D E W I G m b H

Wind Speed Correction Matrix for Wake Shading Effects on a Wind Measurement located in the Vicinity of a Wind Farm at the Site Florida (Uruguay)

- Draft of Final Report -

DEWI-GER-WP13-03074.01.02

Service	**Wind Speed Correction Matrix for Wake Shading Effects on a Wind Measurement located in the Vicinity of a Wind Farm**
Site	**Florida (Uruguay)**
Offer	21003719
Report	DEWI-GER-WP13-03074.01.02
Status	Draft of Final Report
Client	POLESINE SA Rambla Rep. de México 6517 of 104 11500 Montevideo Uruguay
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Related reports (main reports):

DEWI-W WP 09-154.01	2009-08-05	Pre-Assessment of the Energy Yield at the Site Florida
DEWI-W WP 09-214.01	2010-02-24	Site-related Wind Potential Analysis and Energy Yield Assessment
DEWI-GER-WP12-01797-01.01	2012-03-19	Site-related Wind Potential Analysis and Energy Yield Assessment, update of meteorological input data.
DEWI-GER-PV13-02675-01.01	2013-08-13	Site Assessment for Wind Turbine Power Performance Measurements according to IEC 61400-12-1 Turbine: Nordex N117/2400

Oldenburg, 2013-12-05

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Contents

1. Introduction

The customer is planning the installation of a wind farm at the site Florida. It is planned to permanently operate a wind measurement mast in the wind farm.

The aim of the following calculation is to determine a wind speed correction matrix for the wake effects caused by the wind farm Florida.

The input data like the topographical and meteorological input data are identical to the one used in DEWI-GER-WP12-01797-01.01.

The planned wind farm consists of 21 wind turbines of the type Nordex N117 with a hub height of 91 m. The coordinates are shown in Table 1; they differ from the coordinates in DEWI-GER-WP12-01797-01.01. Figure 1 shows a map of the wind farm site Florida.

The new measurement mast will be located at the position UTM WGS84 south, zone 21 E 586’441, N 6’228’389. The correction matrix has been generated for the measurement height of 91 m. The position of the measurement mast is shown in Figure 2.

At the position UTM WGS84 south, zone 21 E 583’110, N 6’224’236 a former wind measurement mast has been collecting data since January 2009. The data was measured at a height of 79 m during a 36.5-months period; the measured average wind speed was 7.2 m/s (DEWI-GER-WP12-01797-01.01). Figure 3 shows the long-term wind distribution at a height of 79 m as determined by DEWI in the same assessment.

For this report, all coordinates of wind energy converters, site centres and measuring masts are presented in UTM WGS84 south, zone 21 coordinates.

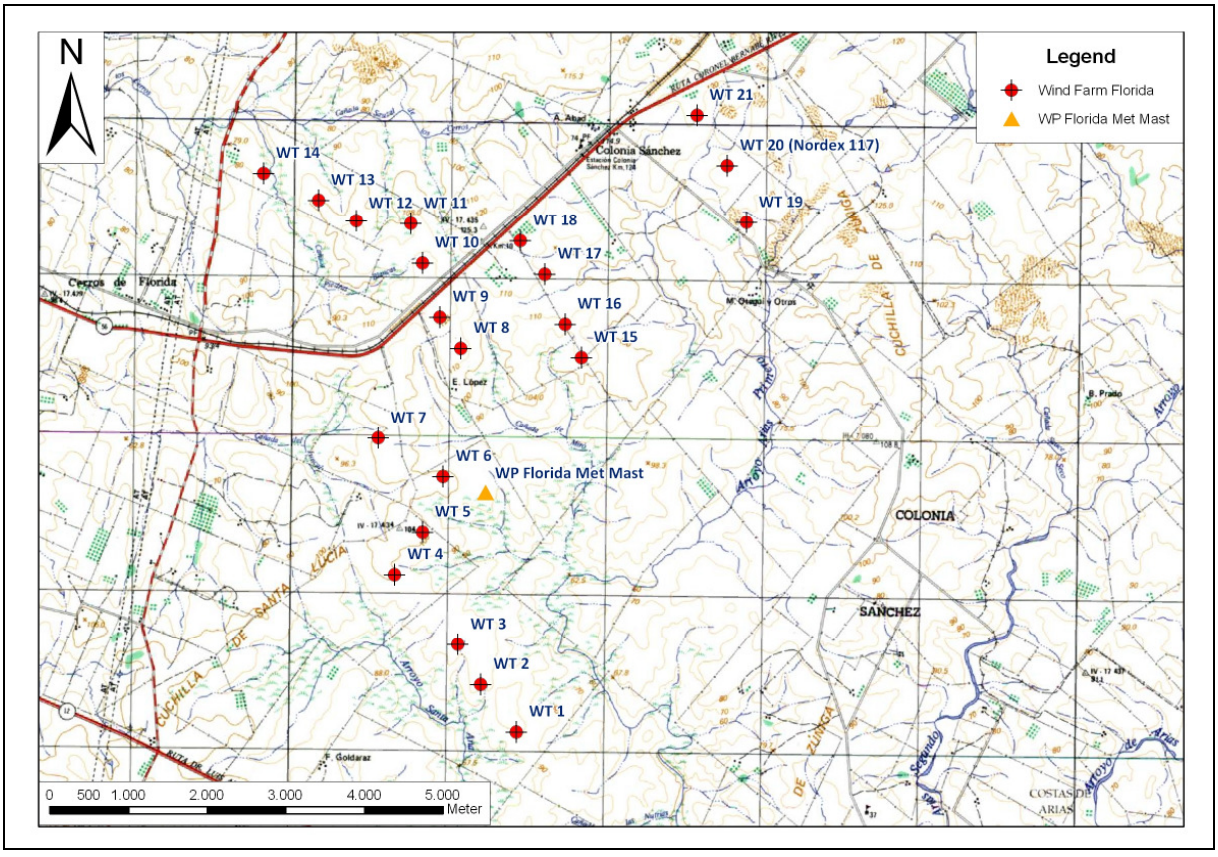

Figure 1: Map of the wind farm site Florida. The positions of the wind turbines are marked.

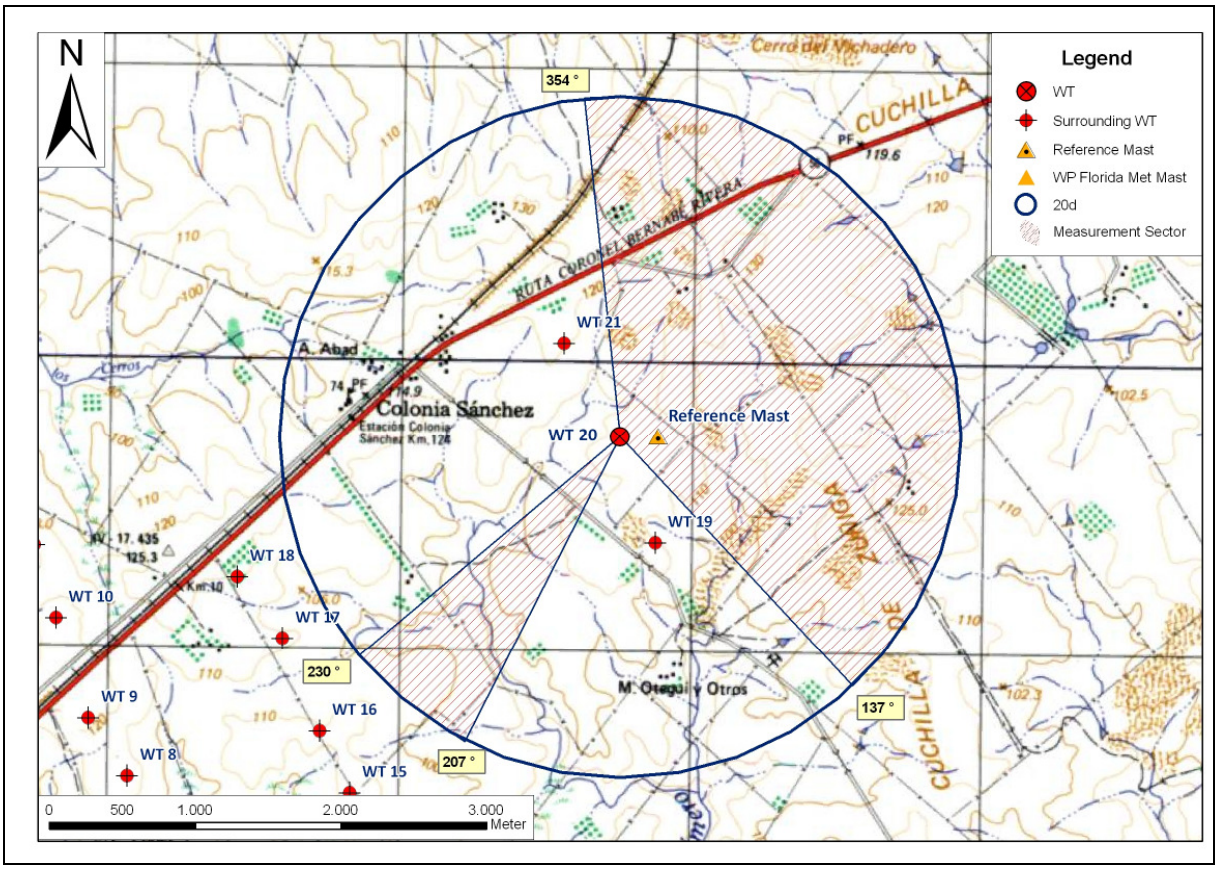

Figure 2: The position of the new measurement mast (Reference Mast). For this mast the wind speed correction matrix has been calculated.

	Coordinates WGS84 south zone 21	
	E [m]	N [m]
WT_1	583501	6221188
WT_2	583049	6221791
WT_3	582756	6222306
WT_4	581953	6223194
WT_5	582306	6223728
WT_6	582569	6224436
WT_7	581743	6224930
WT_8	582797	6226064
WT_9	582531	6226459
WT_10	582310	6227148
WT_11	582162	6227652
WT_12	581465	6227685
WT_13	580989	6227954
WT_14	580286	6228296
WT_15	584327	6225948
WT_16	584120	6226372
WT_17	583866	6227007
WT_18	583554	6227431
WT_19	586425	6227663
WT_20	586184	6228389
WT_21	585799	6229033

Table 1: Coordinates of the wind turbines in the wind farm Florida.

	Coordinates WGS84 south zone 21	
	E [m]	N [m]
Reference Mast Florida	586441	6228389

Table 2: Coordinates of the reference mast Florida.

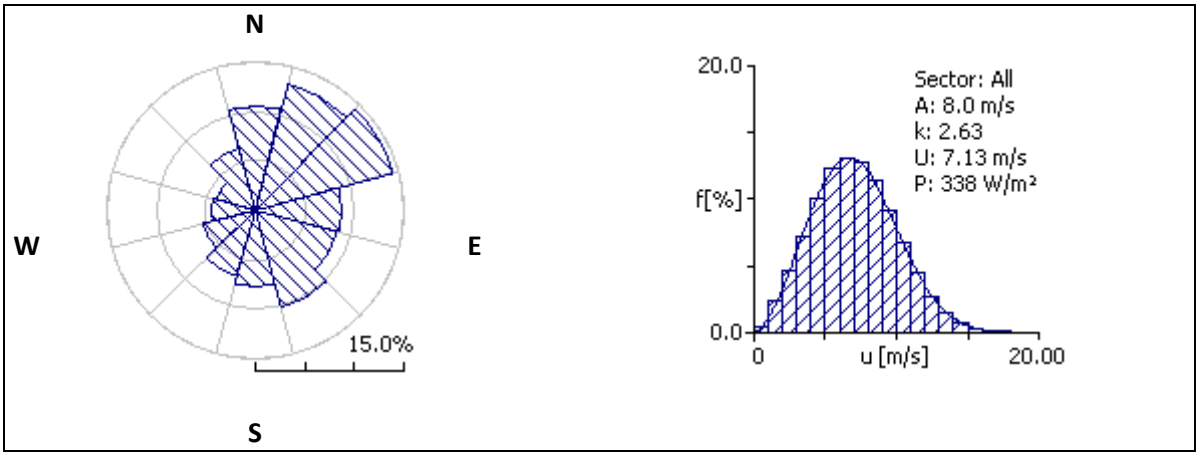

Figure 3: Long-term wind direction and wind speed distribution at mast Florida at a height of 79 m (from DEWI-GER-WP12-01797-01.01, coordinates: UTM WGS84 south, zone 21 E 583’110, N 6’224’236).

2. Wind Speed Correction Matrix

2.1. Input data and Description of the Calculation Method

The shading effects were calculated with the software Windfarmer 5.2.11.0. As wake model the Eddy Viscosity model has been applied [4]. The calculations have been performed for a wind speed resolution of 1 m/s and a wind direction resolution of 5°.

The distance to the nearest wind turbine is 257 m (WT20). This corresponds to 2.2 rotor diameter which is outside the range of validity of the wake models. This leads to enlarged uncertainties of the correction matrix.

Meteorological input data for this site have been derived for the 79m measurement height as described in chapter 3 of report DEWI-GER-WP12-01797-01.01. Based on these results, a wind resource grid has been calculated for the wind speed in 91m height (WASP RSF file). The power curve and the thrust curve of the Nordex N117 have been used as shown in section 3.4 of report DEWI-GER-WP12-01797-01.01.

As hub height and as measurement height 91 m were applied.

From these a correction matrix has been generated for the mast Florida for the measurement height 91 m.

2.2. Correction Matrix

A correction matrix with a resolution of 1 m/s in wind speed and 5° in wind direction has been generated (Table 3). It gives a scaling factor for each wind speed and wind direction combination. The scaling factor has to be multiplied with the measured data in order to correct the shading effects due to the wind turbines in the wind farm Florida. The data will be provided to the client additionally as Excel file.

The wind speed reduction by the wind farm is largest for wind speeds of the partial load region of the power curve. Here the largest share of the wind energy is converted by the wind turbines. With higher wind speeds the shading effects decrease.

The wind turbine WT20 located west of the reference mast in a direction of 270° has the largest shading effects on the wind measurements on the mast Florida. The distance is 257 m corresponding to 2.2 D. In 2.2 D distance the wake is not fully developed and the used wake model is not valid for this close distance. Therefore the uncertainty of the correction matrix is enlarged in the wind direction sector [255°;285°].

Apart from WT20 mainly the wind turbines WT19 (in 179°) and WT21 (in 315°) have shading effects on the wind measurement. No other wind turbines have distinct influence on the wind measurements.

According to the assessed correction matrix the mean wind speed deficit caused by the wind farm is approximately 4%. This is an estimate based on the wind direction and wind speed distribution as assessed in the energy yield assessment DEWI-GER-WP12-01797-01.01 (Figure 3), scaled to a height of 91 m.

For a permanent operation of the mast in the wind farm the mast position is suited well. Its position is northeast of the wind farm. This position corresponds with the wind direction distribution at the site Florida (Figure 3). The main wind direction northeast is undisturbed. Furthermore is the mast position located east of the nearest wind turbine, this corresponds well with the fact that the wind direction sector 270° has a small frequency.

If the matrix is applied on the wind mast data then the mast position is suitable for a permanent operation mast.

Due to the short distance to the nearest wind turbine the uncertainty of the correction matrix is enlarged in the wind direction sector [255°;285°]. This wind direction sector is not frequent. Therefore for the evaluation of longer periods, e.g. full months or full year, the enlarged uncertainties in this wind direction sector have no large weight. But it shall be noted that for the assessment of 10-minute data it is recommended to exclude the wind direction sector [255°;285°] from the evaluation.

	Free Wind Speed [m/s]																												
dir[°]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
45	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
55	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
65	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
70	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
75	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
80	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
85	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
90	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
95	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
105	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
110	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
115	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
120	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
125	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
130	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
135	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
140	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
145	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
150	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
155	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
160	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
165	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
170	1	1.01	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
175	1.03	1.07	1.11	1.11	1.11	1.11	1.1	1.09	1.08	1.06	1.04	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1
180	1.1	1.2	1.28	1.28	1.27	1.27	1.27	1.24	1.22	1.17	1.12	1.09	1.06	1.05	1.04	1.03	1.02	1.02	1.01	1.01	1	1	1	1	1	1	1	1	1
185	1.07	1.14	1.2	1.2	1.2	1.2	1.19	1.17	1.16	1.12	1.08	1.06	1.05	1.03	1.03	1.02	1.02	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1
190	1.01	1.03	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1
195	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
200	1	1	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
205	1	1	1.01	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
210	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
215	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
220	1.02	1.04	1.05	1.05	1.05	1.05	1.05	1.05	1.04	1.04	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1
225	1.01	1.02	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1
230	1.02	1.04	1.06	1.06	1.06	1.06	1.05	1.05	1.05	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1
235	1.01	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
240	1.02	1.03	1.05	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1
245	1.01	1.02	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1
250	1.02	1.03	1.07	1.08	1.07	1.07	1.07	1.06	1.05	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1
255	1.04	1.11	1.22	1.23	1.22	1.21	1.2	1.17	1.14	1.09	1.06	1.04	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1
260	1.11	1.28	1.56	1.6	1.57	1.55	1.53	1.46	1.39	1.27	1.16	1.11	1.08	1.06	1.04	1.03	1.03	1.02	1.01	1.01	1	1	1	1	1	1	1	1	1
265	1.21	1.58	2.23	2.31	2.24	2.2	2.15	1.98	1.81	1.54	1.31	1.2	1.14	1.1	1.07	1.05	1.04	1.03	1.02	1.01	1	1	1	1	1	1	1	1	1
270	1.26	1.78	2.78	2.87	2.76	2.68	2.61	2.33	2.08	1.68	1.38	1.24	1.16	1.11	1.08	1.06	1.04	1.03	1.02	1.01	1	1	1	1	1	1	1	1	1
275	1.2	1.59	2.32	2.3	2.22	2.17	2.13	1.91	1.75	1.47	1.27	1.18	1.12	1.09	1.06	1.05	1.03	1.02	1.01	1.01	1	1	1	1	1	1	1	1	1
280	1.11	1.29	1.6	1.59	1.56	1.54	1.52	1.43	1.36	1.24	1.14	1.1	1.07	1.05	1.04	1.03	1.02	1.02	1.01	1.01	1	1	1	1	1	1	1	1	1
285	1.04	1.11	1.23	1.23	1.22	1.21	1.2	1.17	1.14	1.09	1.06	1.04	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1
290	1.01	1.03	1.08	1.08	1.07	1.07	1.07	1.05	1.04	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1
295	1	1	1.02	1.02	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
300	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
305	1	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
310	1.03	1.07	1.1	1.1	1.1	1.1	1.09	1.08	1.08	1.06	1.04	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1
315	1.08	1.16	1.23	1.23	1.22	1.22	1.21	1.2	1.18	1.14	1.1	1.07	1.05	1.04	1.03	1.03	1.02	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1
320	1.03	1.07	1.11	1.11	1.1	1.1	1.1	1.09	1.08	1.06	1.04	1.03	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1
325	1	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
330	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
335	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
340	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
345	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
350	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
355	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3: Correction matrix of the reference mast Florida for the measurement height 91 m.

3. General Comments and Notes

The results are based on the data submitted, the site description, the restrictions and the prerequisites mentioned throughout the report.

The input data for the calculations were checked for consistency and plausibility. This does not rule out possible errors in the measurement or data processing procedure, especially if the data are not processed solely by DEWI GmbH.

DEWI GmbH does not guarantee for the calculated wind conditions or the calculated energy yield. The results documented in this report relate only to the items under investigation. A *partial* duplication of this report is not allowed without a written permission of DEWI GmbH.

4. Appendix

4.1. Used Software

DEWI used among several tools and programs for evaluation and correlation of the wind data the following software for the investigation in hand:

- Wind Atlas Analysis and Application Program (WA^{S}P), version 5.01, build 81110, Risø National Laboratory, Roskilde, Denmark.
- Garrad Hassan and Partners Limited; Windfarmer, Bristol, 1997 – 2013 version 5.2.11.0.

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