A METHODOLOGY FOR CALCULATING EMISSIONS REDUCTIONS FROM RENEWABLE ENERGY PROGRAMS AND ITS APPLICATION TO THE WIND FARMS IN THE TEXAS ERCOT REGION

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ABSTRACT

Recently Texas Legislature required adding 5,880 MW of generating capacity from renewable energy technologies by 2015, and 500 MW from non-wind renewables. This legislation also required the Public Utility Commission (PUC) to establish a target of 10,000 MW of installed renewable capacity by 2025, and required Texas Commission on Environmental Quality (TCEQ) to develop a methodology for computing emissions reductions from renewable energy initiatives and the associated credits. In this legislation the Energy Systems Laboratory was to assist the TCEQ to quantify emissions reductions credits from energy efficiency and renewable energy programs. To satisfy these requirements the ESL has been developing and refining a method to annually calculate creditable emissions reductions from wind and other renewable energy resources for the TCEQ. This paper provides a detailed description of the methodology developed to calculate the emissions reductions from electricity provided by a wind farm. Details are presented for the wind farm Sweetwater I as well as results from the application of this procedure to all the wind energy providers in the Texas ERCOT region.

INTRODUCTION

Texas is now the largest producer of wind energy in the United States. The 79th Texas legislature through Senate Bill 20, House Bill 2481, House Bill 2129, and amended Senate Bill 5 has created legislative requirements for wind and renewable generation. Wind developers are attracted to Texas by the many windy sites suitable for wind development here. As of March 2007 the capacity of installed wind turbines totaled 3026 MW with another 887 MW under construction (Figure 1)[1]. The capacity announced for new projects is 3,125 MW by 2010. Electricity produced by wind farms in Texas reduces emission of pollutants from conventional power plants. As new wind farms come online and older turbines are retired, creditable accounting of pollution credits for wind energy requires normalization of the power generation to a base year. This paper presents the methodology that was developed to assist the Texas Commission on Environmental Quality (TCEQ) for calculating the electricity savings and emissions reductions from wind energy within the Electrical Reliability Council of Texas (ERCOT) region for the state's SIP credits. In the proposed method, the ASHRAE Inverse Model Toolkit (Kissock et al. 2003; Haberl et al. 2003) is used for weather normalization of the daily wind power generation to the base year selected by TCEQ (i.e., 1999). The US EPA's Emissions and Generations Resource Integrated Database (eGRID) is used for calculating annual and Ozone Season Day's NOx emissions reductions from the wind energy programs[2].

METHODOLOGY

To determine the performance of a wind farm in the 1999 base year, at least one year of hourly wind power generation data from a wind farm and the corresponding hourly on-site wind speed for the same period and the base year need to be collected. Unfortunately, it is difficult to obtain wind data at the site of the farm in 1999 because most wind farms did not exist at that time. In fact, even for an operating wind farm, on-site wind data may not be available on a long-term basis. On the other hand, the National Oceanic and Atmospheric Administration (NOAA), has a network of weather stations that provide ongoing as well as archived data on wind speeds at a 10 meter high tower as well as a number of other meteorological variables. Therefore, it was decided

[1] Wind project information obtained from Public Utility Commission of Texas (www.puc.state.tx.us) and Electric Reliability Council of Texas (ERCOT).

[2] Currently, the TCEQ is using a special version of eGRID that projects emissions to 2007 using a 1999 base year.

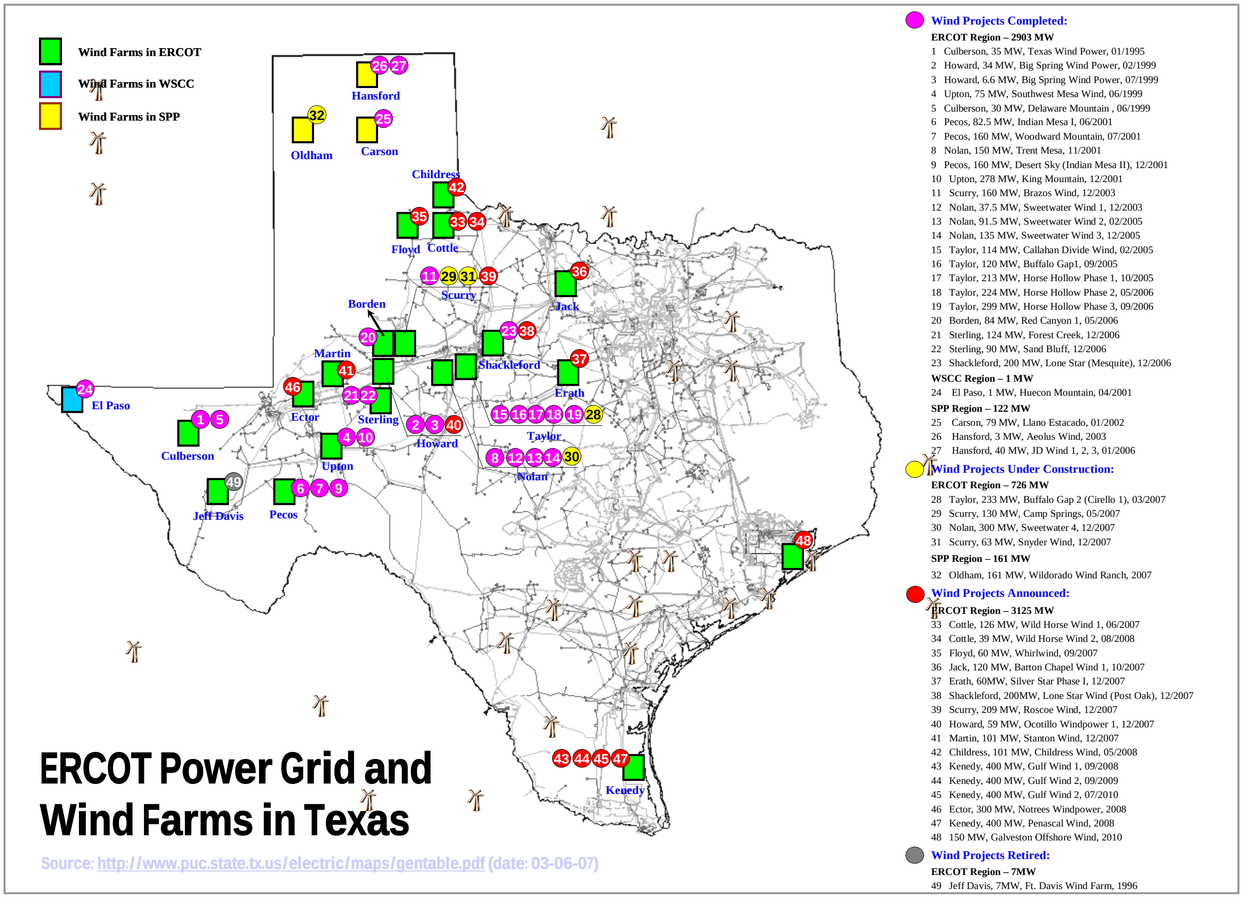

Figure 1: Completed and Announced Wind Projects in Texas

that the wind speed from the nearest NOAA weather station to be used in the weather normalization procedure. Accordingly the hourly measured wind power generation data was obtained from ERCOT for each wind farm.

Description of the Daily Modeling Procedure

The proposed procedure includes modeling of the daily power production from wind farms using the ASHRAE's Inverse Model Toolkit (IMT). This procedure forecasts wind power for the 1999 base year.

For a given site the measured hourly wind power production from a wind farm for the study year (i.e., 2005), the corresponding hourly wind speed data from the nearest National Oceanic & Atmospheric Administration (NOAA) weather station in 2005, and the hourly NOAA wind speed for the base year 1999 were collected.

Next, the hourly data were converted to daily data and a daily performance curve was developed for the specific facility by regressing the daily electricity production from the wind farm against the daily average wind data from the selected NOAA weather station for the study year.

Finally, the coefficients from the 2005 regression and the 1999 average daily NOAA wind speed data were used to calculate the daily electricity the wind farm would have produced in 1999.

Analysis on Sweetwater I Wind Farm

In this section, the Sweetwater I wind farm is used as an example to illustrate the development of the methodology in detail.

The Sweetwater I wind farm was completed and commenced operation in late December 2003. It is a 37.5-megawatt project that has 25 GE Wind turbines, located in Nolan County, Texas. The project characteristics are listed in Table 1.

Table 1: Project Characteristics

Wind Turbines	GE 1.5s 1500 kW
Tower Height	80 m
Rotor Diameter	70.5 m
Rotor Speed	11-22 rpm
Number of Turbines	25
Generating Capacity	37.5 MW
Projected Annual Output	141,748 mph

1. Weather and Power Data:

In Figure 2, the 2005 hourly wind power data were plotted against 2005 hourly NOAA wind measurements at Abilene (ABI) for Sweetwater Wind Farm. The power curve from the manufacture is also shown super-imposed on the hourly data. The data shows scatter and discretization due to the NOAA measurements. It is also found that using hourly model to predict wind power generation in the base year was impractical because of the significantly different profiles of on-site wind versus the NOAA wind.

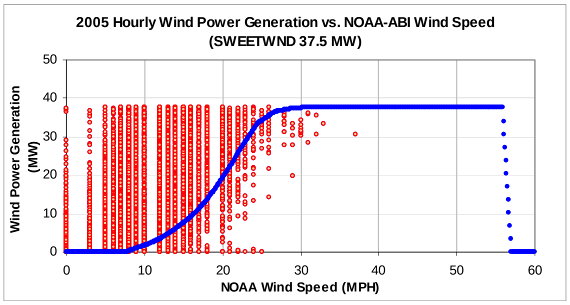

Figure 2: Hourly Wind Power vs. NOAA-ABI Wind Speed (2005)

In Figure 3 the hourly electricity produced by the wind farm were summed to daily totals and plotted against the daily average wind speed using the NOAA measurements. This figure shows that the daily wind power data had an acceptable correlation to the NOAA wind data and are more appropriate for the modeling purpose.

3. Modeling of Turbine Power vs. Wind Speed

Figure 3 shows the application of a three-parameter change-point linear regression to the average daily wind power output versus average daily wind speeds using ASHRAE's IMT. The summary of the model coefficients from the daily model are listed in Table 2. This table shows that the NOAA daily model is well described with a root-mean-squared error (RMSE) of 112.8 MWh/day for 2005. In Table 3 the predicted electricity production using the daily model is shown for 2005 to compare against the measured monthly electricity for the same period. Table 3 shows that, on average, the model performs well, yet still contains month-to-month variations, for example, in July 2005. In July, the data can be seen to be unevenly distributed around the model predictions (Figure 4), which provides significant over-prediction during the first half of the month. During the second half of the month the model shows good agreement with measured values.

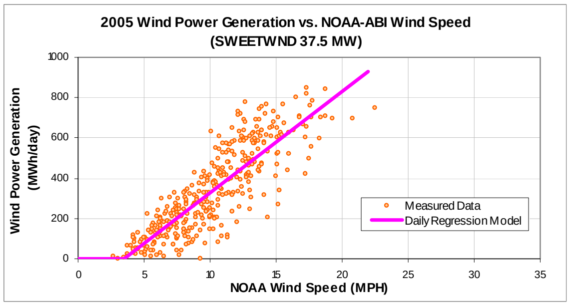

Figure 3: Daily Wind Power vs. NOAA-ABI Wind Speed (2005)

Table 2: Model Coefficients

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-172.9893
Left Slope (MWh/mph-day)	50.1761
RMSE (MWh/day)	112.8012
R2	0.7237
CV-RMSE	32.8%

Table 3: Predicted Wind Power Using Daily Models

Month	No. Of Days	Average Daily Wind Speed (MPH)	Measured Power Generation (MWh)	Predicted Power Generation Using Daily Model (MWh)	Diff.	CV-RMSE
Jan-05	31	10.34	11,105	10,726	3.41%	42.79%
Feb-05	28	8.92	7,130	7,729	-8.40%	43.40%
Mar-05	31	11.54	11,611	12,584	-8.38%	32.27%
Apr-05	30	12.97	13,597	14,331	-5.40%	22.98%
May-05	30	11.03	11,029	11,417	-3.51%	30.15%
Jun-05	30	11.86	13,323	12,660	4.97%	20.98%
Jul-05	31	9.94	8,465	10,102	-19.34%	35.09%
Aug-05	31	8.26	7,882	7,489	4.98%	31.71%
Sep-05	30	9.29	9,062	8,789	3.01%	36.16%
Oct-05	30	9.26	9,167	8,428	8.06%	35.57%
Nov-05	30	10.33	11,094	10,364	6.57%	37.64%
Dec-05	31	10.02	11,322	10,227	9.66%	34.43%
Total	363	10.32	124,787	124,846	-0.05%	32.76%
Total in OSP (07/15-09/15)	63	8.98	18,131	17,485	3.56%	24.02%

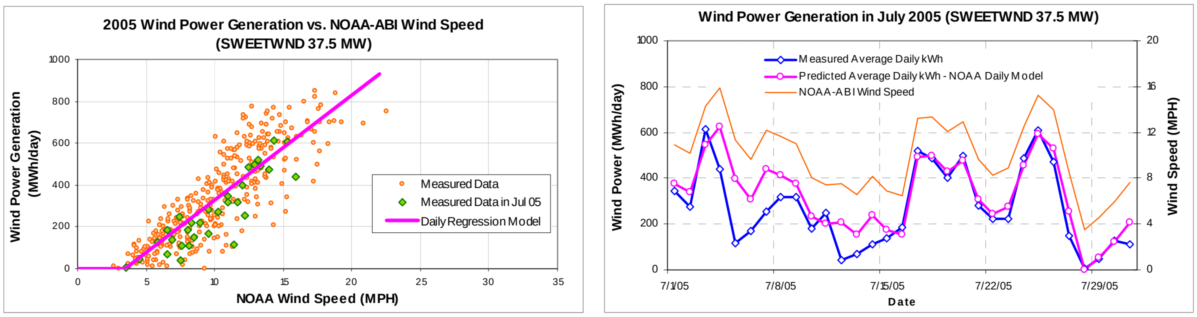

Figure 4: Measured Power Production in July 2005

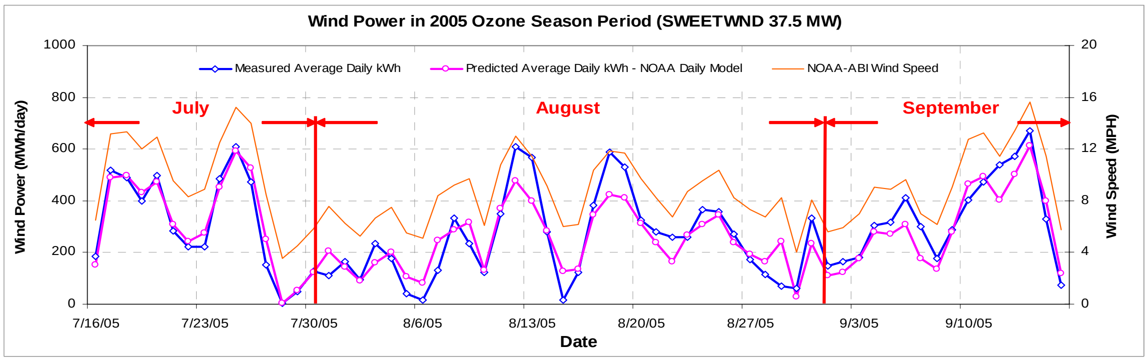

Figure 5: Predicted Wind Power in OSP Using NOAA-ABI Wind Speed (2005)

Figure 5 shows the predicted electricity production from the wind farm as a time-series trace for the Ozone Season Period (OSP), from July 15 to September 15, using the NOAA daily model. The measured power output for the same period is also presented for comparison purposes. In general, it shows the model performed well on the daily basis tracking the measured wind power production.

4. Testing of the Model

To test the performance of the NOAA daily model, the 2005 model coefficients were applied to the 2004 NOAA daily wind speed to predict the daily wind power generation in 2004. The predicted daily wind power was then summed to monthly to compare against the monthly measurements from ERCOT, as shown in Table 4. The largest error occurred in November 2005 (16.3%) when the measured daily power production was not evenly distributed around the model predictions (Figure 6). With the exception of the November data, the test results show that this model is sufficiently robust to allow for its use in projecting wind production into other weather base years.

Table 4: Predicted vs. Measured Wind Power in 2004

Month	2004 Predicted MWh/mo Daily Model	2004 Measured-ERCOT MWh/mo	2004 Diff. Daily Model
Jan	11,914	11,898	-0.10%
Feb	11,303	11,073	-2.10%
Mar	11,813	12,625	6.40%
Apr	12,869	12,238	-5.20%
May	14,886	16,017	7.10%
Jun	12,063	11,049	-9.20%
Jul	10,595	10,055	-5.40%
Aug	8,645	8,375	-3.20%
Sep	7,989	8,067	1.00%
Oct	8,798	9,974	11.80%
Nov	8,673	7,456	-16.30%
Dec	9,553	10,543	9.40%
Total	129,103	129,371	0.20%

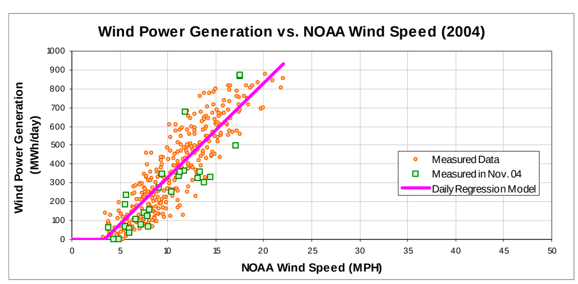

Figure 6: Measured Power Production in November 2004

5. Prediction of Wind Power in the 1999 Base Year

To predict the wind power the wind farm would have produced in 1999, the resultant 2005 coefficients (Table 2) from the 3-parameter model were applied to 1999 average daily NOAA-ABI wind speed. Table 5 shows that the estimated annual power production increased about 15% when compared against 2005 because 1999 was much windier than 2005. The average daily power production during the Ozone Season Period increased as well. This result highlights the importance of a weather normalization procedure for a more accurate estimation on wind power production in base year.

Table 5: Predicted Power Production in 1999 Using 2005 Daily Model

1999 Estimated MWh/yr	2005 Measured MWh/yr
143,711	125,249
1999 OSP Estimated MWh/day	2005 OSP Measured MWh/day
314	288

Capacity Factor Analysis

In addition to forecasting the power production, TCEQ was also interested in reliable capacity factors in the base year. The predicted monthly capacity factors for 2005 using the daily model and the measured monthly capacity factors for the same period are shown in Figure 7. Figure 8 shows the predicted capacity factors using the 2005 NOAA model from January to December for the periods 1999 through 2005, as well as the measured monthly capacity factor in 2005 and the average monthly capacity factors for these seven years, using daily NOAA model. In Figure 7, the model shows good agreement tracking the measured capacity factor. In comparison, in Figure 8, it can be seen that there is more variation in the year-to-year wind speeds than the uncertainty from the model. It also shows the importance of weather normalizing the wind speeds back to the base year.

According to the modeled results, the annual capacity factors for the years 1999 to 2005 vary between 38.2% and 43.8%, with an average of 41.5%. The highest electricity production occurs in the spring months. It is interesting to note that the variation across the same month of these years can be more than 20%, for example, March and May, due to the significantly different wind conditions.

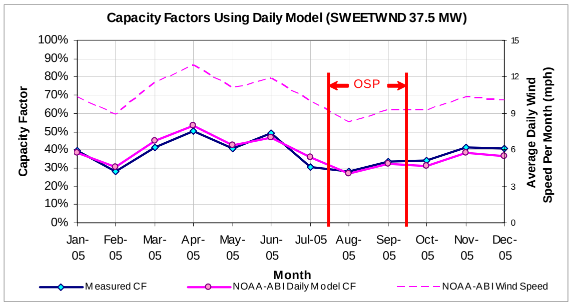

Figure 7: Predicted Capacity Factors Using Daily Models (2005)

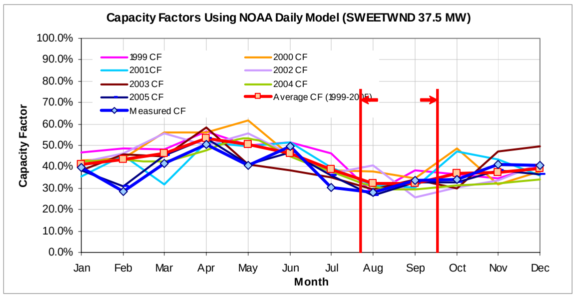

Figure 8: Predicted Capacity Factors Using Daily Models (1999-2005)

APPLICATION TO ALL WIND FARMS

The methodology presented in the previous section was applied to all the wind farms within the Texas ERCOT region to calculate the total energy savings from wind power programs for the NOx emissions credits. Table 6 shows the summary of this application.

As seen in Table 6, the predicted power production in the 1999 base year (4,682,682 MWh/yr) increased approximately 17% when compared to what was measured in 2005 (4,008,696MWh/yr). For the Ozone Season Period, the estimated average daily power production projected to be 11,310 MWh/day, a 26% increase from measured in 2005 (8,949 MWh/day). This is because for all four NOAA weather stations involved in the modeling, 1999 was windier than 2005 (Figure 9). For Ozone Season Period, 1999 was windier than 2005 for weather stations at Abilene (ABI) and For Stockton (FST). For Midland (MAF) and Guadalupe Pass (GDP), 2005 was windier.

Table 6 also presents the modeling results for each wind farm. For the Horse Hollow wind farm, which started operation in July 2005, the power production during the testing period (July through September) was therefore excluded from the analysis. Therefore, only three months of data were used in the modeling.

Table 6: Summary of Power Production for All Wind Farms

Wind Unit Name	County	NOAA Weather Station	Capacity (MW)	2005 Measured (MWh/yr)	1999 Estimated Using Daily Model (MWh/yr)	Increase - 1999 vs. 2005 (MWhyr)	2005 OSP Measured (MWh/day)	1999 OSP Estimated (MWh/day)	Increase - 1999 vs. 2005 (MWh/day)
BRAZ_WND_WND1	SCURRY	ABI	160	290,411	331,570	41,159	641	724	83
BRAZ_WND_WND2	SCURRY	ABI		170,608	191,907	21,299	368	420	52
CALLAHAN_WND1	TAYLOR	ABI	114	332,572	433,697	101,125	831	955	124
DELAWARE_WIND_NWP	CULBERSON	GDP	30	66,267	68,298	2,031	103	114	11
H_HOLLOW_WND1 *	TAYLOR	ABI	213	203,673	328,264	124,591			
INDNENR_INDNENR	PECOS	FST	160	246,131	273,888	27,757	625	639	14
INDNENR_INDNENR_2	PECOS	FST		224,842	250,714	25,872	585	583	-2
INDNNWP_INDNNWP_J01	PECOS	FST	82.5	142,264	158,580	16,316	372	369	-3
INDNNWP_INDNNWP_J02	PECOS	FST		87,914	97,971	10,057	230	228	-2
KING_NE_KINGNE	UPTON	MAF	79	172,198	192,701	20,503	378	417	39
KING_NW_KINGNW	UPTON	MAF	79	207,634	227,493	19,859	534	515	-19
KING_SE_KINGSE	UPTON	MAF	40	85,097	95,931	10,834	182	204	22
KING_SW_KINGSW	UPTON	MAF	79	190,202	209,671	19,469	474	469	-5
KUNITZ_WIND_LGE_J01	CULBERSON	GDP	35	42,119	43,855	1,736	40	67	27
KUNITZ_WIND_LGE_J02	CULBERSON	GDP		17,210	17,913	703	16	27	11
SGMTN_SIGNALMT	HOWARD	MAF	41	93,939	103,431	9,492	217	232	15
SW_MESA_SW_MESA	UPTON	MAF	75	197,694	217,416	19,722	522	488	-34
SWEETWN2_WND2	NOLAN	ABI	91.5	262,537	323,218	60,681	623	717	94
SWEETWND_WND1	NOLAN	ABI	37.5	125,259	143,711	18,452	288	314	26
TRENT_TRENT	NOLAN	ABI	150	492,444	563,714	71,270	1,095	1,227	132
WOODWRD1_WOODWRD1	PECOS	FST	80	185,149	211,627	26,478	401	474	73
WOODWRD2_WOODWRD2	PECOS	FST	80	172,532	197,112	24,580	424	442	18
TOTAL			1,627	4,008,696	4,682,682	673,986	8,949	11,310	2,361

* Only three months data is good for modeling (Oct 05 to Dec 05). The 1999 estimated MWh/yr includes six months since the farm started operating in July 2005.

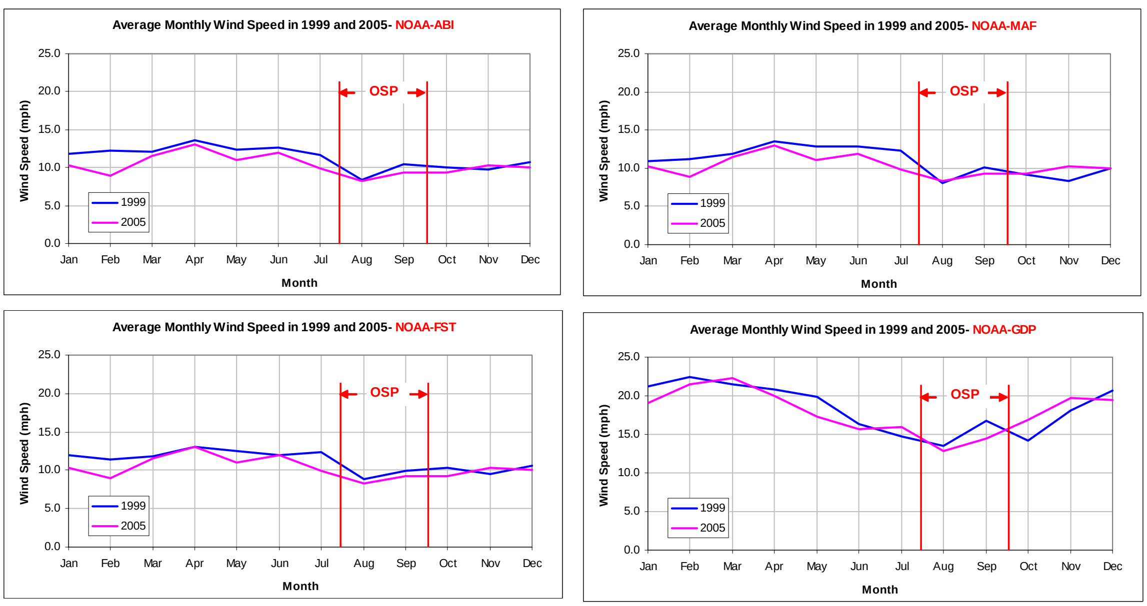

Figure 9: 1999 and 2005 Monthly Average Wind Speed for Four NOAA Weather Stations

From this analysis, it was concluded that use of a weather normalization for predicting the 1999 base-year production based on 2005 measured power production is more accurate than simply using the measured 2005 power production as the base year power production.

UNCERTAINTY ANALYSIS

To calculate the uncertainty, a prediction uncertainty, $\sigma^2\left(\hat{E}_{pred,j}\right)$ was used assuming no autocorrelation effects in the data used to generate the linear model. Use of such a model, for a particular observation, *j*, during any time at a particular condition can be represented as follows (Reddy, et al. 1992):

$$\sigma^2\left(\hat{E}_{pred,j}\right) = MSE\left(\hat{E}_i\right)\cdot\left[1+\frac{1}{n}+\frac{\left(V_j-\overline{V}_n\right)^2}{\sum_{i=1}^{n}\left(V_i-\overline{V}_n\right)^2}\right] \quad (1)$$

The mean square error, $MSE\left(\hat{E}_i\right)$, during the period of the development of the linear model can be calculated by

$$MSE\left(\hat{E}_i\right)=\left[\frac{1}{n-(k+1)}\right]\sum_{i=1}^{n}\left(E_i-\hat{E}_i\right)^2 \quad (2)$$

Where n is the number of days in the period used for the developed model, k is the number of regression variables in the linear model, and $\overline{V}_n$ is the mean value of the velocity on the modeling period.

The last term in the brackets of the equation 2, accounts for the increase in the variance of the energy prediction for any particular observation, j, which is different of the centroid of the modeling data. On the other hand, the second term accounts for the variance in predicting the mean energy predicted for the observation j.

The total uncertainty for a period of interest, of m days, is the sum of all the wind energy predicted $\hat{E}_{pred,j}$ in each individual observation.

This can be calculated assuming that

$$\sum_{j=1}^{m}\sigma^2\left(\hat{E}_{pred,j}\right)=\sigma^2\left(\sum_{j=1}^{m}\left(\hat{E}_{pred,j}\right)\right)=\sigma^2\left(\hat{E}_{pred,total}\right) \quad (3)$$

with the total prediction variance –uncertainty, obtained through

$$\sigma^2\left(\hat{E}_{pred,total}\right)=MSE\left(\hat{E}_i\right)\cdot m\cdot\left[1+\frac{1}{n}+\frac{\sum_{j=1}^{m}\left(V_j-\overline{V}_n\right)^2}{m\sum_{i=1}^{n}\left(V_i-\overline{V}_n\right)^2}\right] \quad (4)$$

Note that the last equation is affected by the number of days that the wind energy will be predicted, the number of days used for the modeling development and the uncertainty due to the distances between the data predicted and the centroid of the modeling data. Therefore, increasing n and m yields an effective relative decrease in the uncertainty which is expected.

Table 7 presents all the statistics parameters for the daily linear models of all the wind farms in Texas. Table 8 shows the uncertainty of applying the linear models to predict the energy generation that they would have had in the year 1999, ranging from 2.4% to 5.5%. The results indicate that the daily models are reasonably reliable for predicting the performance of the wind farm in the base year within the same range of wind conditions.

Table 7: 1999 Annual and OSP Uncertainty of the Power Generation Prediction Using the Linear Daily Models

Wind Farm	Ycp	Left Slope	$AdjR^2$	RMSE	CV-RMSE	# Days
BRAZ_WND_WND1	-404.82	116.27	0.62	334.6	42.10%	364
BRAZ_WND_WND2	-228.04	66.74	0.62	190.6	41.50%	361
CALLAHAN_WND1	-473.03	147.09	0.79	276.2	26.00%	305
H_HOLLOW_WND1 *	-870.88	229.13	0.62	636.4	49.40%	92
INDNENR_INDNENR	-265.72	90.84	0.49	298.2	44.30%	364
INDNENR_INDNENR_2	-259.82	84.63	0.46	290.7	47.30%	364
KING_NE_KINGNE	-313.24	77.09	0.64	179.1	38.00%	365
KING_NW_KINGNW	-200.28	75.53	0.48	242.8	42.70%	365
KING_SE_KINGSE	-178.09	40.38	0.64	93.1	39.90%	365
KING_SW_KINGSW	-230.38	73.79	0.54	210.7	40.40%	365
SWEETWN2_WND2	-316.39	106.43	0.73	237.1	30.40%	333
SWEETWND_WND1	-172.99	50.18	0.72	112.8	32.80%	363
TRENT_TRENT	-718.21	200.32	0.73	439.5	32.60%	364
DELAWARE_WIND_NWP	-112.61	16.35	0.66	76.4	42.00%	349
INDNNWP_INDNNWP	-163.63	53.47	0.44	192	49.40%	364
INDNNWP_INDNNWP2	-101.55	33.07	0.44	118.6	49.40%	364
KUNITZ_WIND_LGE	-101.97	12.1	0.6	63.8	54.90%	349
KUNITZ_WIND_LGE2	-41.55	4.94	0.6	26	54.80%	349
SGMTN_SIGNALMT	-109.06	35.98	0.48	116.2	45.20%	365
SW_MESA_SW_MESA	-220.85	74.87	0.47	242.7	44.80%	365
WOODWRD1_WOODWRD1	-379.24	85.71	0.61	219	43.30%	364
WOODWRD2_WOODWRD2	-350.53	79.59	0.66	182.6	38.70%	364

Table 8: 1999 Annual and OSP Uncertainty of the Power Generation Prediction Using the Linear Daily Models

Wind Farm	1999 Annual				1999 Ozone Season Period (OSP)			
	Pred Days	Total Variance	Total Estimated	Rel Uncer	Pred Days	Total Variance	Total Estimated	Rel Uncer
BRAZ_WND_WND1	365	12,549	331,570	3.80%	63	5,208	45,617	11.40%
BRAZ_WND_WND2	365	7,148	191,907	3.70%	63	2,967	26,458	11.20%
CALLAHAN_WND1	365	10,364	433,697	2.40%	63	4,301	60,173	7.10%
H_HOLLOW_WND1 *	365	23,949	626,846	3.80%	63	9,917	85,292	11.60%
INDNENR_INDNENR	363	11,155	273,888	4.10%	63	4,642	40,256	11.50%
INDNENR_INDNENR_2	365	10,904	249,340	4.40%	63	4,525	36,733	12.30%
KING_NE_KINGNE	365	6,721	192,701	3.50%	63	2,789	26,266	10.60%
KING_NW_KINGNW	365	9,112	227,493	4.00%	63	3,781	32,451	11.70%
KING_SE_KINGSE	365	3,492	95,931	3.60%	63	1,449	12,878	11.30%
KING_SW_KINGSW	365	7,906	209,671	3.80%	63	3,280	29,521	11.10%
SWEETWN2_WND2	365	8,895	323,218	2.80%	63	3,691	45,168	8.20%
SWEETWND_WND1	365	4,231	143,711	2.90%	63	1,756	19,794	8.90%
TRENT_TRENT	365	16,487	563,714	2.90%	63	6,843	77,287	8.90%
DELAWARE_WIND_NWP	365	2,864	68,298	4.20%	61	1,171	7,201	16.30%
INDNNWP_INDNNWP	363	7,183	157,711	4.60%	63	2,989	23,239	12.90%
INDNNWP_INDNNWP2	363	4,436	97,434	4.60%	63	1,846	14,354	12.90%
KUNITZ_WIND_LGE	365	2,393	43,856	5.50%	60	970	4,201	23.10%
KUNITZ_WIND_LGE2	365	976	17,913	5.40%	60	396	1,717	23.00%
SGMTN_SIGNALMT	365	4,361	103,431	4.20%	63	1,809	14,602	12.40%
SW_MESA_SW_MESA	365	9,106	217,416	4.20%	63	3,778	30,765	12.30%
WOODWRD1_WOODWRD1	363	8,193	210,468	3.90%	63	3,410	29,882	11.40%
WOODWRD2_WOODWRD2	363	6,829	196,032	3.50%	63	2,842	27,851	10.20%

Also, in the same table is the uncertainty related to the predicted wind generation for each wind farm in the 1999 Ozone Season Period, which are higher than the annual values. This is because the uncertainty analysis for OSP was based on annual models. A model developed using only the measured power in the OSP would improve the reliability of the wind power prediction in the OSP. Hence, the uncertainty for the OSP is probably a value less than the OSP value shown, but greater than the annual value shown.

EMISSIONS REDUCTION

To calculate the NOx emissions reduction from the wind projects within ERCOT region, 2007 annual and OSD eGRID has been used. The total MWh savings for each Power Control Area are used to calculate the NOx emissions reduction for each of the different county through the USA-EPA prescribed emission fractions. According the developed models, the total MWh savings in the base year 1999 for the wind farms built before September 2001 within the ERCOT region is 2,674,858 MWh and 6,652 MWh/day in the Ozone Season Period. The total NOx emissions reductions across all the counties amount to 1,639 tons/yr and 4.08 tons/day for the Ozone Season Period.

SUMMARY

In this paper, a methodology for predicting wind power the wind farms would have produced in the 1999 base year using 2005 measured wind power generation for each wind farm and the wind speed data from the nearest NOAA weather stations is discussed. The total wind power production in the base year (1999) and the corresponding emissions reduction from all the wind farms in the ERCOT region using this procedure is then presented to show the improved accuracy of using this weather normalization procedure compared to the non-weather normalization procedure. The uncertainty analysis performed on all the daily regression models shows that the developed daily regression models are sufficiently reliable to allow for their use in projecting wind production into other weather base years.

REFERENCES

Haberl, J., Claridge, D., Kissock, K. 2003. "Inverse Model Toolkit (1050RP): Application and Testing, ASHRAE Transactions-Research, Vol. 109, Part 2, pp. 435-448, 2003.

Kissock, K., Haberl, J., Claridge, D. 2003. "Inverse Model Toolkit (1050RP): Numerical Algorithms for Best-Fit Variable-Base Degree-Day and Change-Point Models", ASHRAE Transactions-Research, Vol. 109, Part 2, pp. 425-434.

Reddy, T.A., Kissock, K., and Claridge D., 1992, "Uncertainty Analysis in Estimating building energy retrofit Savings in the LoanSTAR Program", Proceedings of the ACEEE 1992 summer Study on energy Efficiency in Buildings. Commercial Performance: Analysis and Measurement, Washington, D.C.