DEVELOPMENT OF A WEB-BASED, EMISSIONS REDUCTION CALCULATOR FOR GREEN POWER PURCHASES FROM TEXAS WIND ENERGY PROVIDERS

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ABSTRACT

Four areas, involving 16 counties, in Texas have been designated by the United States Environmental Protection Agency (EPA) as non-attainment areas because ozone levels exceed the National Ambient Air Quality Standard (NAAQS) maximum allowable limits. These areas face severe sanctions if attainment is not reached by 2007. Four additional areas in the state are also approaching national ozone limits (i.e., affected areas).

In 2001, the Texas State Legislature formulated and passed the Texas Emissions Reduction Plan (TERP), to reduce ozone levels by encouraging the reduction of emissions of NOx by sources that are currently not regulated by the state. Ozone results from photochemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOCs) in the presence of sunlight. An important part of this legislation is the State's energy efficiency program, which includes reductions in energy use and demand that are associated with the adoption of the 2000 International Energy Conservation Code (IECC 2000), including the 2001 Supplement (IECC 2001) which represents one of the first times that the EPA is considering State Implementation Plan (SIP) credits from energy conservation and renewable energy– an important new development for building efficiency professionals, since this could pave the way for documented procedures for financial reimbursement for building energy conservation from the state's emissions reductions funding.

This paper provides a detailed description of the procedures that have been developed to calculate the emissions reductions from electricity provided by wind energy providers in the Texas ERCOT region, including an analysis of actual hourly wind power generated from a wind turbine in Randall County, Texas.

INTRODUCTION

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to further reduce ozone levels by encouraging the reduction of emissions of NOx by sources that are currently not regulated by the state, including area sources (e.g., residential emissions), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.)[1]. An important part of this legislation is the evaluation of the State's new energy efficiency programs, which includes reductions in energy use and demand that are associated with specific utility-based energy conservation measures, and implementation of the International Energy Conservation Code (IECC), published in 2000 as amended by the 2001 Supplement (IECC 2000; 2001). In 2001 thirty-eight counties out of the 254 counties in Texas were designated by the EPA as either non-attainment or affected areas[2]. In 2003, three additional counties were classified as affected counties[3], bringing the total to forty-one counties (sixteen non-attainment and twenty-five affected counties).

Texas is the second-largest producer of wind energy in the United States. Wind developers are attracted to Texas by the many windy sites suitable for wind development here. The capacity of installed wind turbines totals 1,407 MW as of April 2005 and the planned capacity for new projects[4] rises to 3,700

[1] In the 2003 Texas State legislative session, the emissions reductions legislation in Senate Bill 5 was modified by House bill 3235, and House bill 1365. In general, this new legislation strengthens the previous legislation, and did not reduce the stringency of the building code or the reporting of the emissions reductions.

[2] The sixteen counties designated as non-attainment counties include: Brazoria, Chambers, Collin, Dallas, Denton, El Paso, Fort Bend, Hardin, Harris, Jefferson, Galveston, Liberty, Montgomery, Orange, Tarrant, and Waller counties. The twenty-two counties designated as affected counties include: Bastrop, Bexar, Caldwell, Comal, Ellis, Gregg, Guadalupe, Harrison, Hays, Johnson, Kaufman, Nueces, Parker, Rockwall, Rusk, San Patricio, Smith, Travis, Upshur, Victoria, Williamson, and Wilson County.

[3] These counties are Henderson, Hood and Hunt counties in the Dallas – Fort Worth area.

[4] Testimony presented by Mr. Gregg Cooke to the Texas State Legislature, May, 2005.

MW by 2009 to 7,000 MW by 2015. This paper presents the procedures that have been developed to calculate the electricity savings from green power purchases from Texas wind energy providers. In this method, the ASHRAE Inverse Model Toolkit (IMT) (Kissock, Haberl et al. 2003) is used for weather normalization of the monthly electric generation data, and includes a peak-extractor for calculating peak-day, or peak period electricity savings from monthly wind generation data, and the use of the EPA's Emissions and Generations Resource Integrated Database (eGRID) for calculating NOx emissions reductions for the electric utility provide associated with the user.

METHODOLOGY

Wind Power Generation Data Analysis

To develop and test a methodology for calculating NOx emissions reductions from green power purchases, hourly data from an actual wind electricity generator[5] with a 13.4-m (44-ft) rotor diameter, installed in Randall County, Texas Figure 1 and Figure 2) were used as a case study site to calculate and verify the electricity savings and emissions reduction. The wind turbine is an Enertech 44 wind turbine with a rated gearbox capacity of 40 kW, and a rated generator capacity of 60 kW. Additional details about the wind turbine are provided in Table 1.

Figure 1. The Enertech Wind Turbine Installed in Randall County, Texas

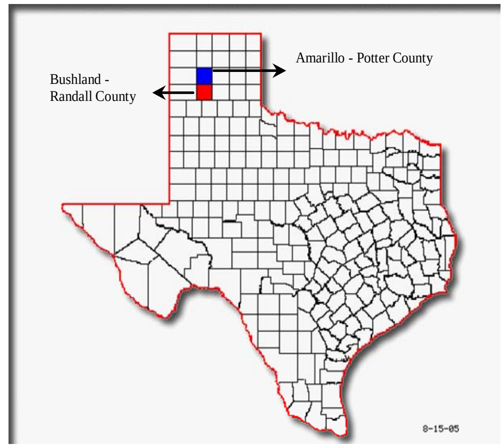


Figure 2. Texas Map Showing Randall County (red) and Potter County(blue).

Table 1: Specifications for Wind Turbine in Randall County, Texas.

SYSTEM	
Type	Utility interface
Axis of rotor	Horizontal
Location of rotor (with respect to tower)	Downwind
Number of blades	Three
Centerline hub height	25 m (82 ft)
ROTOR	
Rotor diameter	13.4 m (44 ft)
Rotor type	Fixed pitch
Rotor speed at rated power	57 rpm (40 kW) and 67 rpm (60 kW)
Blade material	Wood/epoxy laminate, fiberglass coat
GENERATOR	
Type	Induction, three-phase (40 & 60 kW)
Output voltage	480 V (40 & 60 kW)
Frequency	60 Hz
TRANSMISSION	
Type	Double reduction, Planetary
Ratio	1:32 (40 kW) and 1:27 (60 kW)
YAW SYSTEM	
Yaw control	None, rotates freely 360 degrees
BRAKES	
Normal stops	Dynamic brake
Parking brake	Electro-mechanical, fail safe spring
ROTOR SPEED CONTROL	
Rotor overspeed (Normal operation)	Blades stall in high winds
Rotor overspeed (Emergency)	Control system applied braking
Rotor overspeed (Emergency back up)	Blade tip brakes deploy
TOWER	
Type	Galvanized self-supporting
Height	24.4 m (80 ft)
PERFORMANCE	
Rated wind speed	13.4 m/s (30 mph)
Start-up wind speed	5.4 m/s (12 mph)
Shut-down wind speed	3.2 m/s (8 mph)
Cut-out wind speed	22.3 m/s (50 mph)

In Figure 3 the measured, hourly electricity produced by the wind turbine is shown for the 2001/2002 period. These data are plotted against hourly, on-site wind measurements[6] in Figure 4. In Figure 5 the same hourly electricity data are plotted

[5] Data for this site was provided by Alternative Energy Institute from West Texas A&M University. The wind turbine operated for 53.6% of the hours since installation and recorded a capacity factor of 20.4%. Although several component failures occurred during the testing period, the wind turbine had an availability of 90%.

[6] On-site wind measurements were taken at a height of 33 ft.

against the coincident hourly wind data obtained from National Oceanic & Atmospheric Administration (NOAA) from the nearby Amarillo Station[7], which shows considerably more scatter due to differences in the wind velocity measurements, and physical separation of wind measurements from the wind turbine[8]. As expected, these differences become less pronounced when one compares average daily electricity production against average daily wind measurements[9], as shown in Figure 6 and Figure 7. Comparisons of the average daily production from monthly data have a similar convergence as shown in Figure 8 and Figure 9, although there is a noticeable shift in the trend, which is due to the higher recorded daily wind speeds for the average data (Figure 6 and Figure 7) versus the average-day, monthly data (Figure 8 and Figure 9).

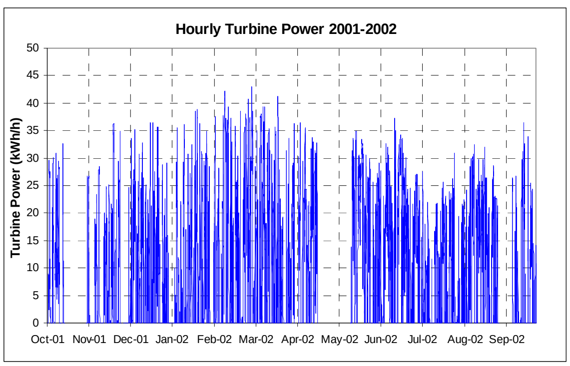


Figure 3. Measured Hourly Turbine Power (2001-2002)

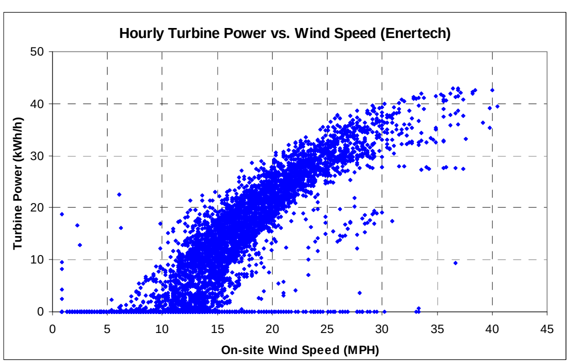


Figure 4. Hourly Turbine Power vs. On-site Wind Speed

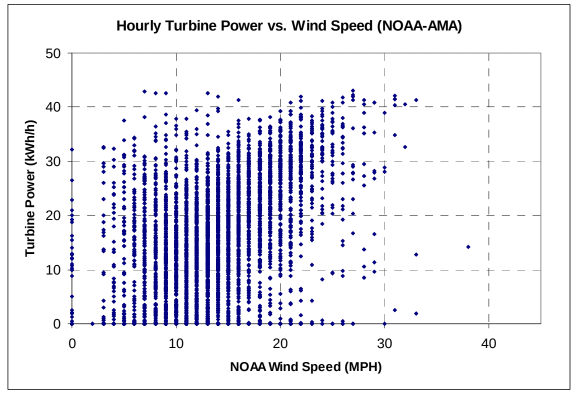


Figure 5. Hourly Turbine Power vs. NOAA Wind Speed

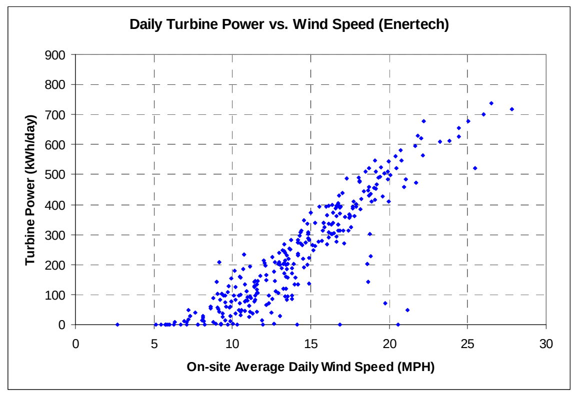


Figure 6. Daily Turbine Power vs. On-site Wind Speed

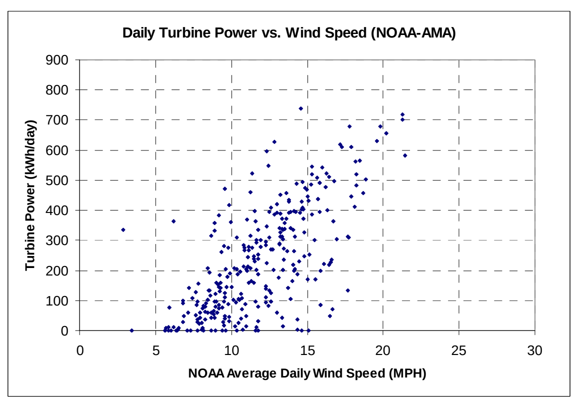


Figure 7. Daily Turbine Power vs. NOAA Wind Speed

Application of a 3-parameter change-point linear regression[10] to the average daily wind power output

[7] The NWS wind measurements are from the Amarillo airport, located in Potter County.

[8] The on-site wind measurements were taken with an integrating data logger, and thereby represent the average hourly wind speed. The NWS wind measurements represent an average wind speed taken over a 3 to 5 minute interval at about 15 minutes before the hour, and therefore represent a peak gust measurement, which is required by the FAA for pilots at airports.

[9] Similar trends had been previously observed by Crowley and Haberl (1994).

[10] The ASHRAE Inverse Model Toolkit - IMT (Kissock, Haberl et al. 2003) was used to calculate the 3-parameter model shown, and included the insertion of dummy zeros below the change-point to improve the model's fit. The daily time period for the regression was chosen to match the daily output from the wind turbine with the daily NOx emissions reductions for the Ozone Season Period.

versus average period wind speeds is shown in Table 2, Figure 8 and Figure 9. The resultant coefficients (Table 2) from the 3-parameter model were sufficiently robust to allow for their use in projecting the daily average wind production into other weather base years. In Table 3 the measured and predicted electricity production using the 3-parameter, change-point linear monthly model is shown for the 2001 to 2002 period. This model is moderately well described (Table 2) with a root-mean-squared error (RMSE) of 21.8 kWh/month, and a coefficient of variation of root-mean-squared error (CV(RMSE)) of 29.1% for the 2001 to 2002 period. Table 3 shows that, on average, the model performs well, but does contain significant month to month variations (July and November). Table 4 shows a predicted[11] 1999 annual electricity production of 94,894 kWh, an Ozone Episode Period peak day[12] production of 184 kWh/day, and an average daily production of 189 kWh/day for the 34 day Ozone Episode period.

Table 2. Coefficients of 3PC Model for Monthly Daily Turbine Power

	3PC-NOAA-AMA	3PC-Enertech
Ycp (Y Value at Change Point)	0.0150	-0.0594
Right Slope	54.1917	36.2811
Change Point (X Value at Change Point)	7.5007	7.4265
R2 (Coefficient of Determination)	0.9676	0.9674
AdjR2 (Adjusted Coefficient of Determination)	0.9667	0.9665
RMSE (Root Mean Square Error)	21.8854	21.9790
CV-RMSE (Coefficient of Variation of RMSE)	0.291160802	0.2924058

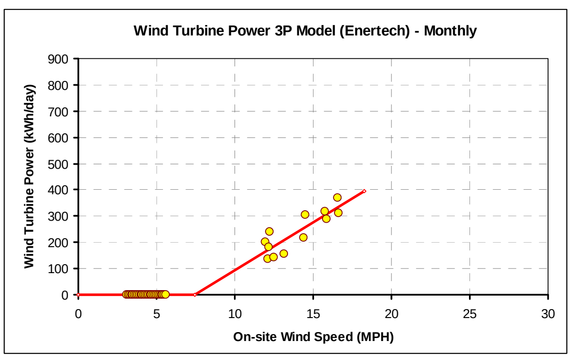


Figure 8. Monthly Daily Turbine Power vs. On-site Wind Speed

More accurate hourly modeling of wind turbines has been demonstrated by many previous studies, including the SolarSim model developed by the University of Dayton, http://www.engr.udayton.edu/faculty/jkissock/http/research/SolarSim.htm.

[11] This monthly 3-parameter model was derived with the 2001-2002 electricity production data regressed against the 2001-2002 daily wind data from the Amarillo, Texas NWS station. The model then predicted the 1999 electricity production using the 1999 daily wind data from the NWS for the Amarillo, Texas station.

[12] The peak day for the 1999 Ozone Episode Period was August 19th, 1999.

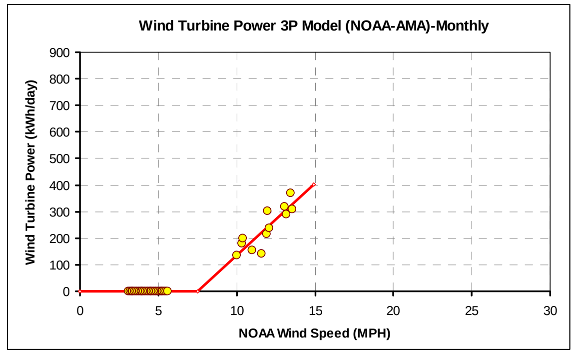


Figure 9. Monthly Daily Turbine Power vs. NOAA Wind Speed

Table 3. Comparison of Measured Turbine Power and Turbine Power Predicted by the 3-Parameter Monthly Model Using NOAA Wind Data

Month	NOAA Daily Avg. Wind Speed (MPH)	Measured Turbine Power (kWh/mo)	Predicted Turbine Power (kWh/mo)	Diff.
Oct-01	12.11	7,398	7,976	7.83%
Nov-01	11.58	4,267	6,797	59.29%
Dec-01	10.41	6,174	5,127	-16.96%
Jan-02	10.35	5,612	5,231	-6.78%
Feb-02	11.99	8,491	6,984	-17.75%
Mar-02	13.17	8,965	9,559	6.63%
Apr-02	13.07	9,526	9,051	-4.98%
May-02	13.28	11,457	9,964	-13.03%
Jun-02	13.58	9,295	9,880	6.30%
Jul-02	11.02	4,810	6,053	25.84%
Aug-02	11.93	6,704	7,437	10.93%
Sep-02	10.04	3,900	4,264	9.34%
Total		86,597	88,323	1.99%

Table 4. 1999 Predicted Turbine Power

	kWh
Annual Total	94,894
Ozone Episode Period Peak Day	184
34-day Ozone Episode Period Total	6,410
Average Daily Ozone Episode Period	189

Figure 10 and Figure 11 show four years of predicted electricity production, the measured 2001-2002 electricity production data, and average wind production for the wind turbine in Randall County, Texas. First, on average, the wind turbine has a 20 to 40% capacity factor, varying from a low of 20% in August to almost 40% in April. Second, the variations from the model-predicted monthly use are well within the variation of the wind turbine's measured output, which can be seen by comparing the measured 2001-2002 production against the modeled production.

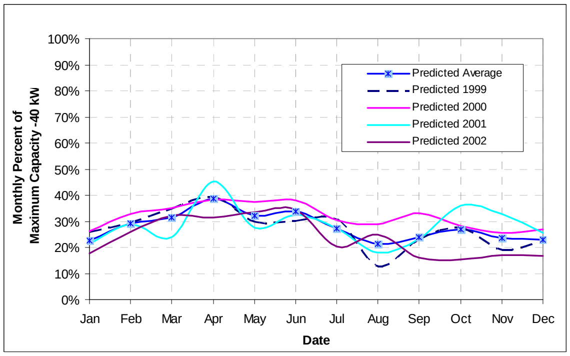


Figure 10: Electricity Produced by the Wind Turbine for 1999-2002 (Monthly Percent of Maximum Capacity)

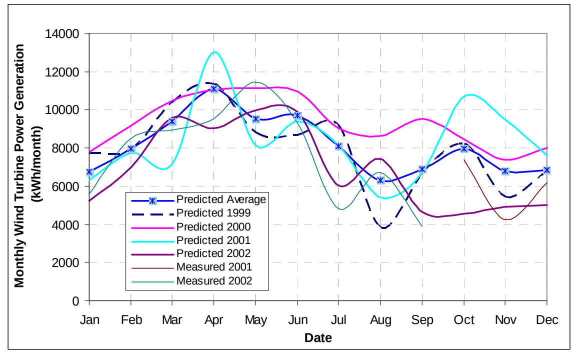


Figure 11: Electricity Produced by the Wind Turbine for 1999-2002

Table 5: 1999 eGRID Matrix for Selected Utilities in ERCOT.

Area	County	American Electric Power - West (ERCOT) /PCA	NOx Reductions (lbs)	Austin Energy/PCA	NOx Reductions (lbs)	Brownsville Public Utils Board/PCA	NOx Reductions (lbs/year)	Lower Colorado River Auhotrity /PCA	NOx Reductions (lbs)	Reliant Energy HL&P/PCA	NOx Reductions (lbs)	San Antonio Public Service Bd/PCA	NOx Reductions (lbs)	South Texas Electric Coop INC/PCA	NOx Reductions (lbs)	Texas Municipal Power Pool/PCA	NOx Reductions (lbs)	Texas-New Mexico Power Co/PCA	NOx Reductions (lbs)	TXU Electric/PCA	NOx Reductions (lbs)	Total NOx Reductions (lbs)	Total NOx Reductions (Tons)
Austin-San Antonio Area	BASTROP	0.012215415	0.0000	0.466390101	0.0000	0.009021629	0.0000	0.817318002	0.0000	0.007554281	0.0000	0.021706586	0.0000	0.006483441	0.0000	0.011331421	0.0000	0.002453005	0.0000	0.011206033	1.0634	1.06	0.00
	BEXAR	0.055151593	0.0000	0.085459434	0.0000	0.04073191	0.0000	0.149645941	0.0000	0.001884684	0.0000	1.887540372	0.0000	0.077368362	0.0000	0.007707389	0.0000	0.000857605	0.0000	0.004132794	0.3922	0.39	0.00
	HAYS	9.07402E-06	0.0000	0.00034645	0.0000	6.70157E-06	0.0000	0.000607132	0.0000	5.61158E-06	0.0000	1.61244E-05	0.0000	4.81612E-06	0.0000	8.41736E-06	0.0000	1.82218E-06	0.0000	8.32422E-06	0.0008	0.00	0.00
	TRAVIS	0.000828265	0.0000	0.486562876	0.0000	0.00061171	0.0000	0.055118588	0.0000	0.000543576	0.0000	0.001471564	0.0000	0.000440334	0.0000	0.000766124	0.0000	0.000167806	0.0000	0.000758965	0.0720	0.07	0.00
	FAYETTE	0.001485019	0.0000	0.056698717	0.0000	0.001096753	0.0000	0.099360775	0.0000	0.000918369	0.0000	0.002638854	0.0000	0.000788187	0.0000	0.001377553	0.0000	0.00029821	0.0000	0.00136231	0.1293	0.13	0.00
	LLANO	0.007176248	0.0000	0.273992417	0.0000	0.005299979	0.0000	0.480153706	0.0000	0.004437949	0.0000	0.012752072	0.0000	0.003808858	0.0000	0.006656924	0.0000	0.001441079	0.0000	0.006583261	0.6247	0.62	0.00
	CALDWELL		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	COMAL		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	GUADALUPE		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	WILLIAMSON		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	WILSON		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
Dallas-Fort Worth Area	ANGELINA	0.000494588	0.0000	0.00049881	0.0000	0.000365275	0.0000	0.000825851	0.0000	0.000216196	0.0000	7.12657E-05	0.0000	0.000704579	0.0000	0.002448715	0.0000	0.000837839	0.0000	0.004499471	0.4270	0.43	0.00
	COLLIN	0.007169953	0.0000	0.012538407	0.0000	0.00529533	0.0000	0.020113269	0.0000	0.008218606	0.0000	0.00238641	0.0000	0.062210088	0.0000	0.248405779	0.0000	0.003864706	0.0000	0.018702036	1.7747	1.77	0.00
	DALLAS	0.049181758	0.0000	0.050069935	0.0000	0.036322921	0.0000	0.08284103	0.0000	0.021947182	0.0000	0.007206079	0.0000	0.074651961	0.0000	0.262289147	0.0000	0.082583806	0.0000	0.443320905	42.0685	42.07	0.02
	DENTON	0.004478418	0.0000	0.008248434	0.0000	0.003307512	0.0000	0.013202327	0.0000	0.005532748	0.0000	0.00159686	0.0000	0.042940735	0.0000	0.171878188	0.0000	0.00176352	0.0000	0.008027328	0.7617	0.76	0.00
	JOHNSON	4.90169E-05	0.0000	9.02803E-05	0.0000	3.62012E-05	0.0000	0.000144501	0.0000	6.05567E-05	0.0000	1.74779E-05	0.0000	0.000469992	0.0000	0.001881231	0.0000	1.9302E-05	0.0000	8.78602E-05	0.0083	0.01	0.00
	PARKER	0.000692972	0.0000	0.001276329	0.0000	0.000511791	0.0000	0.002042874	0.0000	0.000856115	0.0000	0.000247092	0.0000	0.006644473	0.0000	0.026595727	0.0000	0.00027288	0.0000	0.001242116	0.1179	0.12	0.00
	CHEROKEE	0.010981286	0.0000	0.011075021	0.0000	0.00811017	0.0000	0.018336302	0.0000	0.004800172	0.0000	0.001582305	0.0000	0.015643707	0.0000	0.054368586	0.0000	0.018602464	0.0000	0.099901318	9.4800	9.48	0.00
	COKE	0.021538872	0.0000	0.000431296	0.0000	0.015907417	0.0000	0.000720531	0.0000	0.000159092	0.0000	0.000153973	0.0000	0.000428762	0.0000	0.000685852	0.0000	0.000152329	0.0000	0.000784005	0.0744	0.07	0.00
	COLEMAN	0.007243808	0.0000	0.00014505	0.0000	0.005349875	0.0000	0.000242324	0.0000	5.35048E-05	0.0000	5.1783E-05	0.0000	0.001489451	0.0000	0.000230661	0.0000	5.12301E-05	0.0000	0.000263671	0.0250	0.03	0.00
	FANNIN	0.020337335	0.0000	0.020510931	0.0000	0.015020028	0.0000	0.033958817	0.0000	0.008889916	0.0000	0.002930428	0.0000	0.028972134	0.0000	0.100690582	0.0000	0.03445175	0.0000	0.185017169	17.5570	17.56	0.01
	FRIO	0.047394602	0.0000	0.004808715	0.0000	0.035003026	0.0000	0.007841019	0.0000	0.002603666	0.0000	0.00120542	0.0000	1.140454367	0.0000	0.070348792	0.0000	0.00103497	0.0000	0.00489394	0.4644	0.46	0.00
	HARDEMAN	0.007011794	0.0000	0.000140405	0.0000	0.005178522	0.0000	0.000234563	0.0000	5.17911E-05	0.0000	5.01245E-05	0.0000	0.001441745	0.0000	0.000223273	0.0000	4.95893E-05	0.0000	0.000255226	0.0242	0.02	0.00
	HASKELL	0.195882927	0.0000	0.003922373	0.0000	0.144668275	0.0000	0.006552794	0.0000	0.001446847	0.0000	0.001400287	0.0000	0.040276892	0.0000	0.00623741	0.0000	0.001385336	0.0000	0.007130046	0.6766	0.68	0.00
	HENDERSON	0.003151289	0.0000	0.003178188	0.0000	0.002327367	0.0000	0.00526195	0.0000	0.001377501	0.0000	0.000454072	0.0000	0.004489259	0.0000	0.015602099	0.0000	0.005338331	0.0000	0.028668582	2.7205	2.72	0.00
	HOWARD	0.001294958	0.0000	0.001306011	0.0000	0.000956384	0.0000	0.002162291	0.0000	0.000566056	0.0000	0.000186592	0.0000	0.001844769	0.0000	0.006411364	0.0000	0.002193678	0.0000	0.011780769	1.1179	1.12	0.00
	HOOD	0.029930315	0.0000	0.030185796	0.0000	0.022104872	0.0000	0.049976957	0.0000	0.013083228	0.0000	0.00431269	0.0000	0.04263809	0.0000	0.148185635	0.0000	0.050702403	0.0000	0.272288493	25.8385	25.84	0.01
	JONES	0.093145673	0.0000	0.001865155	0.0000	0.068792232	0.0000	0.003115966	0.0000	0.000688001	0.0000	0.00066586	0.0000	0.019152349	0.0000	0.002965995	0.0000	0.000658751	0.0000	0.003390459	0.3217	0.32	0.00
	LAMAR	0.001155059	0.0000	0.001164918	0.0000	0.000853063	0.0000	0.001928691	0.0000	0.000504903	0.0000	0.000166434	0.0000	0.001645472	0.0000	0.00571872	0.0000	0.001956687	0.0000	0.010508051	0.9972	1.00	0.00
	LIMESTONE	0.012894146	0.0000	0.015971348	0.0000	0.009522902	0.0000	0.005377657	0.0000	0.097727305	0.0000	0.022202385	0.0000	0.008920477	0.0000	0.005660292	0.0000	0.006824779	0.0000	0.009372537	0.8894	0.89	0.00
	MCLENNAN	0.05325577	0.0000	0.053710353	0.0000	0.039331761	0.0000	0.08892527	0.0000	0.023279319	0.0000	0.007673679	0.0000	0.075867036	0.0000	0.263670465	0.0000	0.090216073	0.0000	0.484489832	45.9752	45.98	0.02
	MITCHELL	0.04519919	0.0000	0.045585003	0.0000	0.033381617	0.0000	0.075472576	0.0000	0.019757603	0.0000	0.006512798	0.0000	0.064389803	0.0000	0.223782162	0.0000	0.076568105	0.0000	0.411195779	39.0200	39.02	0.02
	NOLAN	0.001025023	0.0000	0.001033772	0.0000	0.000757025	0.0000	0.00171156	0.0000	0.000448061	0.0000	0.000147697	0.0000	0.001460226	0.0000	0.005074911	0.0000	0.001736404	0.0000	0.00932506	0.8849	0.88	0.00
	PALO PINTO	0.010167179	0.0000	0.018726099	0.0000	0.007508915	0.0000	0.029972731	0.0000	0.012560783	0.0000	0.00362529	0.0000	0.097486682	0.0000	0.390208375	0.0000	0.004003651	0.0000	0.018224131	1.7294	1.73	0.00
	RED RIVER	0.00311042	0.0000	0.00313697	0.0000	0.002297184	0.0000	0.005193709	0.0000	0.001359636	0.0000	0.000448184	0.0000	0.004431038	0.0000	0.015399758	0.0000	0.005269099	0.0000	0.028296783	2.6852	2.69	0.00
	TAYLOR	0.001885023	0.0000	3.77458E-05	0.0000	0.001392174	0.0000	6.30589E-05	0.0000	1.39233E-05	0.0000	1.34753E-05	0.0000	0.000387593	0.0000	6.00239E-05	0.0000	1.33314E-05	0.0000	6.86139E-05	0.0065	0.01	0.00
	TITUS	0.007854045	0.0000	0.007921086	0.0000	0.005800562	0.0000	0.013114505	0.0000	0.003433183	0.0000	0.001131697	0.0000	0.011188705	0.0000	0.038885545	0.0000	0.01330487	0.0000	0.071451504	6.7803	6.78	0.00
	TOM GREEN	0.00089529	0.0000	1.79273E-05	0.0000	0.000661211	0.0000	2.99498E-05	0.0000	6.61287E-06	0.0000	6.40006E-06	0.0000	0.000184087	0.0000	2.85083E-05	0.0000	6.33172E-06	0.0000	3.25881E-05	0.0031	0.00	0.00
	YOUNG	0.019487528	0.0000	0.019653871	0.0000	0.014392408	0.0000	0.03253983	0.0000	0.008518446	0.0000	0.002807978	0.0000	0.027761517	0.0000	0.096483171	0.0000	0.033012165	0.0000	0.177286126	16.8234	16.82	0.01
	TARRANT	0.029723615	0.0000	0.029977331	0.0000	0.021952215	0.0000	0.049631813	0.0000	0.012992874	0.0000	0.004282906	0.0000	0.042343628	0.0000	0.147162256	0.0000	0.050352249	0.0000	0.270408052	25.6601	25.66	0.01
	WICHITA	0.000471631	0.0000	0.000475657	0.0000	0.00034832	0.0000	0.000787519	0.0000	0.000206161	0.0000	6.79578E-05	0.0000	0.000671875	0.0000	0.002335055	0.0000	0.00079895	0.0000	0.004290622	0.4072	0.41	0.00
	WILBARGER	0.074052599	0.0000	0.001482834	0.0000	0.054691146	0.0000	0.002477252	0.0000	0.000546974	0.0000	0.000529372	0.0000	0.015226485	0.0000	0.002358023	0.0000	0.000523719	0.0000	0.00269548	0.2558	0.26	0.00
	WISE	1.54736E-05	0.0000	2.84996E-05	0.0000	1.1428E-05	0.0000	4.56161E-05	0.0000	1.91165E-05	0.0000	5.5174E-06	0.0000	0.000148367	0.0000	0.000593866	0.0000	6.09324E-06	0.0000	2.77357E-05	0.0026	0.00	0.00
	ELLIS		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	HUNT		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	KAUFMAN		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	ROCKWALL		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	RUSK		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
Houston - Galveston Area	BRAZORIA	0.011584147	0.0000	0.014348717	0.0000	0.008555409	0.0000	0.004831306	0.0000	0.087798562	0.0000	0.019946702	0.0000	0.008014188	0.0000	0.005085227	0.0000	0.006131406	0.0000	0.008420321	0.7990	0.80	0.00
	BRAZOS	0.002939669	0.0000	0.005414338	0.0000	0.002171077	0.0000	0.008666113	0.0000	0.00363174	0.0000	0.001048192	0.0000	0.02818664	0.0000	0.112822211	0.0000	0.001157589	0.0000	0.005269202	0.5000	0.50	0.00
	GRIMES	0.000352817	0.0000	0.000649825	0.0000	0.000260571	0.0000	0.0010401	0.0000	0.000435879	0.0000	0.000125803	0.0000	0.003382938	0.0000	0.013540483	0.0000	0.000138933	0.0000	0.000632405	0.0600	0.06	0.00
	WHARTON	0.000859628	0.0000	0.00106478	0.0000	0.000634874	0.0000	0.000358518	0.0000	0.006515295	0.0000	0.001480191	0.0000	0.000594711	0.0000	0.000377361	0.0000	0.000454995	0.0000	0.000624849	0.0593	0.06	0.00
	CHAMBERS	0.026549037	0.0000	0.032884994	0.0000	0.019607647	0.0000	0.011072591	0.0000	0.201220447	0.0000	0.045714693	0.0000	0.018367255	0.0000	0.011654537	0.0000	0.014052215	0.0000	0.019298047	1.8313	1.83	0.00
	FORT BEND	0.101391373	0.0000	0.125588538	0.0000	0.074882049	0.0000	0.042286475	0.0000	0.768465451	0.0000	0.17458545	0.0000	0.070144962	0.0000	0.044508942	0.0000	0.053665727	0.0000	0.07369968	6.9937	6.99	0.00
	GALVESTON	0.045304684	0.0000	0.055916435	0.0000	0.033459529	0.0000	0.019985056	0.0000	0.337157707	0.0000	0.07663686	0.0000	0.031980551	0.0000	0.023814611	0.0000	0.510829164	0.0000	0.040215829	3.8162	3.82	0.00
	ROBERTSON	0.003269549	0.0000	0.003701179	0.0000	0.002414708	0.0000	0.003261613	0.0000	0.013959492	0.0000	0.003239267	0.0000	0.00337216	0.0000	0.008271533	0.0000	0.849322645	0.0000	0.015058902	1.4290	1.43	0.00
	HARRIS	0.069468248	0.0000	0.086046924	0.0000	0.051305398	0.0000	0.028972557	0.0000	0.526513718	0.0000	0.119617134	0.0000	0.048059785	0.0000	0.030495279	0.0000	0.036769046	0.0000	0.050495299	4.7917	4.79	0.00
	HARDIN		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	JEFFERSON		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	LIBERTY		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	MONTGOMERY		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	ORANGE		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	WALLER		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
El Paso Area	EL PASO		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
Etc.	ANDREWS	6.67623E-05	0.0000	6.73322E-05	0.0000	4.93069E-05	0.0000	0.000111478	0.0000	2.91833E-05	0.0000	9.61985E-06	0.0000	9.51081E-05	0.0000	0.000330542	0.0000	0.000113096	0.0000	0.000607364	0.0576	0.06	0.00
	CROCKETT	0.075441526	0.0000	0.001510646	0.0000	0.05571693	0.0000	0.002523716	0.0000	0.000557233	0.0000	0.000539301	0.0000	0.015512072	0.0000	0.00240225	0.0000	0.000533542	0.0000	0.002746036	0.2606	0.26	0.00
	FREESTONE	0.025200214	0.0000	0.025415319	0.0000	0.018611481	0.0000	0.042078742	0.0000	0.011015592	0.0000	0.003631125	0.0000	0.035899688	0.0000	0.124766801	0.0000	0.04268954	0.0000	0.229256798	21.7551	21.76	0.01
	CALHOUN	0.169651094	0.0000	0.003397105	0.0000	0.125294896	0.0000	0.005675271	0.0000	0.001253092	0.0000	0.001212766	0.0000	0.034883177	0.0000	0.005402121	0.0000	0.001199817	0.0000	0.00617522	0.5860	0.59	0.00
	HIDALGO	0.125605549	0.0000	0.002515134	0.0000	0.092765297	0.0000	0.004201833	0.0000	0.000927759	0.0000	0.000897903	0.0000	0.025826656	0.0000	0.003999599	0.0000	0.000888316	0.0000	0.004571983	0.4339	0.43	0.00
	CAMERON	0.125578894	0.0000	0.0025146	0.0000	0.393419343	0.0000	0.004200941	0.0000	0.000927562	0.0000	0.000897712	0.0000	0.025821176	0.0000	0.003998751	0.0000	0.000888127	0.0000	0.004571013	0.4338	0.43	0.00
	PECOS	0.000135659	0.0000	4.98399E-05	0.0000	0.00010019	0.0000	8.25436E-05	0.0000	2.1488E-05	0.0000	7.49797E-06	0.0000	8.60031E-05	0.0000	0.000238822	0.0000	8.13779E-05	0.0000	0.000436887	0.0415	0.04	0.00
	PRESIDIO	0.000237673	0.0000	4.75918E-06	0.0000	0.000175532	0.0000	7.95078E-06	0.0000	1.75552E-06	0.0000	1.69903E-06	0.0000	4.88697E-05	0.0000	7.56811E-06	0.0000	1.68089E-06	0.0000	8.65119E-06	0.0008	0.00	0.00
	SAN PATRICIO	0.038088543	0.0000	0.000762688	0.0000	0.028130087	0.0000	0.001274161	0.0000	0.000281333	0.0000	0.000272279	0.0000	0.007831658	0.0000	0.001212836	0.0000	0.000269372	0.0000	0.001386405	0.1316	0.13	0.00
	WARD	0.057516808	0.0000	0.058007762	0.0000	0.042478727	0.0000	0.096040254	0.0000	0.025141917	0.0000	0.008287656	0.0000	0.08193722	0.0000	0.284766956	0.0000	0.097434336	0.0000	0.523254261	49.6537	49.65	0.02
	WEBB	0.051854261	0.0000	0.001038333	0.0000	0.038296683	0.0000	0.00173466	0.0000	0.00038301	0.0000	0.000370685	0.0000	0.010662126	0.0000	0.001651171	0.0000	0.000366727	0.0000	0.001887471	0.1791	0.18	0.00
	NUECES	0.556471643	0.0000	0.011142825	0.0000	0.410979117	0.0000	0.018615427	0.0000	0.004110259	0.0000	0.003977989	0.0000	0.11442012	0.0000	0.017719469	0.0000	0.003935514	0.0000	0.020255306	1.9221	1.92	0.00
	UPTON	3.45456E-05	0.0000	3.48405E-05	0.0000	2.55135E-05	0.0000	5.76835E-05	0.0000	1.51007E-05	0.0000	4.97772E-06	0.0000	4.9213E-05	0.0000	0.000171036	0.0000	5.85208E-05	0.0000	0.000314276	0.0298	0.03	0.00
	VICTORIA	0.26869859	0.0000	0.008105145	0.0000	0.198445888	0.0000	0.013404713	0.0000	0.00357559	0.0000	0.002532595	0.0000	0.853462815	0.0000	0.057152747	0.0000	0.002394313	0.0000	0.012017487	1.1404	1.14	0.00
	GREGG		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	HARRISON		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	SMITH		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	UPSHUR		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	0.00	0.00
	TOTAL	**2.59433808**		**2.15884660**		**2.21670807**		**2.46753295**		**2.26120971**		**2.46530416**		**3.34809944**		**3.09910920**		**2.11715092**		**3.63318167**		**344.77**	**0.17**
Energy Savings by PCA from ESL (MWh)		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**0.00**		**94.89**			

Emissions Reductions Calculations

The Energy Systems Laboratory (ESL) has worked closely with the Texas Commission for Environmental Quality (TCEQ) and the EPA to develop acceptable procedures for calculating NO_x reductions from electricity savings using the EPA's Emissions and Generation Resource Integrated Database (eGRID)[13]. This procedure calculates annual and peak-day, county-wide NO_x reductions from electricity savings from Energy Efficiency and Renewable Energy projects implemented in each

[13] E-GRID, Ver. 2, is the EPA's Emissions and Generation Resource Integrated Database (Version 2). This publicly available database can be found at www.epa.gov/airmarkets/egrid/.

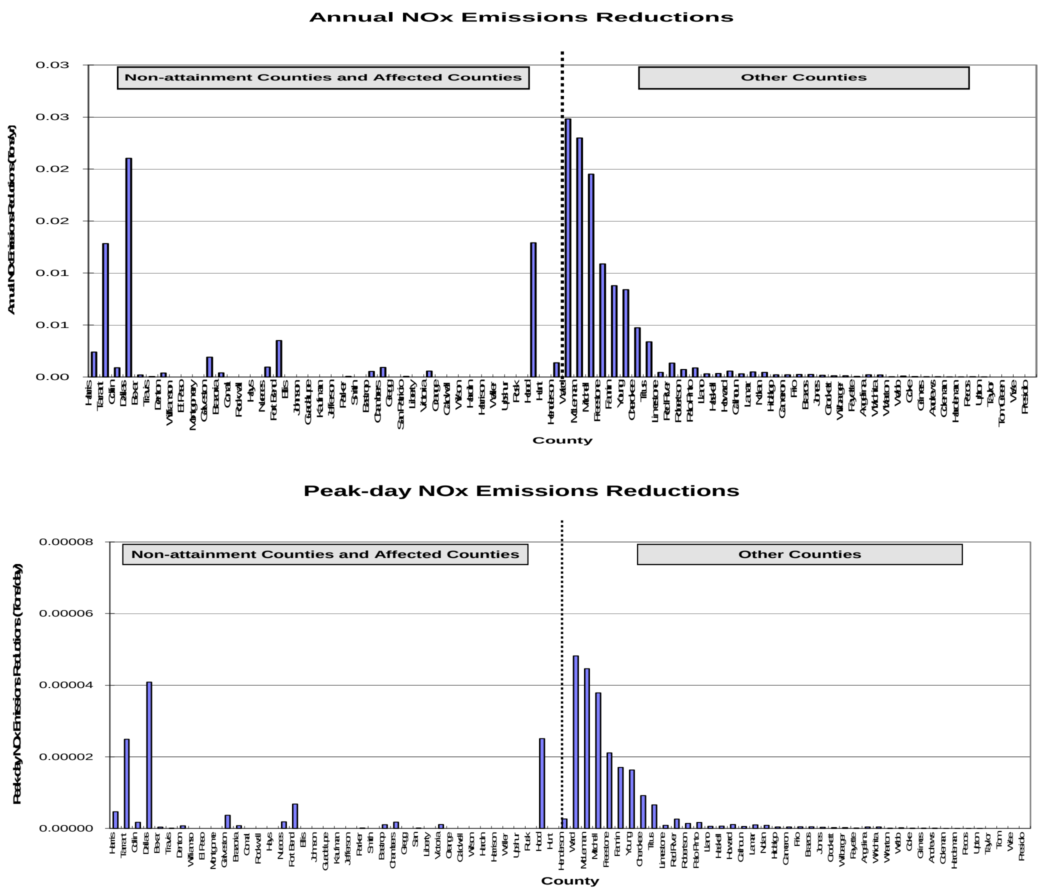


Figure 12. 1999 Annual and Peak-day NOx Emissions Reductions Based on the Electricity Provided by the Wind Turbine.

Power Control Area (PCA) in the Electric Reliability Council of Texas (ERCOT) region[14]. This procedure also includes a method for assigning a utility to each of the 41 non-attainment and affected counties, then, using eGRID, assigns the electricity production to specific power plants, located in different counties throughout the state.

For this analysis a special version of eGRID was developed by the EPA that reflects the 1999 electricity and pollution for utilities in the ERCOT Power Control Area. In Table 5 the NOx production for each power plant is provided from the 1999 eGRID database[15], for ten electric utility suppliers. This matrix was utilized to assign the power plant used by the utility provider, once the utility provider had been chosen for a given county. Figure 12 presents an example the distribution of NOx reductions from eGRID associated with TXU.

Using the Emissions Calculator (eCALC)

The emissions calculator, developed by the ESL for the TCEQ, with support from the EPA, is composed of four major elements, including: a web interface, a calculation engine, a weather database, and a general project/operations database. The web interface handles the interaction with the user, which includes receiving the general project information (including their email address for returning the results). Instructions from the user are passed to the calculation engine along with other information kept in the calculator's libraries. Once the user decides on a particular analysis, the calculator then routes their information into one of several legacy models, as shown in Figure 13. Annual and peak-day

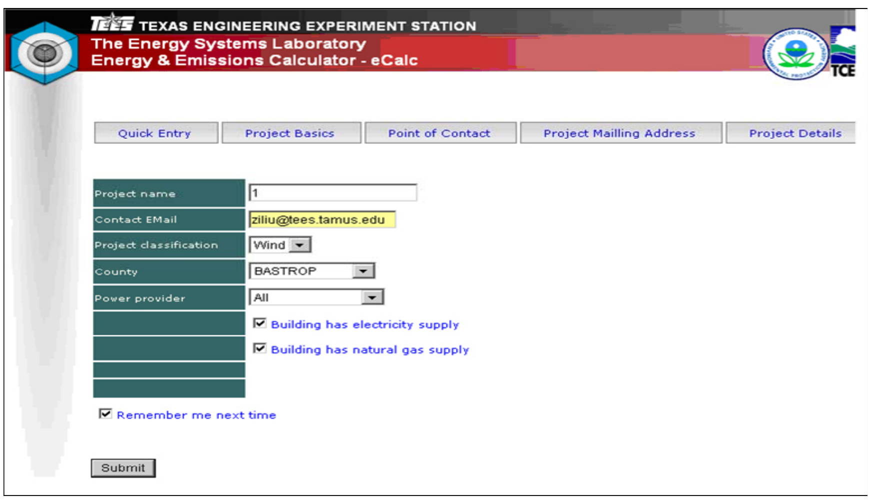
[14] For more information about these procedures see the ESL's 2004 Annual report to the TCEQ (Haberl et al. 2004).

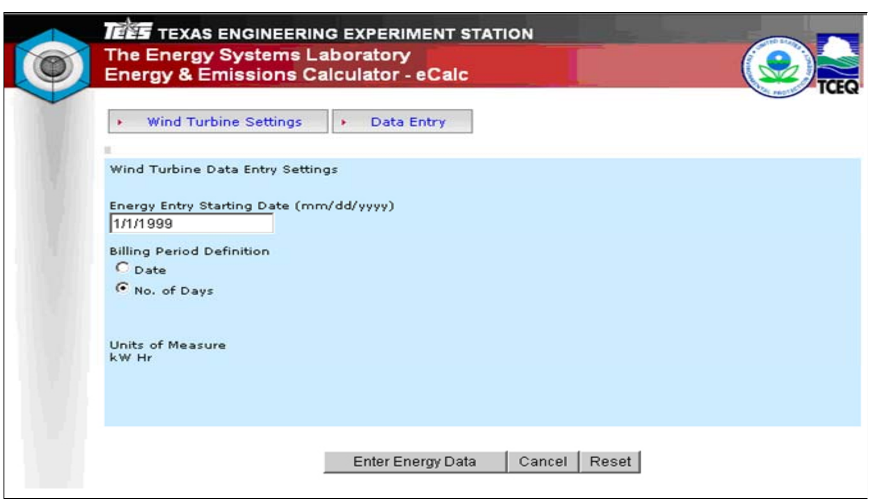
[15] This 1999 eGRID table for Texas, was provided by Art Diem at the USEPA, and includes emissions values for AEP, Austin Energy, Brownsville Public Utility, LCRA, Reliant, San Antonio Public Service, South Texas Coop, TMPP, TNMP, and TXU.

Figure 13. Three Groups of Models in the eCalc

savings are then passed to the USEPA's eGRID database, where specific emissions data are contained for the electric utility provider associated with the user.

The user input screens for wind energy projects begin with the project input screen, as shown in the first screen of Figure 14. When the user submits this type of project to the emissions calculator, they are directed to next screen shown in the middle pane of Figure 14. This input screen asks for specific information about the date when the wind energy system became operational. When the user completes the screen, they are redirected to the third screen shown in Figure 14 where they are asked for 12 months of data from the project. When the user completes entering 12 months of data, they press the "done entering data" button and the project is submitted for analysis.





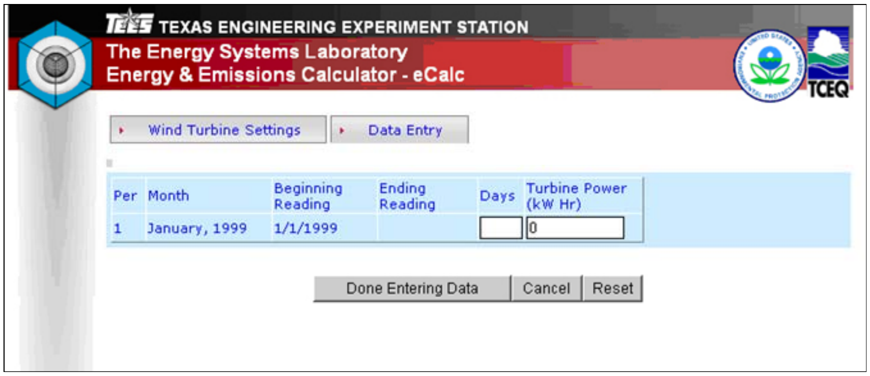


Figure 14. Wind Energy Systems Input Screens

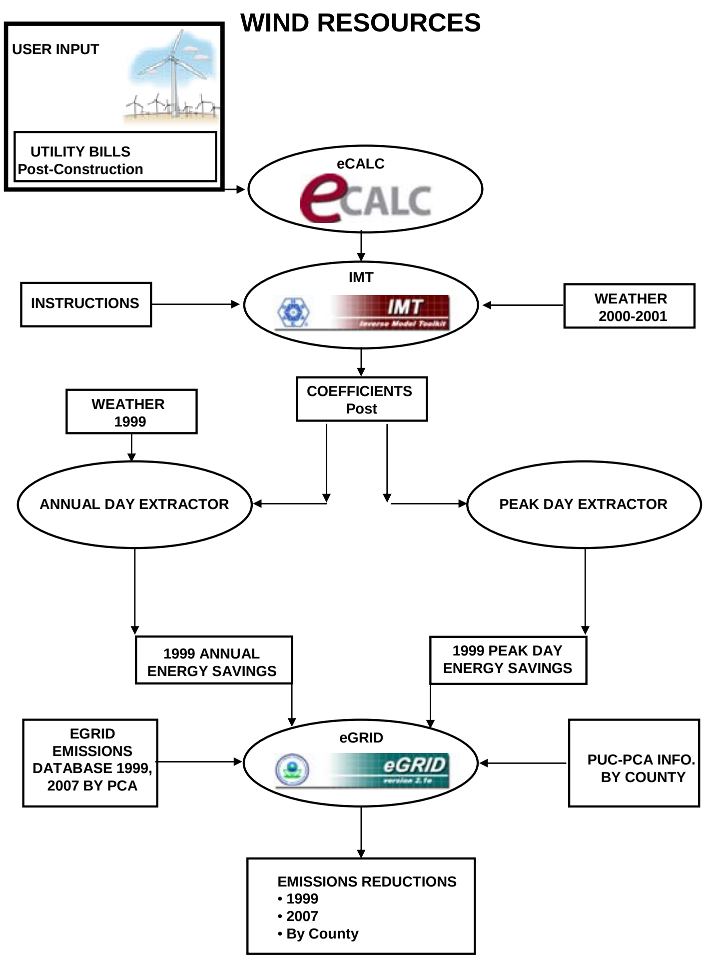


Figure 15. Wind Energy Analysis Flowchart.

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When the project is submitted for analysis, the emissions calculator performs a series of calculations, as indicated in Figure 15, which follow the procedures outlined in this paper. For each analysis, the user is required to enter 12 months of wind energy production data. Next, ASHRAE's IMT (Kissock et al. 2003; Haberl et al. 2003) is used to determine a statistical relationship between the wind-energy production and the local wind conditions during the coincident period using daily average

NOAA weather data from the nearest weather location. IMT produces coefficients that represent the daily average electrical output of the wind turbine vs. the average daily wind speed for the monthly period. These coefficients are then used to calculate the daily power production in 1999 and then determine the annual power production in 1999 and the 1999 peak day power production for the Ozone Episode Day (August 19, 1999), as shown in Table 4***.***

SUMMARY

The Energy Systems Laboratory has developed an emissions calculator to provide web-based energy and emissions calculations for the evaluation of new building models, community projects and renewables. This paper has provided a detailed description of the procedures that have been developed to calculate the emissions reductions from electricity provided by wind energy providers in the Texas ERCOT region, including an analysis of actual hourly wind power generated from a wind turbine in Randall County, Texas.

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