins). The regression is then applied to the long-term reference data in order to generate a transformed time-series that is representative of on-site conditions. This process is applied to discrete top-of-the-hour readings or 10-minute averages where applicable.

The wind speed residuals in the correlation are converted to an equivalent power density using the turbine power curve. The regression is then weighted to minimize both the energy-equivalent and wind speed residuals for this relationship thereby optimizing the prediction process to match both the turbine power output and the overall average wind speed.

In order to ensure that the wind directions in the predicted dataset are representative of onsite conditions, wind directions were re-distributed to match the wind direction distribution for the on-site data. This was accomplished by randomly sampling the wind directions for each wind speed bin from the measured data and applying them to the entire prediction period.

The correlation method involves linearization of the cumulative Weibull distribution function to enable a regression of the form $y = mx + b$.

The process is robust for conditions where the wind speed distribution differs between the on-site and reference wind speeds whereas a simple linear relationship is based on the assumption that the two correlated sites have the same shape (k) parameters. Further discussion about this process is provided in the literature[20,21].

The cumulative Weibull distribution function (a form of the standard gamma distribution) is represented by the following equation:

$$Z = 1 - e^{-\left(S/_{A}\right)^{K}}$$

Equation E-1

where S is the wind speed, A is the Weibull scale factor and K is the Weibull shape factor.

For two distributions to be equal, equivalent velocities for the two distributions should have the same percentiles, Z. The equivalent velocities at the reference and local met mast are determined by inverting the cumulative function. That is,

[20] Rob Istchenko, Advanced MCP Techniques, CanWEA Conference and Exhibition, 2011.
[21] Dr Joanna McKenzie, et al., Considering the Correlation in Measure-Correlate-Predict Techniques, World Renewable Energy Congress, 2008.

$$S_l = A_l \sqrt[K_l]{-\,ln(1-Z_l)}$$
$$= A_l \sqrt[K_l]{-\,ln(1-Z_R)}$$
$$= A_l \left({S_R}/{A_R}\right)^{K_R/K_l}$$

Equation E-2

where S_l and S_R are the local and reference speeds (short- and long- term), A_l, A_R, K_l, K_R are the local and reference Weibull scale and shape parameters.

From this point, a linear correlation procedure may be followed for the determination of the transformation without the requirement of calculating the A and k parameters directly. For the measured correlation period, Equation E-2 can be rewritten by taking the logarithm of both sides:

$$y = mx + b$$

Equation E-3

where $y = \ln(S_l)$, $m = \frac{K_R}{K_l}$, $x = \ln(S_R)$, and $b = \ln(A_l) - \mathrm{m} \cdot \ln(A_R)$.

Finally, Equation E-2 can be used for long-term prediction in the following form:

$$S_l = e^b \cdot S_R^m$$

Equation E-4

For prediction, b and m are calculated from the measured and reference data sets and are used for long-term prediction (Equation E-4) at the local met mast based on the long-term reference data. Using this method, it is not necessary to calculate A and k directly.

Appendix F Losses and Confidence Interval Values

Availability

Turbine (Technical): This category consists of losses due to downtime of wind turbines in the facility as defined in the turbine manufacture technical availability. Note that the availability assessment has been made based on the expected long-term average availability of the turbines. Increased availability losses are common during the initial operational period of the facility. These losses, if assessed for a specific short-term period, would be included in the "other" availability category.

Turbine (Other): Downtime not covered under the warranty of the manufacturer (maintenance factors, manual stops, and production vs. time based loss metrics).

Balance of Plant: This category consists of losses due to downtime in components of the wind facility excluding the wind turbines. This includes various components of the facility's electrical collection system.

Grid: This category includes losses due to downtime of the power grid external to the wind turbine facility.

Other: Other availability losses not included in the above categories. This category may be used to assess additional availability losses expected for a specific short-term period.

Wake Effects

Internal Wake Effects: This category accounts for losses attributed to the wake effect of turbines within the wind power project. There was also uncertainty in the modelling of wind turbine wake losses. The magnitude of this uncertainty was typically estimated as one quarter of the magnitude of the overall wake losses.

External Wake Effects: This loss accounts for wake effects caused by existing neighbouring wind power projects.

Future Wake Effects: This loss is applied if any future wind power projects are expected in the vicinity of the project. This loss may be difficult to assess precisely; however, an approximation may be included.

Turbine Performance

Power curve: This category accounts for the turbines not producing according to their reference power curve under conditions that meet the specified operational conditions. This does not include, for example, deviation from the reference power curve due to blade degradation or wind flow conditions.

High Wind Hysteresis: Once the cut-out wind speed of the turbine has been exceeded, the turbine ceases to produce power until the re-start wind speed conditions are met. This is referred to as high wind hysteresis.

Wind Flow: This category includes losses attributed to turbulence, off-axis wind flow, inclined flow, and high wind shear. These losses represent differences between the site-specific wind flow and the wind turbine power curve test conditions.

Turbine Performance (Other): Additional turbine performance losses not accounted for in the above categories may be included here.

Electrical

Electrical Losses: Electrical losses for the facility include losses for transformers, the collector system, the substation and transmission. These losses are calculated based on the power delivered to the point of revenue metering.

Facility Consumption: This category accounts for losses resulting from parasitic consumption of the facility. This includes the consumption of heaters and transformers. These losses are not intended to account for all facility electrical consumption; rather, they reflect the reduction of energy output due to consumption within the facility.

Environmental

Performance Degradation Not Due to Icing: This category reflects losses due to degradation of the wind turbine blades. This loss can increase with time; however, this can be mitigated by periodic blade cleaning and precipitation.

Performance Degradation Due to Icing: Temporary ice accumulation on the wind turbine blades can cause decreased aerodynamic performance.

Shutdown Due to Icing, Lightning, Hail, etc.: The category accounts for shutdown of turbines due to ice accumulation, lightning, hail or other similar events. This shutdown may be initiated by the turbine controller, the SCADA system, or by the turbine operator.

High and Low Temperature: This loss category is based on ambient air temperatures that are outside of the operating range of the wind turbines.

Site Access and Other Force Majeure Events: Losses may be caused by difficulty in accessing the project. This loss category is intended to cover losses that are outside of the control of the turbine manufacturer and may include downtime resulting from snow and ice.

Tree Growth or Felling: This loss category accounts for growth or felling of trees in the vicinity of the project.

Curtailment

Wind Sector Management: This loss reflects forced shutdown of turbines in order to reduce mechanical loads on the turbines.

Grid Curtailment and Ramp-Rate: This category reflects losses due to limitations of the grid external to the wind power project. These losses may be caused by limitations on the amount of power that can be delivered at a given time or limitations on the rate of change of the amount of power delivered to the grid.

Power Purchase Agreement Curtailment: The power purchaser may choose to not accept power generated by the facility.

Environmental (Noise, Visual, Bird/Bat): These losses are based on facility curtailment in order to reduce environmental impacts such as noise, shadow flicker, or impacts on wildlife.

Other

This loss accounts for any losses not covered in the above categories.

Appendix G Loss values used in analysis

Loss Category	Subcategories	Loss Distribution					
		P5	Mode	P95	Truncate Left	Truncate Right	Mean
Availability	Turbine (guaranteed)	0.25%	2.70%	6.00%	0.00%	0.00%	3.0%
	Turbine (other)	0.50%	2.00%	3.15%	0.00%	0.00%	1.9%
	Balance of plant	0.00%	0.25%	0.55%	0.00%	0.00%	0.3%
	Grid	0.00%	0.25%	0.55%	0.00%	0.00%	0.3%
	Other	0.00%	0.00%	0.00%	0.00%	0.00%	0.0%
Availability Total		-	-	-	-	-	**5.3%**
Wake Effects	Internal wake effects	2.76%	5.51%	8.27%	0.00%	0.00%	5.5%
	External wake effects	0.02%	0.03%	0.05%	0.00%	0.00%	0.0%
	Future wake effects	0.00%	0.00%	0.00%	0.00%	0.00%	0.0%
Wake Effects Total		-	-	-	-	-	**5.5%**
Turbine performance	Power curve	-1.50%	1.00%	5.00%	0.00%	0.00%	1.5%
	High wind hysteresis	0.02%	0.03%	0.05%	0.00%	0.00%	0.0%
	Wind flow	0.20%	0.40%	0.60%	0.00%	0.00%	0.4%
	Other	0.00%	0.00%	0.00%	0.00%	0.00%	0.0%
Turbine performance Total		-	-	-	-	-	**1.9%**
Electrical	Electrical losses	1.50%	2.00%	2.50%	0.00%	0.00%	2.0%
	Facility consumption	0.20%	0.30%	0.40%	0.00%	0.00%	0.3%
Electrical Total		-	-	-	-	-	**2.3%**
Environmental	Performance degradation not due to icing	0.75%	1.50%	4.00%	0.00%	0.00%	2.0%
	Performance degradation due to icing	0.65%	0.83%	1.00%	0.00%	0.00%	0.8%

Loss Category	Subcategories	Loss Distribution					
		P5	Mode	P95	Truncate Left	Truncate Right	Mean
	Shutdown due to icing, lightning, hail, etc.	0.50%	0.66%	0.85%	0.00%	0.00%	0.7%
	High and low temperature	0.03%	0.07%	0.10%	0.00%	0.00%	0.1%
	Site access and other force majeure events	0.00%	0.10%	0.50%	0.00%	0.00%	0.2%
	Tree growth or felling	0.00%	0.00%	0.00%	0.00%	0.00%	0.0%
Environmental Total		-	-	-	-	-	**3.8%**
Curtailment	Wind sector management	0.00%	0.00%	0.00%	0.00%	0.00%	0.0%
	Grid curtailment and ramp-rate	0.00%	0.00%	0.00%	0.00%	0.00%	0.0%
	Power purchase agreement curtailment	0.00%	0.00%	0.00%	0.00%	0.00%	0.0%
	Environmental (noise, visual, bird/bat)	0.00%	0.00%	0.00%	0.00%	0.00%	0.0%
Curtailment Total		-	-	-	-	-	**0.0%**
Other	Losses not included in above categories	0.00%	0.00%	0.00%	0.00%	0.00%	0.0%
Total		-	-	-	-	-	**17.5%**

Appendix H Long-Term Wind Power Project Yields

Label	Easting (m)	Northing (m)	Z (m)	Gross Yield Result (MWh/yr)	Wake Loss (%)	Net of Wake Yield (MWh/yr)	Net of Wake Capacity Factor	100 m Wind Speed (m/s)
PS-01	660310	5094742	18	6176	3.2	5981	33.3%	6.5
PS-02	660841	5094853	18	6192	5.3	5862	32.6%	6.5
PS-03	661296	5094948	20	6189	6.3	5798	32.3%	6.5
PS-04	659229	5091291	22	6186	2.1	6058	33.7%	6.5
PS-05	659895	5093527	20	6186	3.4	5973	33.2%	6.5
PS-06	660637	5093684	20	6194	7.3	5741	31.9%	6.5
PS-07	661149	5093791	21	6196	7.1	5754	32.0%	6.5
PS-08	660448	5093081	21	6208	7.4	5751	32.0%	6.5
PS-09	660560	5092498	21	6218	7.3	5762	32.1%	6.5
PS-10	660436	5091954	22	6213	7.5	5745	32.0%	6.5
PS-11	660343	5091492	22	6208	5.5	5868	32.7%	6.5
PS-12	659768	5091053	23	6197	4.1	5942	33.1%	6.5

Appendix I Additional Tables

Table 33 shows the monthly wind speeds values over a typical year (long-term) at Met Mast 0091 at 100m hub height. Table 34 gives an estimate of the relative contribution for each wind speed bin of the gross yield values calculated for one Senvion MM92 positioned at Met Mast 0091. This table is meant to provide an indication of the impact of a possible curtailment on the gross production of the wind farm.

Month	Average long-term wind speed at 100 m
Jan	6.99
Feb	7.22
Mar	7.15
Apr	6.86
May	6.14
Jun	5.51
Jul	5.87
Aug	5.83
Sep	6.38
Oct	6.97
Nov	6.47
Dec	6.68

Table 33: Long-term monthly wind speeds at 100m for Met Mast 0091

Wind Speed Range (m/s)	Frequency	Power (kW)	Energy (MWh)	Cumulative Annual Energy (MWh)	Cumulative Annual Energy (%)
0 to 0.5	0.34%	0.0	0.0	0.0	0.0
0.5 to 1.5	2.68%	0.0	0.0	0.0	0.0
1.5 to 2.5	5.70%	0.3	3.3	3.3	0.1
2.5 to 3.5	8.61%	21.6	28.7	31.9	0.5
3.5 to 4.5	10.76%	97.3	104.1	136.1	2.2
4.5 to 5.5	12.24%	211.8	246.6	382.6	6.1
5.5 to 6.5	12.47%	402.2	453.1	835.7	13.2
6.5 to 7.5	11.86%	662.2	689.0	1524.7	24.1
7.5 to 8.5	10.50%	1002.6	894.0	2418.7	38.3
8.5 to 9.5	8.41%	1405.2	1004.0	3422.7	54.1
9.5 to 10.5	6.08%	1813.6	954.9	4377.6	69.2
10.5 to 11.5	4.11%	2004.6	754.9	5132.5	81.2
11.5 to 12.5	2.75%	2041.4	512.8	5645.3	89.3
12.5 to 13.5	1.51%	2050.0	315.4	5960.7	94.3
13.5 to 14.5	0.95%	2050.0	179.9	6140.5	97.1
14.5 to 15.5	0.49%	2050.0	95.7	6236.2	98.6
15.5 to 16.5	0.28%	2050.0	47.7	6284.0	99.4
16.5 to 17.5	0.12%	2050.0	22.4	6306.3	99.7
17.5 to 18.5	0.08%	2050.0	9.9	6316.2	99.9
18.5 to 19.5	0.03%	2050.0	4.2	6320.4	100.0
19.5 to 20.5	0.02%	2050.0	1.7	6322.1	100.0
20.5 to 21.5	0.01%	2050.0	0.7	6322.8	100.0
21.5 to 22.5	0.00%	2050.0	0.3	6323.0	100.0
22.5 to 23.5	0.00%	2050.0	0.1	6323.1	100.0
23.5 to 24.5	0.00%	2050.0	0.0	6323.2	100.0

Table 34: Gross Yield calculations for one Senvion MM92 positioned at Met Mast 0091 at 100m HH (Hub height air density: 1.253 kg/mm^3)