FullView

WIND

Initial Project Assessment

Guam

October 29, 2010

FOR

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3TIER

Contents

1 INTRODUCTION

1.1 Overview

3TIER has been retained to assess the wind resource over the Guam region, and our analysis is presented in this report. This summary section discusses the overall properties of the project. Following it, section 2 shows the mean wind speed and capacity factor over the entire Guam region, at $200m$ resolution, and displays turbine and reference point locations. Section 3 contains mean wind speeds and wind and power roses at the 10 reference points provided . Project-wide monthly, hourly, and annual means for wind speed and capacity factor can be seen in section 4.

In section 5, tabular data for the turbines are available, including location, base elevation, mean wind speed (at hub height), mean air density (also at hub height), and wind shear between $30m$ and $80m$. The turbine power curve for the GE1.6XLE (with hub height $80m$) is also provided, in Table 6. For overall project data and production statistics, see Table 1 directly below. These quantities are computed over every turbine location (see section 5), and do not include data from the reference points.

Project mean wind speed	7.23	m/s
Project mean air density	1.14	kg/m^3
Mean turbine base elvation	211	m
Project gross capacity factor	40.5	%
Project gross power production	6484.8	kW
Project net capacity factor	40.5	%
Project net power production	6484.8	kW

Table 1: Project statistics

Probability exceedance values for ten year and one year mean windspeed and gross capacity factor (CF) can be seen below, in Table 2. For each value (P50, P75, P90) there is a 50, 75, or 90 percent chance, respectively, that the same quantity (mean wind speed or capacity factor) computed over a randomly selected time period of the same length (one or ten calendar years) will exceed the given probability exceedance value. For example, according to Table 2, there is a 90% probability that the mean windspeed computed over any single calendar year will exceed 6.83 m/s.

	Ten year mean windspeed ($\frac{m}{s}$)	Ten year mean gross CF (%)	One year mean windspeed ($\frac{m}{s}$)	One year mean gross CF (%)
P50	7.23	40.5	7.23	40.5
P75	7.14	40.0	6.95	38.9
P90	7.10	39.8	6.83	38.2

Table 2: Probability exceedance values

1.2 Data provided

has provided 3TIER with 10 turbine locations to be used in an analysis of the wind resource across the Guam region (see section 2 for location information). At the turbine locations, timeseries data were extracted from the model output and used to compute the capacity factor for that turbine. Detailed turbine information can be seen in Table 5, and the overall production statistics for the project can be seen on the previous page in Table 1. For reference purposes, the power curve for the GE1.6XLE turbine is provided in Table 6.

has not provided loss factors, so those listed in Table 3 below have been used to compute the net production statistics, which can be seen in Table 1 on the previous page, as well as in Figure 8 in section 4.

Observed data from the Site 8201 tower (located at $13.3778°N$, $144.6710°W$) were also supplied . These data were used to adjust the raw model data according to the MOS correction procedure described in subsection 1.3 on the next page.

has also specified 10 meteorological reference points, labeled on the maps in section 2. Wind speed and direction timeseries were extracted at the reference points, and an analysis is presented in section 3, which includes the overall mean wind speeds and wind and power roses showing the distribution of wind direction. Section 3 is meant to provide an easily readable overview of the wind resource over the area.

Curtailment (low temp, utility, etc)	100.0	%
Wake from existing wind farms	100.0	%
Electrical efficiency	100.0	%
Wake effect	100.0	%
Substation maintenance	100.0	%
Icing and blade degradation	100.0	%
Turbine perform	100.0	%
Availability	100.0	%

Table 3: Loss factors

1.3 Methodology

3TIER used a numerical weather prediction model, the Weather Research and Forecasting model (WRF), to analyze the wind resource across the Guam region, and downscaled that dataset to $200m$ using our proprietary Time-Varying Microscale (TVM) model. WRF enables a very sophisticated but computationally intensive simulation of the dynamical and physical processes of the atmosphere, and the TVM model complements it by using diagnostic techniques to analyze microscale processes without the prohibitive computational cost of running WRF at high resolution. Initial and lateral boundary conditions for WRF were extracted from the NCEP/NCAR Reanalysis data, a multi-decadal coarse-resolution observational dataset sufficient to provide accurate representation of synoptic-scale processes. In this case, a WRF dataset at $2.0km$ resolution, covering January 2000 – December 2009, was downscaled to a $200m$ grid using TVM.

Then, based on a comparison between the raw model data and observed data from the Site 8201 tower provided by , model output statistics (MOS) were computed to remove bias and adjust variance in the raw model output while maintaining spatial structure. The MOS corrections were then applied to the dataset at each vertical level for which 3TIER will deliver data (30, 45, 60, 80, and $120m$).

At the location of Site 8201, the mean observed wind speed at $58m$ over the period of record was 7.87 m/s, and the MOS procedure requires that the MOS-corrected (simulated) mean wind speed at this point over the period of record be the same. When MOS correction was applied to the full ten-year span of the raw model output, the resulting mean wind speed at $58m$ was 7.97 m/s and the mean wind speed at $80m$ (the hub height for the GE1.6XLE turbine) was 8.07 m/s.

After the spatial dataset was generated, the wind resource was analyzed at each reference point and turbine location (as provided), and the results are presented in this report. Additionally, several project-wide statistics are computed (see Table 1 above).

2 WIND RESOURCE AND CAPACITY FACTOR MAPS AT $80M$

This section presents spatial maps of the average simulated wind speed and capacity factor at $80m$ across the Guam region. All maps within this section represent the raw model output of the $200m$ domain. The red box denotes the valid study area.

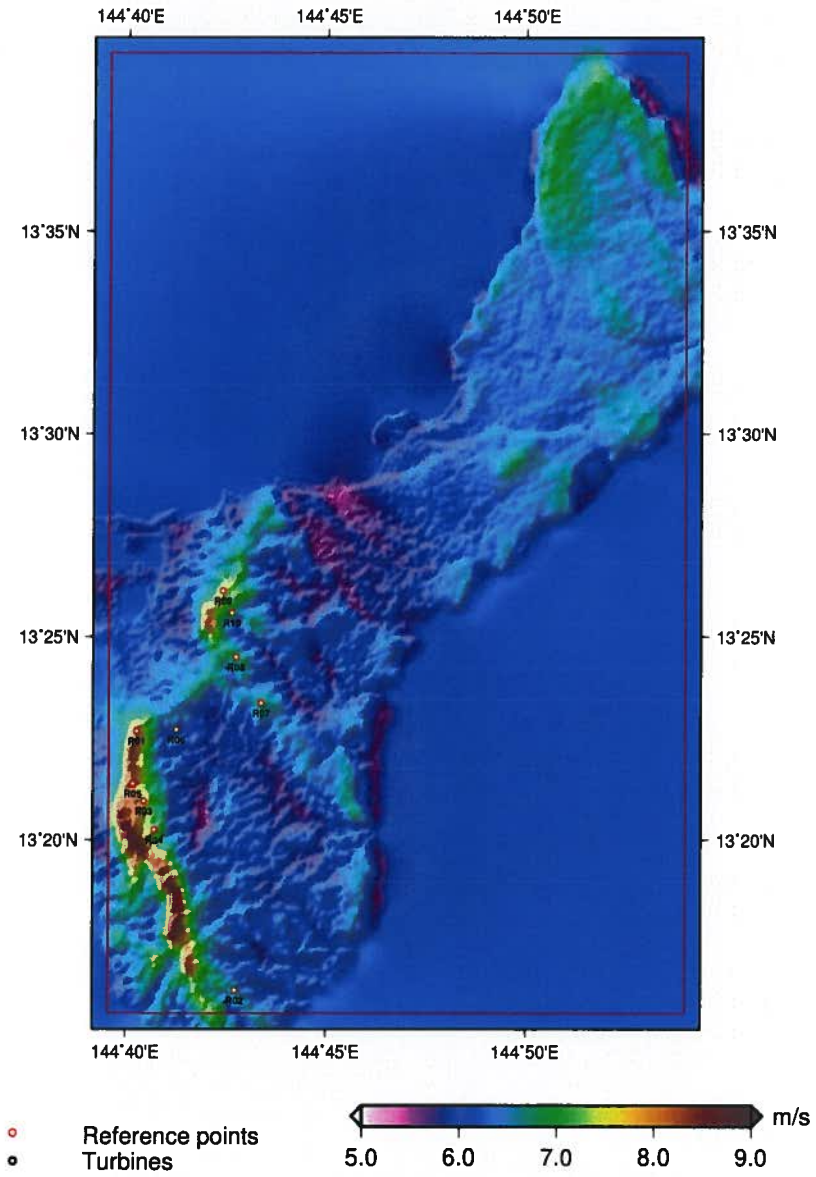

Figure 1: Mean wind speed at $80m$.

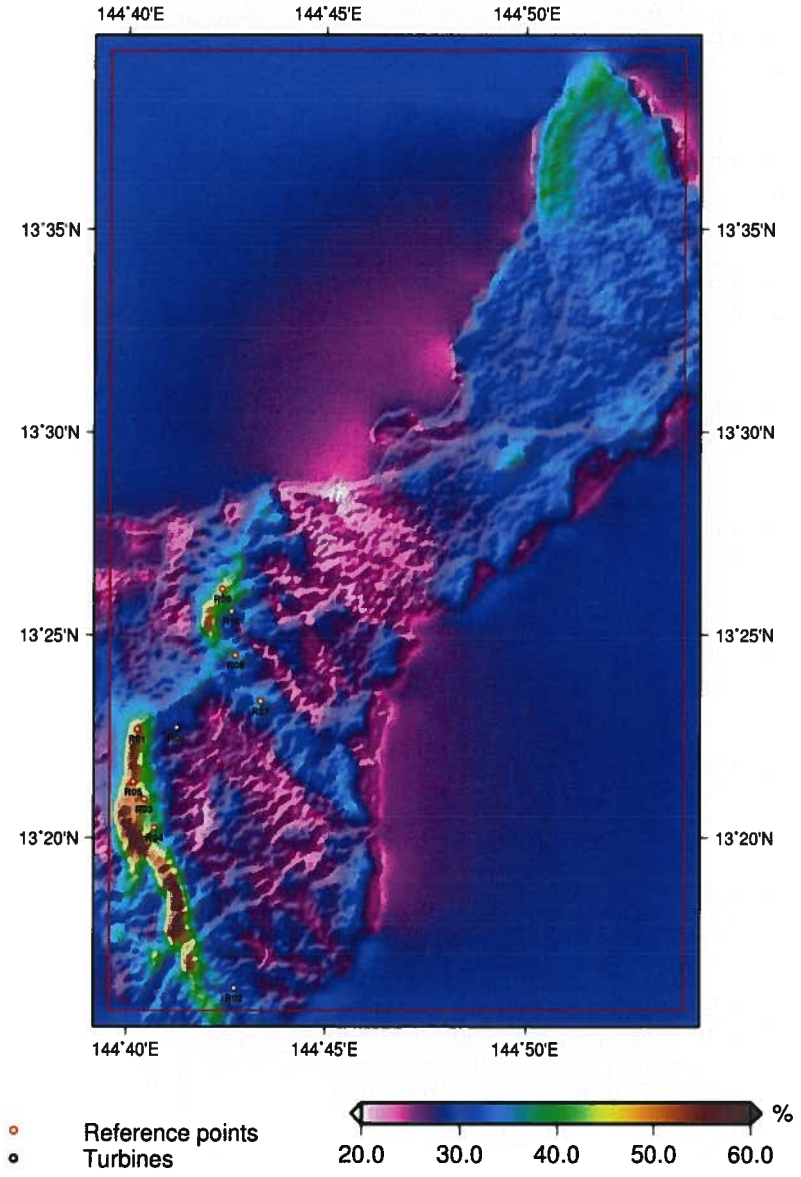

Figure 2: Mean capacity factor for the GE1.6XLE turbine at $80m$.

3 REFERENCE POINT ANALYSIS

The data presented in this section are derived from the 10 reference points provided Table 4 below, location information and mean wind speed are summarized for each reference point, and the following pages contain annual wind speed and power roses for each reference point and monthly wind and power roses for the first reference point specified. In addition to the coordinates given in this table, reference point locations are lableled on the maps in section 2.

ID	Latitude	Longitude	Elevation (m)	Reference height (m)	Mean wind speed (m/s)
R01	13.3778	144.6710	235	80	8.07
R02	13.2718	144.7121	113	80	6.61
R03	13.3492	144.6740	292	80	7.73
R04	13.3375	144.6784	278	80	7.34
R05	13.3563	144.6694	280	80	8.17
R06	13.3785	144.6875	83	80	6.35
R07	13.3894	144.7228	161	80	6.78
R08	13.4083	144.7122	188	80	6.84
R09	13.4355	144.7067	278	80	7.52
R10	13.4264	144.7105	207	80	6.92

Table 4: Reference point information

3.1 Wind roses

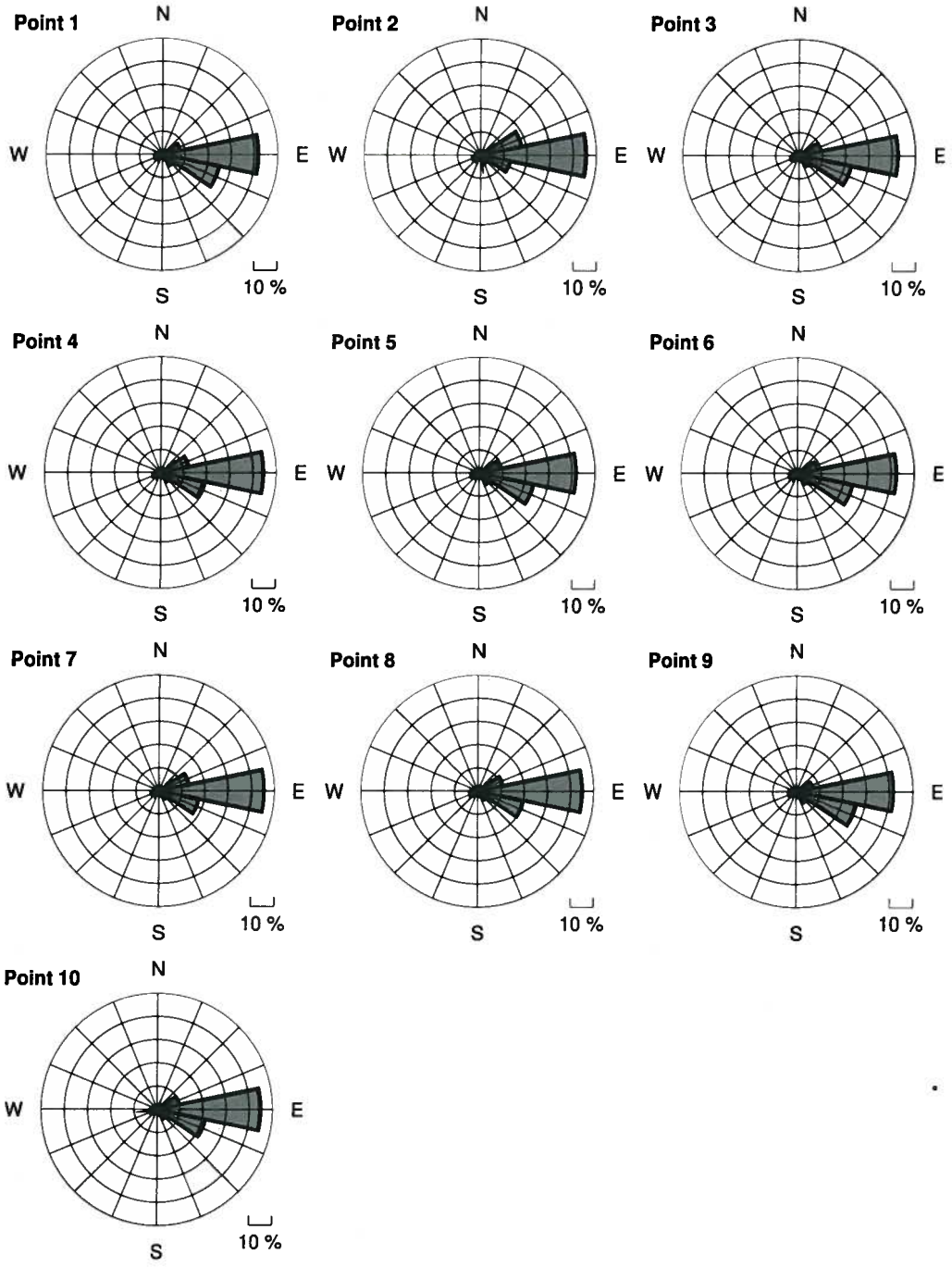

Figure 3: Annual wind roses for all reference points

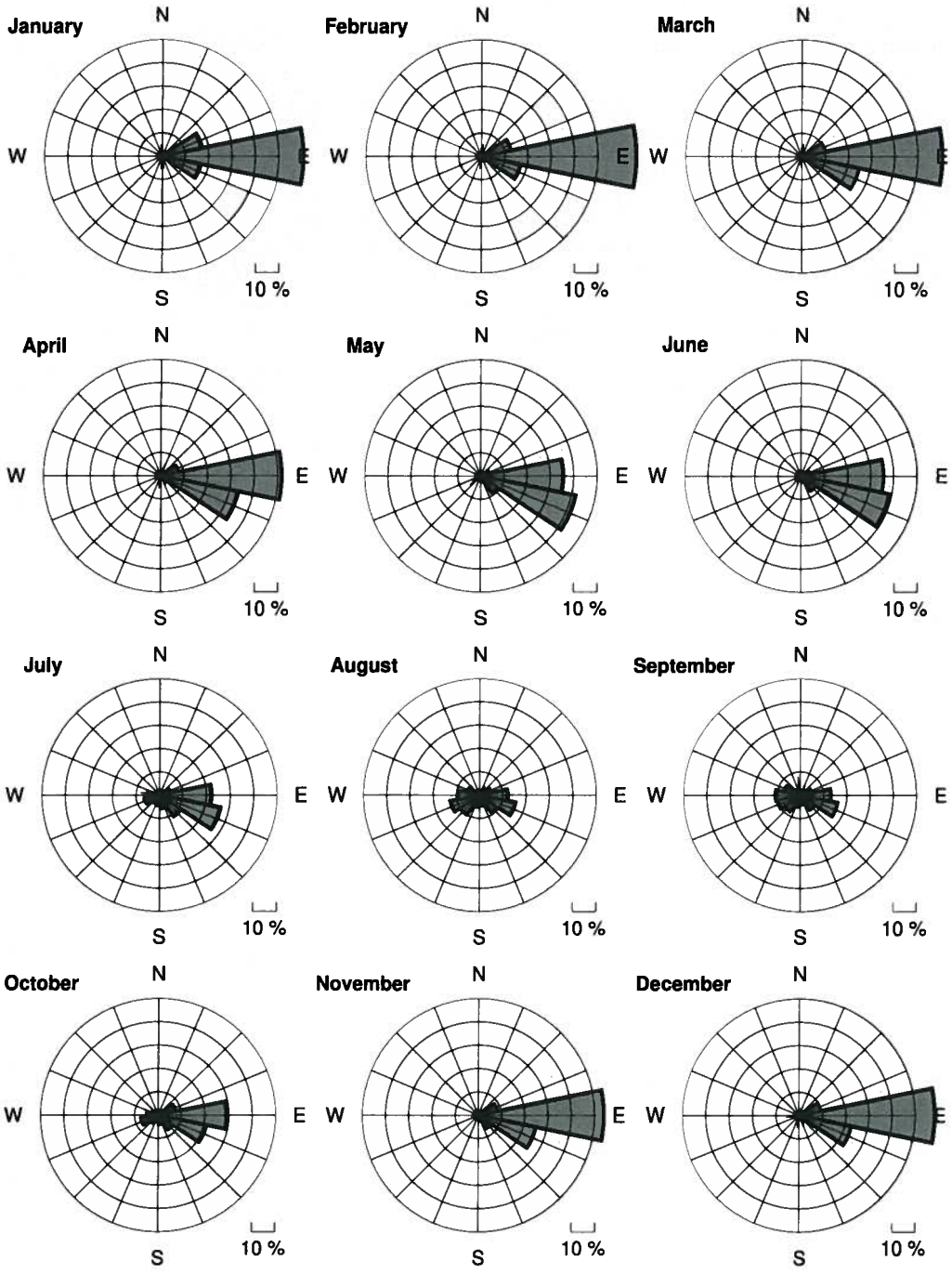

Figure 4: Monthly wind roses for reference point R01

3.2 Power roses

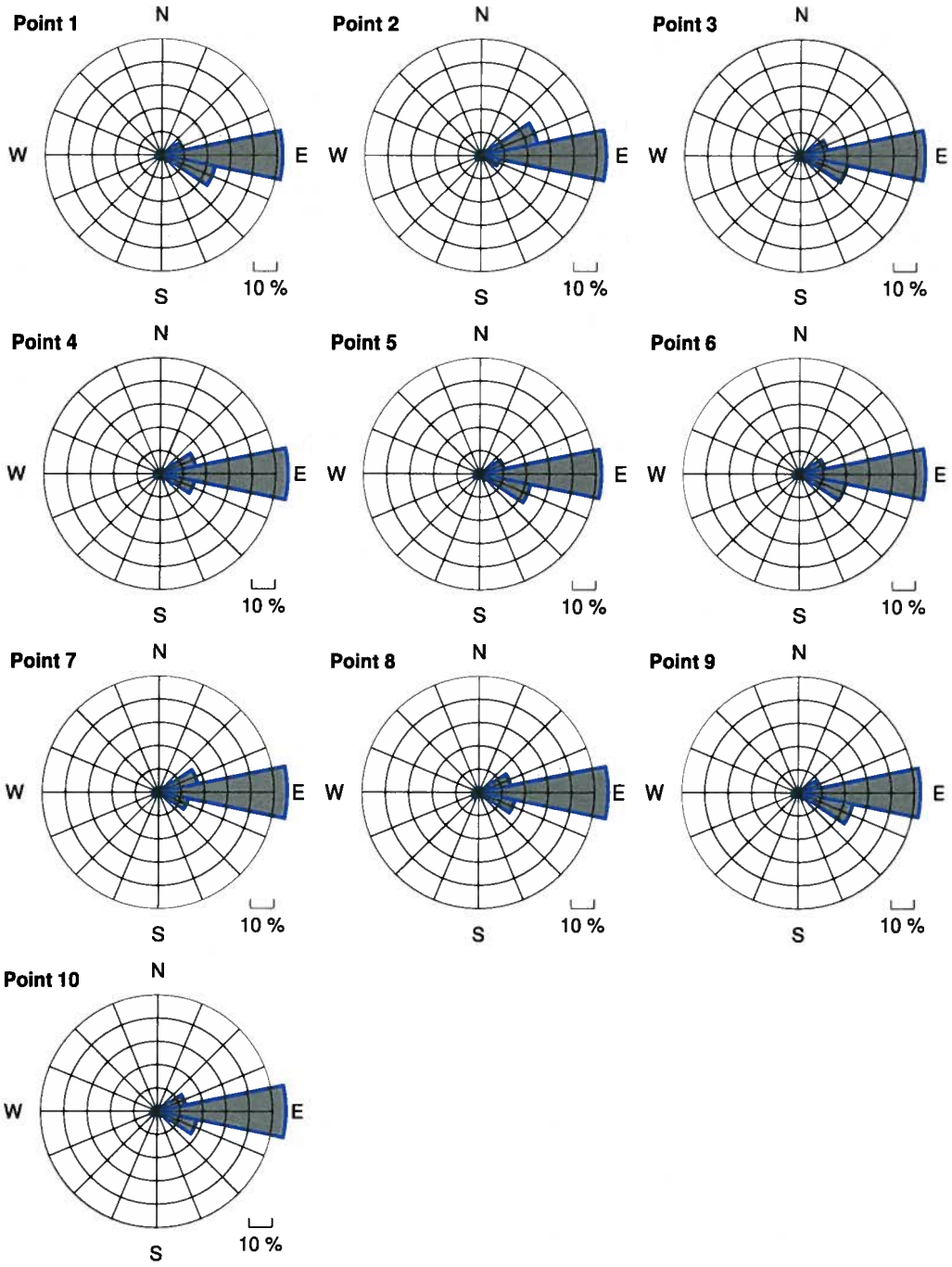

Figure 5: Annual power roses (for the GE1.6XLE turbine) for all reference points

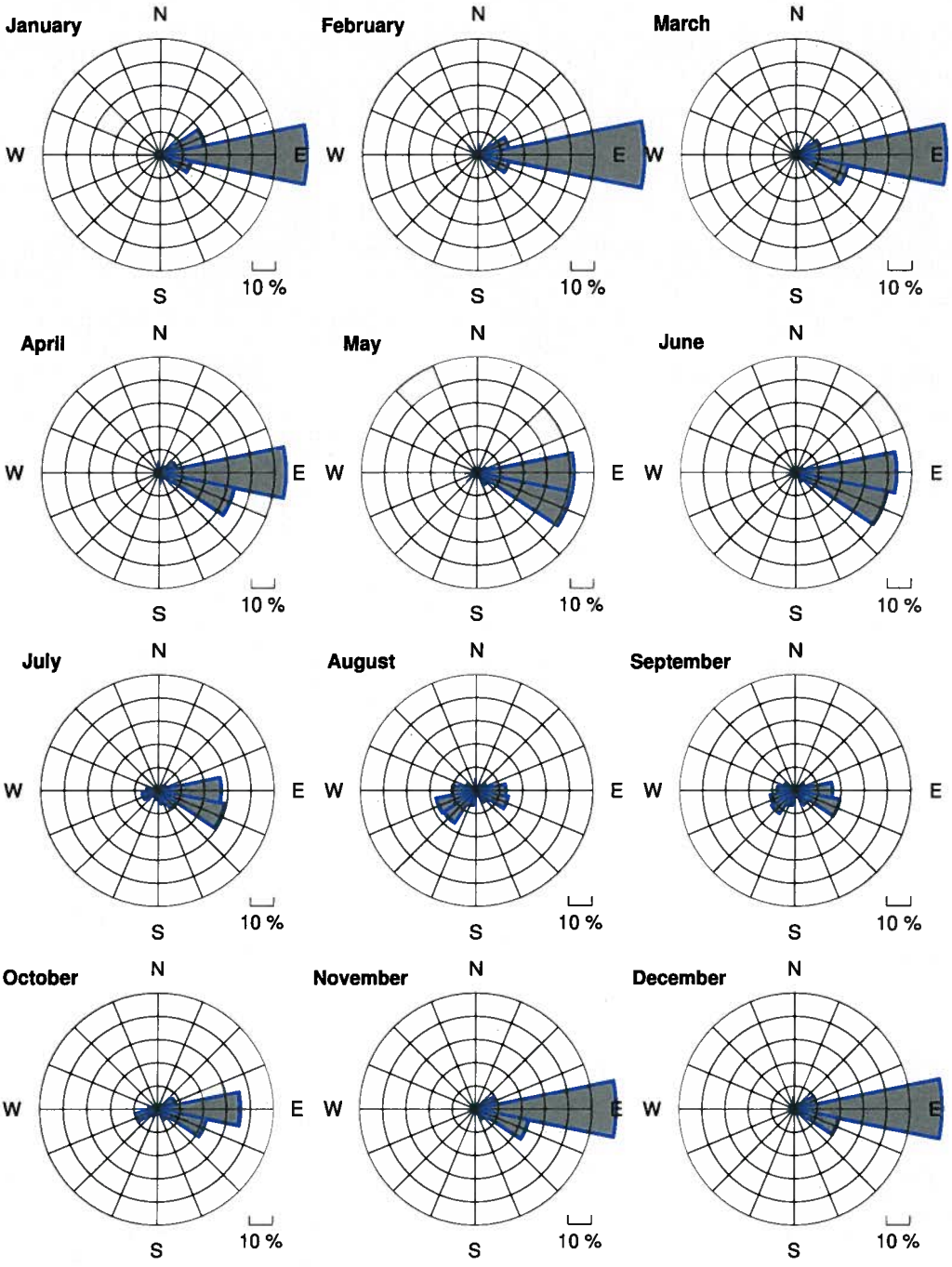

Figure 6: Monthly power roses (for the GE1.6XLE turbine) for reference point R01

4 12X24 TABLES

These tables contain the mean of each hour (0 through 24) from each month in the year. Each column, therefore, shows that month's mean diurnal cycle, and the annual mean diurnal cycle can be read down the rightmost column, which is composed of the overall means of each hour. The bottom row contains each month's mean, and in the bottom right cell is the overall mean. These means are computed across the 10 turbine locations provided and do not include the reference points.

Hour of Day (UTC)	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg
0	9.74	9.11	8.62	9.11	7.20	6.93	5.90	5.69	5.31	6.62	9.25	9.57	7.74
1	9.79	9.52	8.97	9.16	7.48	7.03	6.24	5.91	5.42	6.70	9.34	9.62	7.92
2	9.71	9.55	9.03	9.00	7.62	7.29	6.37	5.88	5.36	6.89	9.08	9.68	7.94
3	9.77	9.71	8.91	8.69	7.38	7.20	6.39	6.23	5.32	6.89	8.78	9.51	7.89
4	9.53	9.65	8.80	8.36	7.08	6.94	6.12	6.47	5.29	6.75	8.53	9.45	7.74
5	9.55	9.38	8.58	8.19	7.03	6.71	5.98	6.65	5.34	6.57	8.34	9.52	7.64
6	9.70	9.40	8.43	7.78	6.80	6.42	5.50	6.00	5.11	6.46	8.44	9.56	7.46
7	9.41	9.22	8.24	7.61	6.48	6.30	5.35	5.84	4.90	6.32	8.08	9.00	7.22
8	8.99	8.73	7.69	7.32	6.17	5.91	5.12	5.55	4.81	6.26	7.87	8.64	6.91
9	8.86	8.64	7.67	7.21	5.99	5.64	5.13	5.36	4.97	6.31	8.15	8.60	6.87
10	8.95	8.74	7.76	7.34	6.28	5.81	5.14	5.43	4.87	5.99	7.91	8.52	6.88
11	9.01	8.86	7.82	7.59	6.50	6.23	5.60	5.58	4.84	5.88	7.83	8.49	7.01
12	8.81	8.92	7.82	7.78	6.62	6.68	5.77	5.61	4.81	5.69	7.64	8.32	7.03
13	8.56	8.73	7.87	7.89	6.69	6.87	5.69	5.43	4.84	5.68	7.36	8.05	6.96
14	8.61	8.43	7.58	7.74	6.69	6.82	5.85	5.65	4.92	5.70	7.37	8.19	6.95
15	8.92	8.33	7.32	7.72	6.72	6.84	5.88	5.87	4.86	5.55	7.37	8.05	6.94
16	8.93	8.25	7.31	7.74	6.55	6.56	5.87	6.27	4.77	5.56	7.59	8.12	6.95
17	8.73	8.14	7.21	7.63	6.66	6.56	5.95	6.22	4.82	5.66	7.68	8.19	6.95
18	8.83	8.30	7.29	7.77	6.59	6.29	5.88	6.13	4.78	5.66	7.62	8.10	6.93
19	8.93	8.56	7.28	7.87	6.51	6.30	5.76	6.09	4.90	5.88	7.93	8.21	7.01
20	8.95	8.44	7.19	7.98	6.56	6.59	5.78	5.96	4.80	6.16	8.10	8.17	7.05
21	8.98	8.37	7.41	8.10	6.45	6.54	5.76	5.82	4.70	6.13	8.05	8.32	7.04
22	8.98	8.43	7.55	8.56	6.66	6.39	5.34	5.51	4.57	5.97	8.17	8.35	7.03
23	9.73	8.91	8.24	9.02	7.15	6.67	5.67	5.53	4.75	6.28	8.71	9.02	7.46
Avg	9.17	8.85	7.94	8.05	6.74	6.56	5.75	5.86	4.96	6.15	8.13	8.72	7.23

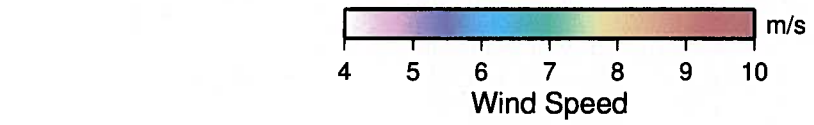

Figure 7: 12 month by 24 hour table of wind speed

Hour of Day (UTC)	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg
0	69.7	63.4	57.9	61.4	37.8	34.7	23.9	22.3	19.5	32.7	63.2	66.9	46.0
1	70.1	67.9	61.9	62.4	41.6	35.7	27.4	24.3	19.9	33.3	64.3	67.4	47.9
2	69.3	68.5	62.6	61.0	43.4	39.4	29.1	24.5	19.3	35.4	62.1	68.2	48.4
3	69.6	70.6	61.0	57.6	40.2	38.4	29.3	28.4	19.1	35.5	58.9	67.0	47.8
4	67.4	70.2	59.3	53.6	36.1	34.7	26.7	31.3	18.7	33.9	56.1	66.9	46.1
5	67.0	67.2	56.0	51.5	35.5	31.7	25.6	33.8	19.3	31.8	53.8	67.8	45.0
6	67.7	66.9	53.8	46.0	32.9	28.4	21.4	27.8	17.4	30.6	55.1	67.5	42.8
7	64.9	64.8	51.7	44.0	29.2	27.2	20.2	26.7	16.1	29.4	50.8	61.8	40.4
8	60.6	58.6	44.4	40.1	25.6	22.9	18.1	23.8	15.4	28.4	47.2	57.2	36.7
9	59.5	58.1	44.3	38.3	23.3	19.6	17.8	21.9	17.1	29.1	50.9	57.1	36.3
10	60.9	59.5	45.7	40.0	26.8	21.8	17.9	22.5	16.7	25.6	47.9	56.1	36.7
11	62.2	60.9	46.6	43.2	29.3	26.9	22.2	23.6	16.8	24.2	46.9	55.5	38.1
12	60.0	61.9	46.8	45.6	30.5	33.1	24.2	23.5	16.5	22.3	44.4	53.4	38.4
13	56.8	59.1	47.7	47.1	31.7	35.9	23.5	21.8	17.1	22.1	40.8	49.8	37.6
14	57.3	55.1	43.6	44.9	32.0	35.1	25.1	23.7	18.2	22.6	40.9	51.7	37.4
15	61.4	53.8	39.8	44.8	32.4	35.4	25.3	25.8	17.3	21.0	40.9	49.9	37.2
16	61.4	52.9	39.6	45.2	30.3	31.7	25.2	30.2	16.3	21.3	43.9	50.5	37.3
17	58.7	51.5	38.3	43.8	32.1	31.5	26.6	29.8	16.8	22.5	44.9	51.5	37.3
18	59.9	53.8	39.8	45.8	31.9	28.3	26.2	29.3	16.5	22.6	44.2	50.2	37.3
19	61.1	57.1	39.8	46.9	30.9	28.6	24.8	28.7	17.8	25.1	48.3	51.7	38.3
20	61.3	55.8	38.8	48.3	31.6	31.9	24.9	27.6	17.1	28.5	50.4	51.3	38.8
21	61.5	55.0	41.7	49.7	29.5	31.4	24.5	25.8	15.8	27.8	49.9	53.3	38.7
22	61.4	55.4	43.7	54.8	32.4	29.7	20.2	22.5	14.1	26.0	51.0	53.4	38.6
23	69.4	61.2	52.9	60.5	38.3	32.2	22.8	21.9	15.1	29.3	57.7	61.1	43.4
Avg	63.3	60.4	48.2	49.0	32.7	31.1	23.9	25.9	17.2	27.5	50.6	57.8	40.5

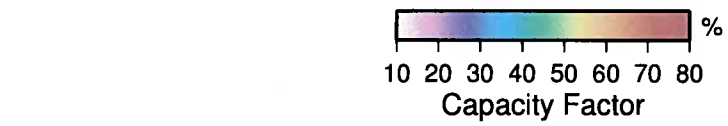

Figure 8: 12 month by 24 hour table of net capacity factor for the GE1.6XLE turbine. These net values are derived from the gross values using the loss factors in Table 3.

5 TURBINE INFORMATION

5.1 Individual turbine information

All wind speed, capacity factor, and air density values in this table are the overall mean values for that turbine. Shear is computed between $30m$ and $80m$. Each turbine is color-coded according to its gross capacity factor, so that the best-performing turbines can be easily identified. Note that the color-coding corresponds to the key used in Figure 8 on the previous page.

ID	Latitude	Longitude	Elevation (m)	Wind Speed ($\frac{m}{s}$)	Gross Capacity (%)	Air Density ($\frac{kg}{m^3}$)	Shear
T01	13.3778	144.6710	235	8.07	50.3	1.138	0.07
T02	13.2718	144.7121	113	6.61	33.5	1.151	0.12
T03	13.3492	144.6740	292	7.73	46.4	1.133	0.12
T04	13.3375	144.6784	278	7.34	41.8	1.135	0.15
T05	13.3563	144.6694	280	8.17	51.3	1.134	0.11
T06	13.3785	144.6875	83	6.35	30.1	1.155	0.11
T07	13.3894	144.7228	161	6.78	35.2	1.147	0.11
T08	13.4083	144.7122	188	6.84	36.0	1.144	0.12
T09	13.4355	144.7067	278	7.52	43.9	1.134	0.10
T10	13.4264	144.7105	207	6.92	36.8	1.142	0.12

Table 5: Individual turbine information

5.2 **Power curve**

Wind Speed ($\frac{m}{s}$)	Capacity (kW)
3.5	14
4.0	56
4.5	109
5.0	170
5.5	239
6.0	320
6.5	413
7.0	525
7.5	650
8.0	793
8.5	950
9.0	1114
9.5	1267
10.0	1412
10.5	1523
11.0	1583
11.5	1600
12.0	1600
12.5	1600
13.0	1600
13.5	1600
14.0	1600
14.5	1600
15.0	1600
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20.0	1600
20.5	1600
21.0	1600
21.5	1600
22.0	1600
22.5	1600
23.0	1600
23.5	1600
24.0	1600
24.5	1600
25.0	1600

Table 6: Power curve for the GE1.6XLE turbine, with a reference density of $1.225\frac{kg}{m^3}$