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STATEWIDE AIR EMISSIONS CALCULATIONS FROM WIND AND OTHER RENEWABLES

SUMMARY REPORT

A Report to the
Texas Commission on Environmental Quality
For the Period September 2006 – August 2007

TCEQ

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August 2007

ENERGY SYSTEMS LABORATORY

Texas Engineering Experiment Station
Texas A&M University System

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Texas A&M University System

3581 TAMU
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August 31, 2007

Chairman Kathleen Hartnett White
Texas Council on Environmental Quality
P. O. Box 13087
Austin, TX 78711-3087

Dear Chairman White:

The Energy Systems Laboratory (ESL) at the Texas Engineering Experiment Station of the Texas A&M University System is pleased to provide its second annual report, "Statewide Emissions Calculations From Wind and Other Renewables," as required by the 79th Legislature. This work has been performed through a contract with the Texas Environmental Research Consortium (TERC).

In this work the ESL is required to obtain input from public/private stakeholders, and develop and use a methodology to annually report the energy savings from Wind and Other Renewables. This report summarizes the work performed by the Laboratory on this project from September 2006 to August 2007.

Please contact me at (979) 862-8480 should you or any of the TCEQ staff have any questions concerning this report or any of the work presently being done to quantify emissions reductions from energy efficiency and renewable energy measures as a result of the TERP implementation.

Sincerely,

Dan Turner

W. Dan Turner, P.E.
Director

Enclosure

cc: Commissioner Larry R. Soward
Executive Director Glenn Shankle

Disclaimer

SUMMARY REPORT

Statewide Air Emissions Calculations From Wind and Other Renewables

1. EXECUTIVE SUMMARY

The 79th Legislature, through Senate Bill 20, House Bill 2481 and House Bill 2129, amended Senate Bill 5 to enhance its effectiveness by adding 5,880 MW of generating capacity from renewable energy technologies by 2015, and 500 MW from non-wind renewables.

This legislation also requires PUC to establish a target of 10,000 megawatts of installed renewable capacity by 2025, and requires TCEQ to develop methodology for computing emissions reductions from renewable energy initiatives and the associated credits. In this Legislation the Laboratory is to assist TCEQ in quantifying emissions reductions credits from energy efficiency and renewable energy programs, through a contract with the Texas Environmental Research Consortium (TERC) to develop and annually calculate creditable emissions reductions from wind and other renewable energy resources for the state's SIP.

The Energy Systems Laboratory, in fulfillment of its responsibilities under this Legislation, submits its second annual report, "Statewide Air Emissions Calculations from Wind and Other Renewables," to the Texas Commission on Environmental Quality.

The report is organized in several deliverables:

- A Summary Report, which details the key areas of work;
- Supporting Documentation;
- Supporting data files, including weather data, and wind production data, which have been assembled as part of the first year's effort.

This executive summary provides summaries of the key areas of accomplishment this year, including:

- continuation of stakeholder's meetings;
- review of electricity savings reported by ERCOT;
- analysis of wind farms using 2005 data;
- preliminary reporting of NOx emissions savings in the 2006 Integrated Savings report to TCEQ;
- prediction of on-site wind speeds using Artificial Neural Networks (ANN);
- improvements to the daily modeling using ANN-derived wind speeds;
- development of a degradation analysis;
- development of a curtailment analysis;
- analysis of other renewables, including: PV, solar thermal, hydroelectric, geothermal and landfill gas;
- estimation of hourly solar radiation from limited data sets;

1.1 Development of Stakeholder's meetings.

Legislation passed during the regular session of the 79th Legislature directed the Energy Systems Laboratory to work with the TCEQ to develop a methodology for computing emissions reductions attributable to renewable energy and for the Laboratory to quantify the emissions reductions attributable to renewables for inclusion in the State Implementation Plan annually. HB 2921 directed the Texas Environmental Research Consortium (TERC) to engage the Texas Engineering Experiment Station for the development of this methodology.

During the 2006-2007 reporting period, Texas A&M held continuing Stakeholder's meetings. A presentation of the overheads used in these meetings is contained in this report.

1.2 Review of Electricity Savings Reported by ERCOT

In this report, the information posted on ERCOT's Renewable Energy Credit Program site www.texasrenewables.com is reviewed. In particular, information posted under the "Public Reports" tab was downloaded and assembled into an appropriate format for review. This includes ERCOT's 2001 through 2006 reports to the Legislature, and information from ERCOT's listing of REC generators.

1.3 Analysis of wind farms using 2005 data.

In this report the weather normalization procedures developed together with the Stakeholders[1] were applied to several additional wind farms that reported their data to ERCOT during the 2005 measurement period, together with wind data from the nearby NOAA weather stations. In the 2006 Wind and Renewables report to the TCEQ (Haberl et al. 2006) weather normalization analysis methods were reviewed, and an analysis was shown for a single wind turbine in Randall, Texas, as well as an analysis of a wind farm containing multiple turbines at the Indian Mesa facility in Pecos, Texas.

In this report, an analysis of wind data for the Sweetwater I wind farm in Nolan County, Texas is provided, including the processing of weather and power generation data, modeling of daily power generation versus daily wind speed using the ASHRAE Inverse Model Toolkit (IMT) (Haberl et al. 2003; Kissock et al. 2003), prediction of 1999 wind power generation using developed coefficients from the 2005 daily model, and the analysis on monthly capacity factors generated using the model.

Finally, a summary of total predicted wind power production in the base year (1999) for all the wind farms in the ERCOT region using the developed procedure is presented to show the improved accuracy of using this weather normalization procedure compared to the non-weather normalization procedure reported in the 2006 integrated savings report to the TCEQ (Haberl et al. 2006). This includes an uncertainty analysis that was performed on all the daily regression models and included in this report to show the accuracy of applying the linear regression models to predict the wind power generation that the wind farms would have had in the base year of 1999. The detailed analysis for each wind farm is provided in the Appendix to this report. The original data used in the analysis is included in the accompanying CD-ROM with this report.

1.4 Preliminary reporting of NOx emissions savings in the 2006 Integrated Savings report to TCEQ;

In this report, the preliminary 2006 cumulative NOx emissions savings are reported. These values represent the electricity and NOx emissions savings that are reported to the TCEQ through the integrated NOx emissions savings reporting procedures, which contain growth, discount, and degradation factors.

1.5 Prediction of on-site wind speeds using Artificial Neural Networks (ANN).

Electricity produced by wind farms in Texas reduces the emission of air pollutants which would otherwise have been produced by burning fossil fuels to generate the same electricity. As more wind farms are commissioned (and some turbines decommissioned), proper accounting of pollution credits for wind energy requires normalization of the generation to a standard year, because year-to-year variations from the long term mean are significant.

In this report, we first discuss extrapolation to a reference year using an advanced Artificial Neural Network (ANN) model. Such a model is needed since we cannot expect to have wind data at the site of the turbine/farm for the reference year. The main question is: is it possible to use available hourly NOAA data, hourly site wind data, and hourly power generation data for a period of a few months bracketing the ozone season for any given year to develop an hourly model relating power generation to site wind, and site wind

[1] See the previous section that describes the conference calls held with the Wind Energy Stakeholder's group to develop the methodologies.

to NOAA data? If so we can extrapolate the hourly wind farm performance to the ozone season of the reference year. A secondary question addressed is how to account for non-utilization of available wind power due to transmission constraints. Actually, two data sets are analyzed: one for a single wind turbine in Randall county, and a second set for the Indian Mesa I wind farm in Pecos county.

1.6 Improvements to the daily modeling using ANN-derived wind speeds.

In this report, the ANN model is shown to substantially improve the on-site wind data predictions using NOAA data as a measure of the site wind. In the analysis, the Indian Mesa wind farm was used again as an example to show that using ANN-derived, on-site wind speed in the daily regression model can provide more accurate prediction on monthly and Ozone Season Periods (OSP) power generation. If this procedure could be used across all the wind farms in the ERCOT region, it is felt that substantial improvements could be made to reduce the uncertainty of the predictions of the power produced in the base year, and therefore reductions in NOx emissions from electricity derived from wind energy. In the report, the procedure was developed to compare the ANN daily model using ANN-derived on-site wind and the NOAA daily model.

1.7 Development of a degradation analysis.

This report contains an analysis to determine what amounts of degradation could be observed in the measured power from Texas wind farms. Currently, the TCEQ uses a very conservative 5% degradation per year for the power output from a wind farm when making future projections from existing wind farms. Accordingly, the TCEQ asked the Laboratory to evaluate any observed degradation from the measured data for Texas wind farms. To accomplish this, nine wind farms (14 sites) in Texas from 2002 to 2005 were evaluated. These wind farms were built before Jan 2002, with a total capacity of 1,010 MW.

In this analysis, a sliding statistical index was established for each site that uses 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, 99^{th} percentiles of the hourly power generation over a 12-month sliding period[2], as well as mean, minimum and maximum hourly power generation of the same 12-month period. These indices are then displayed using one data symbol for each 12-month slide, beginning from the first 12-month period (i.e., January 2002 to December 2002) until the last 12-month period (January 2005 to December 2005) for each of the wind farms.

1.8 Development of a curtailment analysis.

During the analysis of the measured power production from the Indian Mesa wind farm and the subsequent discussions with the wind stakeholders, group, including representatives from ERCOT, it became clear that the dataset contained substantial amounts of data that represented periods when the wind farm owners were instructed to curtail their power production because of constraints on the electric transmission lines. Unfortunately, it was determined that there was no electronic record of the amount of curtailment for this site[3]. As the analysis progressed, it became clear that an hourly analysis that used a manufacturer's wind power curve, multiplied by the prevailing on-site wind speed, and scaled for the number of turbines at the site presented the possibility of empirically determining the curtailment for the site. Therefore, the TCEQ requested that the Laboratory perform a proof-of-concept analysis to empirically determine the curtailment at the Indian Mesa site.

In this report, the measured power production for the period July 2002 to January 2003 from the Indian Mesa wind farm was analyzed using the on-site wind speed and manufacturer's power curves. Significant curtailment was observed during this period due to the power constraints in the McCamey power transmission area.

[2] To calculate this hourly data, the 12-month period is converted into quartiles, and those quartiles are recorded in a table. Then, the oldest month is dropped from the dataset and a new month is added, and the quartiles recalculated and recorded, etc.
[3] This would appear to be true for other sites in ERCOT.

1.9 Analysis of other renewables.

In this report, other renewable energy projects throughout the state of Texas were located to determine the NOx emissions reduction. Searches were conducted on four specific categories: solar photovoltaic, geothermal, hydroelectric, and Landfill Gas-fired Power Plants, and information assembled for inclusion in this report.

1.10 Estimation of hourly solar radiation from limited data sets.

One of the important tasks performed as part of the Laboratory's Senate Bill 5 effort has been the assembly and use of measured weather data for all Texas NOAA sites that correspond to the TMY2 sites for the years 1999 to 2006. Unfortunately, many of these sites have had discontinuous solar data, which requires the use of synthetic solar radiation to fill-in missing records. Therefore, this report contains information about the synthesis procedures used to generate the solar radiation data for those sites where data are missing.

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2 INTRODUCTION

Texas can now take its place as the largest producer of wind energy in the United States. As of March 2007,[4] the capacity of installed wind turbines totals was 3,026 MW with another 887 MW under construction (Figure 2-1 and Figure 2-2). The capacity announced for new projects is 3,125 MW by 2010.

This summary report presents the methodology developed by the Laboratory for the TCEQ to calculate the weather-normalized electricity savings from green power purchases produced by Texas wind energy providers. This report also presents the results of the 2006/2007 emissions reporting to the TCEQ. In the proposed method, the ASHRAE Inverse Model Toolkit (IMT) is used for weather normalization of the daily electric generation data. The U.S. EPA's Emissions and Generations Resource Integrated Database (eGRID) is then used for calculating annual and Ozone Season Day's NOx emissions reductions for the electric utility provider associated with the user.

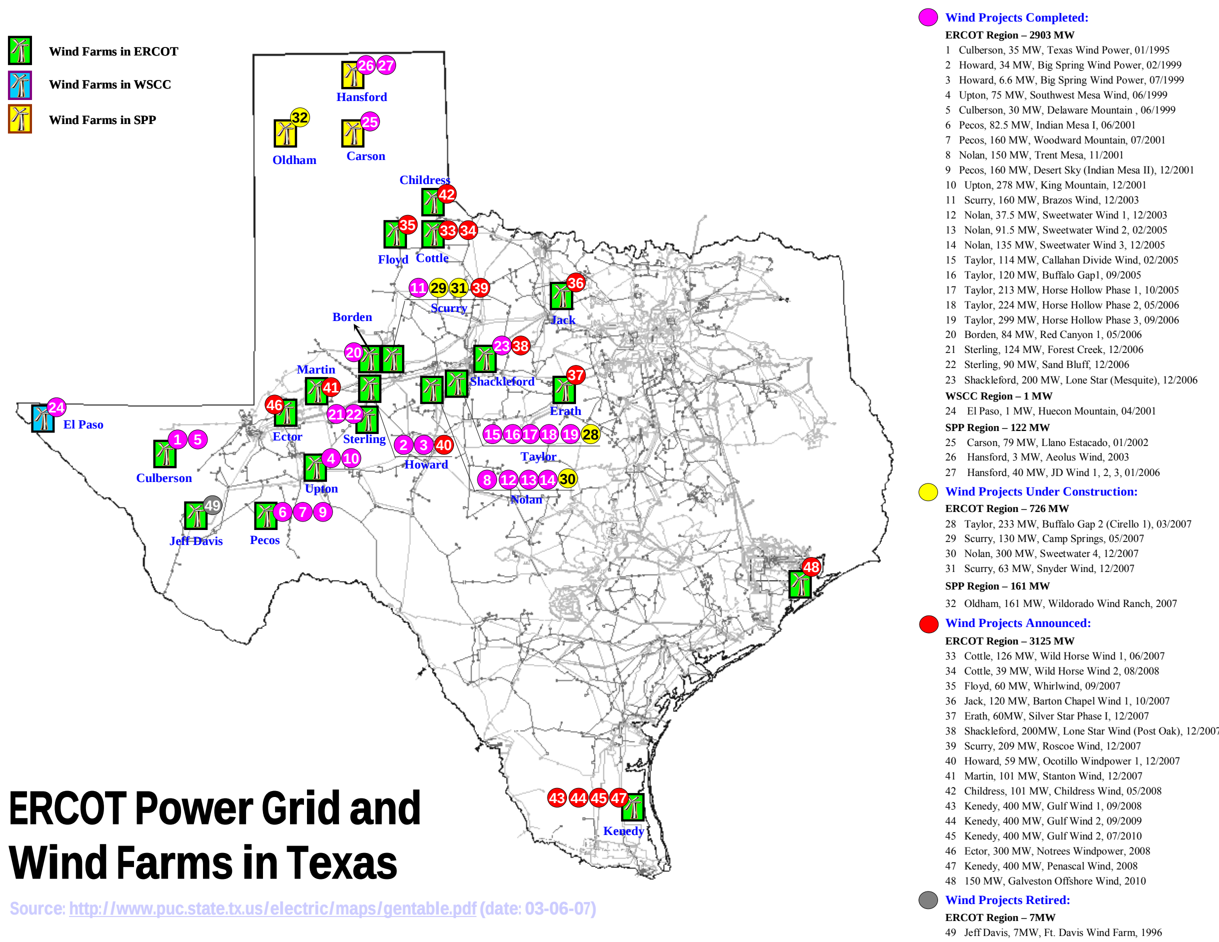


Figure 2-1: Completed and Announced Wind Projects in Texas.

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

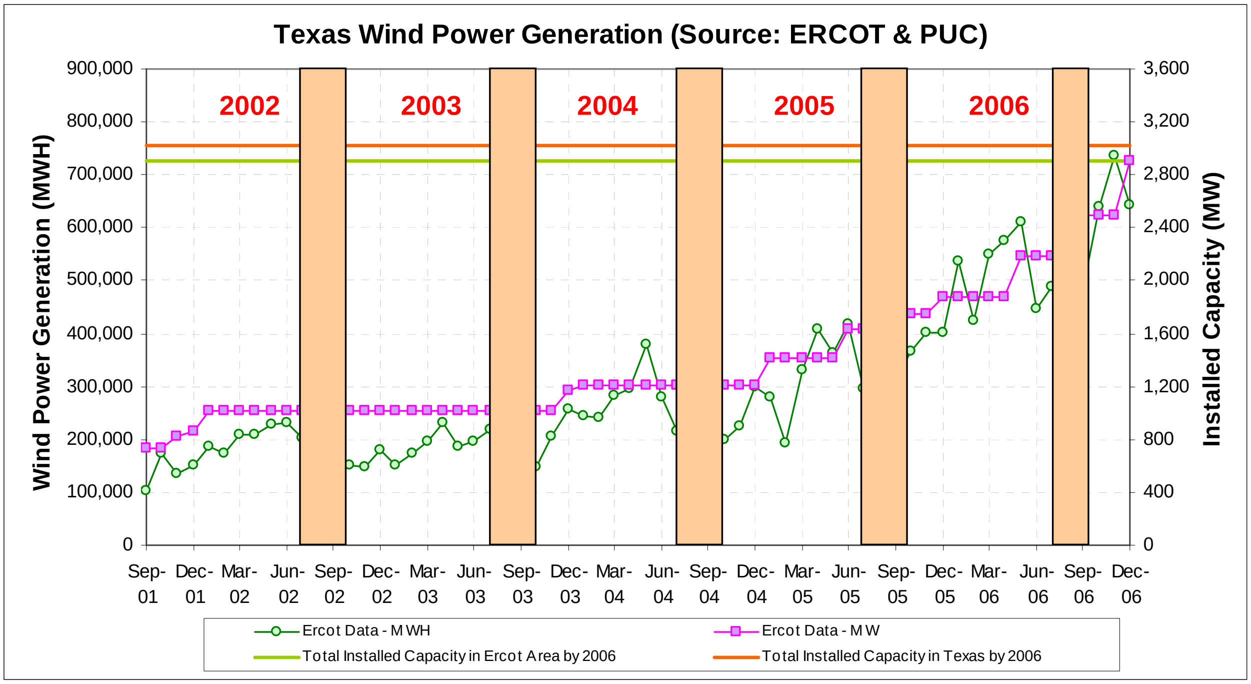


Figure 2-2: Installed Wind Power Capacity and Power Generation in the ERCOT region from 2002 to 2006.

2.1 Statement of Work for Calculations of Emissions from Wind and Other Renewables.

This summary report covers Laboratory's work from September 2006 through August 2007. This work is intended to cover the basic work outline included below:

Task 1: Obtain input from public/private stakeholders.

Task 2: Develop a methodology in cooperation with the Texas Commission on Environmental Quality (TCEQ) and the Environmental Protection Agency for calculating emissions reductions obtained through wind and other renewable energy resources in Texas.

Task 3: Calculate annual, creditable emissions reductions for wind and other renewable energy resources for inclusion in the State SIP.

Task 4: Include emissions reductions by county from wind and renewable energy resources in the ESL's annual report to the TCEQ.

Task 5: Incorporate wind and renewable energy emissions reductions as a component of the ESL annual Energy Leadership & Emissions Reduction Conference to facilitate technical transfer.

The progress toward completing each task is provided in the following section and throughout this report.

<u>Task 1: Obtain input from public/private stakeholders.</u>

Task 1 is composed of the following subtasks:

- Establish list of stakeholders for wind/other renewables.
- Hold stakeholder's meeting & obtain input, including concerns, goals, objectives, etc.
- Develop response to stakeholder input, circulate response to stakeholders.

- Setup and maintain list server for ongoing comments to/from stakeholders.

Legislation passed during the regular session of the 79th Legislature directed the Energy Systems Laboratory to work with the TCEQ to develop a methodology for computing emissions reductions attributable to renewable energy and for the Laboratory to quantify the emissions reductions attributable to renewables for inclusion in the State Implementation Plan annually. HB 2921 directed the Texas Environmental Research Consortium (TERC) to engage the Texas Engineering Experiment Station for the development of this methodology.

To initiate this effort, people from the TERC and the Energy Systems Laboratory at Texas A&M University attended a Stakeholder's meeting at the Texas State Capitol on Tuesday, August 30, 2005, where the draft scope of work, schedule and deliverables were discussed. The Laboratory's 2006 report contains a copy of the invitation letter that was sent to Stakeholders, a listing of the stakeholders in attendance at the meeting and copies of the slides that were used at the meeting.

Task 2: Develop a methodology in cooperation with the Texas Commission on Environmental Quality (TCEQ) and the Environmental Protection Agency for calculating emissions reductions obtained through wind and other renewable energy resources in Texas.

This task is composed of the following subtasks:
- Review existing methodologies for calculating emissions reductions from wind energy and other renewable energy systems with EPA, TCEQ and stakeholders. Develop acceptable methodologies for wind and renewables.
- Determine how to implement methodologies for Texas, including accounting of current installations, future sites, degradation, discounting/uncertainty, grid constraints, etc.
- Review methodologies for verifying wind energy production and renewable energy installations with TCEQ, EPA and stakeholders. Develop acceptable methodologies for verifying installations, including documentation, EPA QAPP, etc.
- Develop draft State Guidelines for TCEQ for EE/RE SIP credits.

Task 3: Calculate annual, creditable emissions reductions for wind and other renewable energy resources for inclusion in the State SIP.

This task is composed of the following subtasks:
- Calculate annual emissions from wind and other renewable energy projects.
- Verify annual installations of wind and renewable energy systems in Texas.
- Verify ERCOT historical data for wind production and other renewables.

Task 4: Include emissions reductions by county from wind and renewable energy resources in the ESL's annual report to the TCEQ.

This task is composed of the following subtasks:
- Report annual emissions from wind and other renewable energy projects.
- Report on verification of installations of wind and renewable energy systems in Texas.
- Develop documentation for all methods developed.

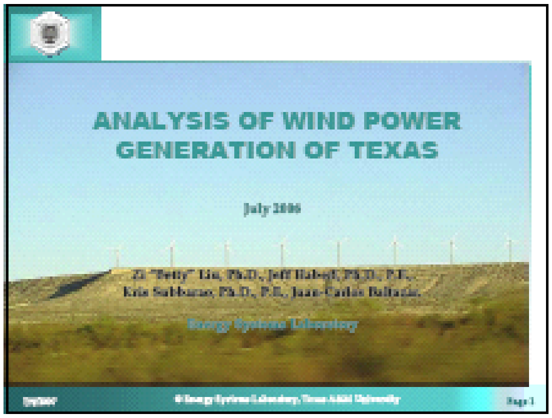
Task 5: Incorporate wind and renewable energy emissions reductions as a component of the ESL's annual Energy Leadership & Emissions Reduction Conference to facilitate technical transfer.

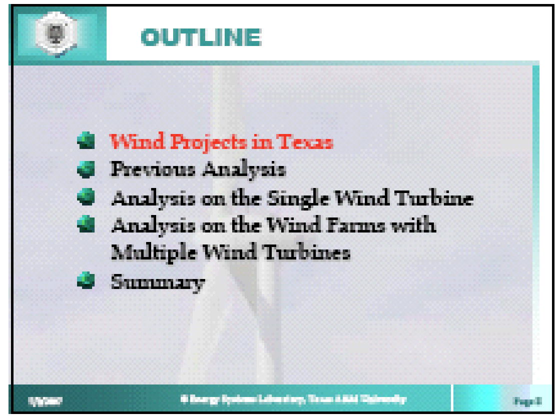
Additional information regarding the Laboratory's efforts on Tasks 2, 3, 4 and 5 are presented in the following sections. This work was performed during the period September 2006 through August 2007.

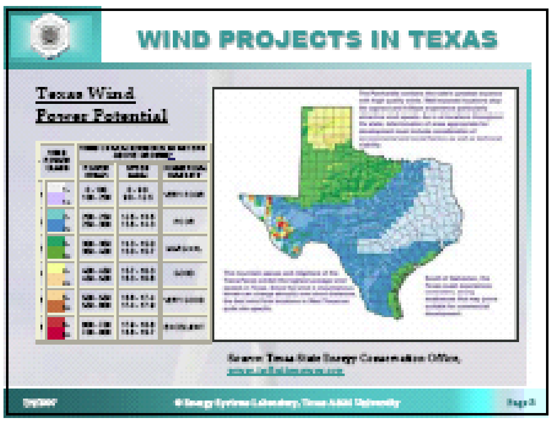
2.2 Review of material presented at Stakeholders meeting during 2006/2007 period.

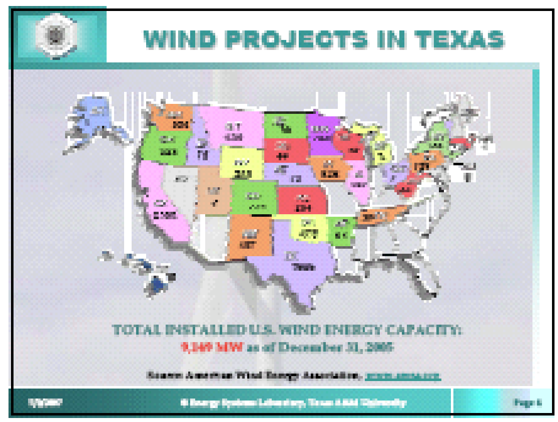
During the period from August 2005 to July 2006, a number of meetings were held; in July of 2006 a presentation was made to the stakeholders to review the analysis methodology and receive input from the stakeholders. Figure 2-3: through Figure 2-12: show the slides that were presented to the stakeholders. In this presentation the following topics were presented:

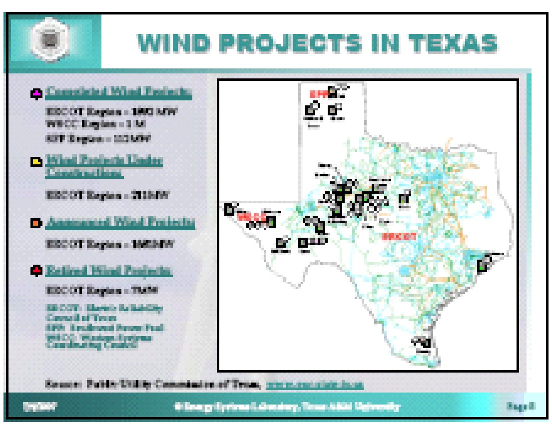
- A review of the current wind projects in Texas was presented.
- A review of the previous analysis (i.e., August 2005 – July 2006) was presented.
- An analysis of base-year and weather normalized calculation methodology for a single turbine was presented. This included the work on the wind turbine in Randall, Texas. Analysis of daily data was presented, including accuracy of the method against measured data from the same site. On-site wind speed and NOAA wind speed data were also compared.
- An analysis of base-year, weather normalized calculation methodology for a wind farm with multiple turbines was presented. This includes the work performed on the Indian Mesa wind farm. Analysis of daily data was presented, including accuracy of the method against measured data from the same site. On-site wind speed and NOAA wind speed data were also compared.
- Summary of work through July 2006 and future work was presented.











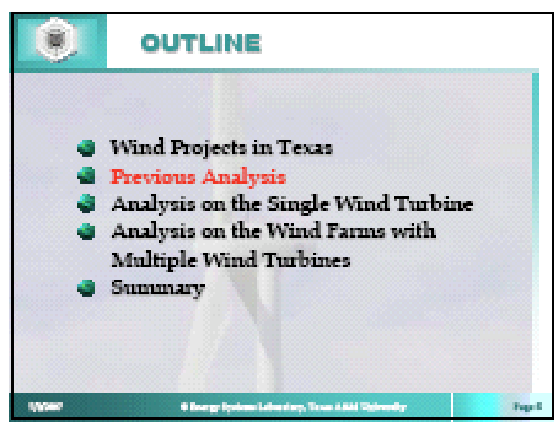
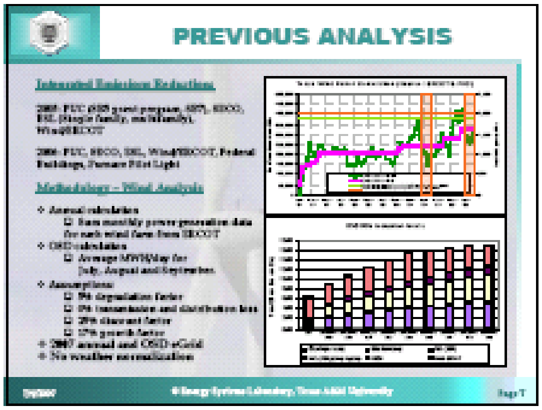
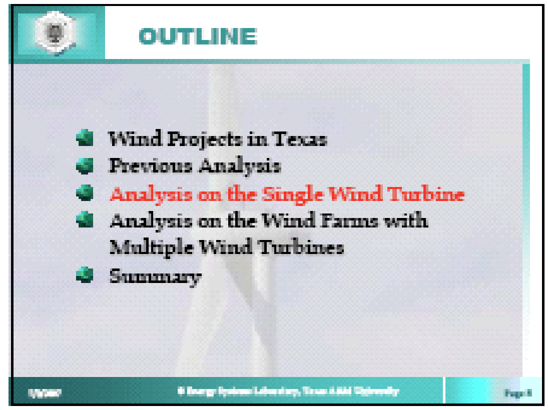
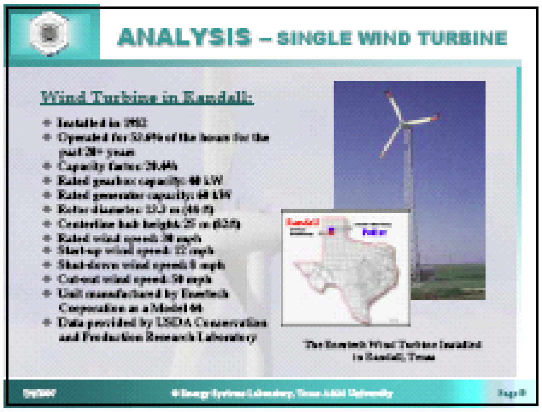
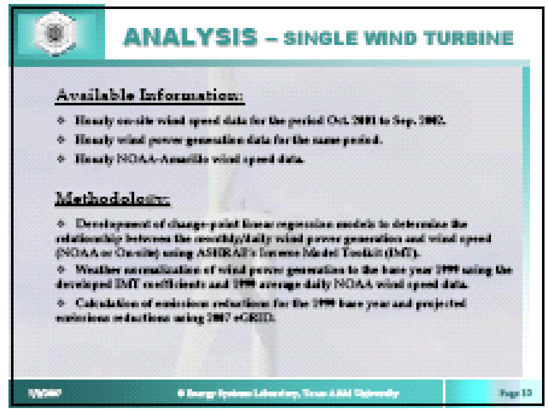


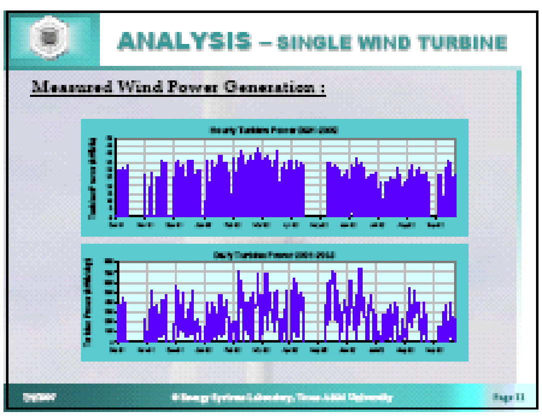
Figure 2-3: Slides Presented at the Wind/Renewables Stakeholder's Meeting, July 2006.











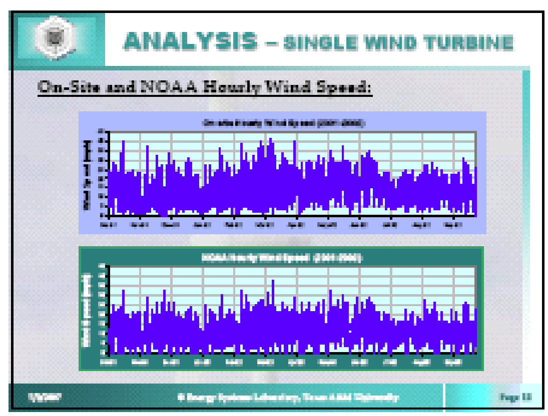


Figure 2-4: Slides Presented at the Wind/Renewables Stakeholder's Meeting, July 2006.

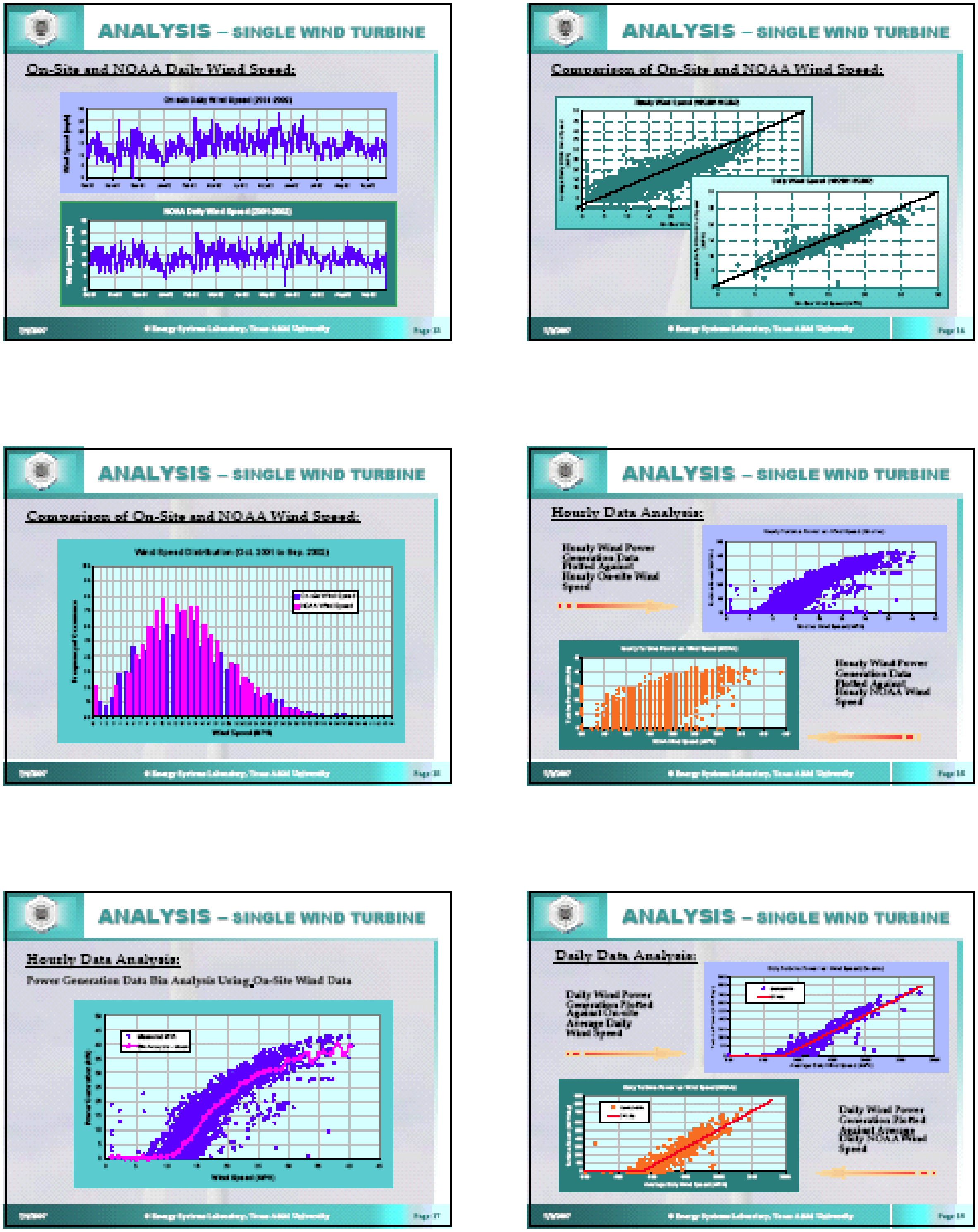
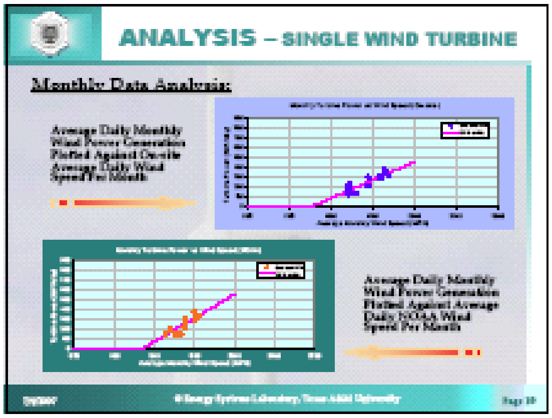
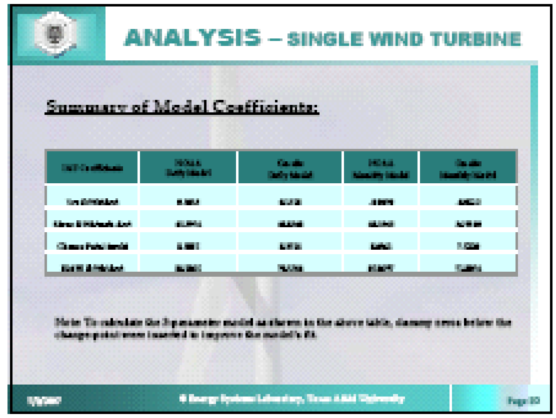
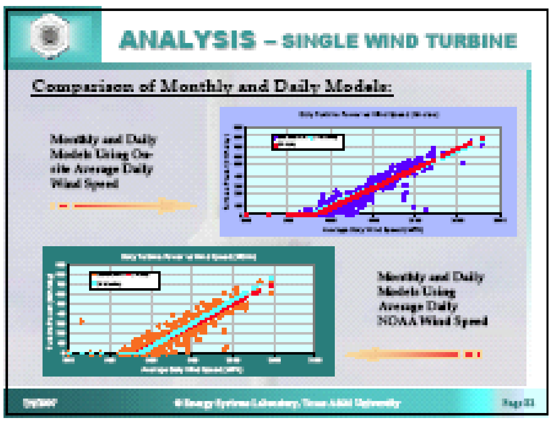
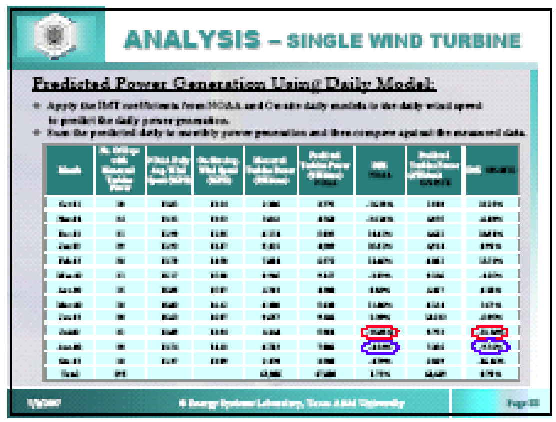


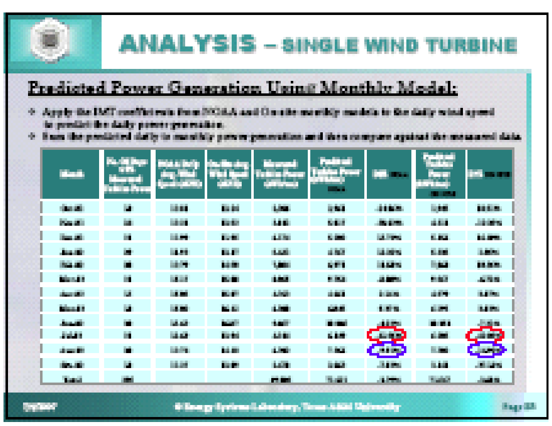
Figure 2-5: Slides Presented at the Wind/Renewables Stakeholder's Meeting, July 2006.











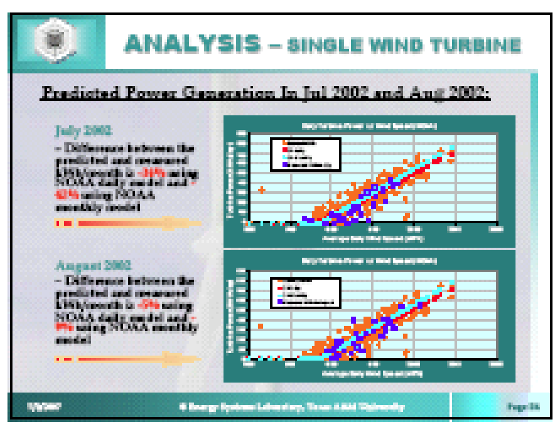
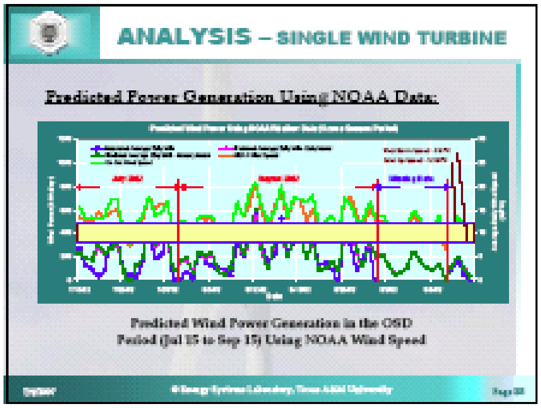
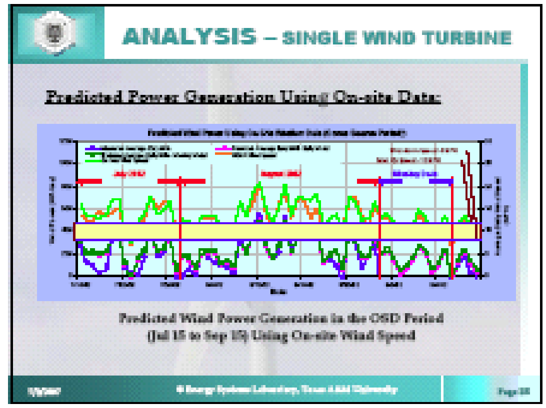
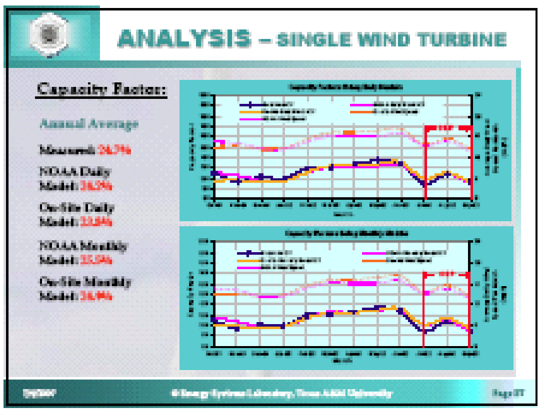
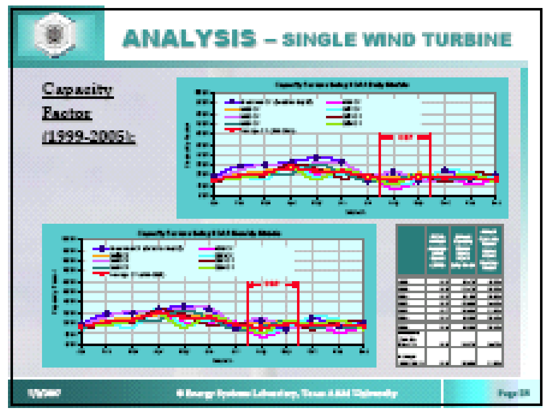


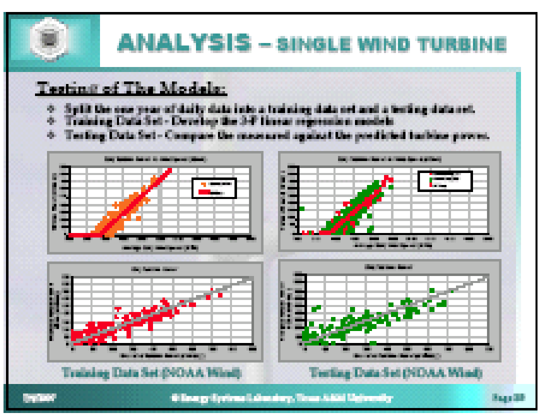
Figure 2-6: Slides Presented at the Wind/Renewables Stakeholder's Meeting, July 2006.











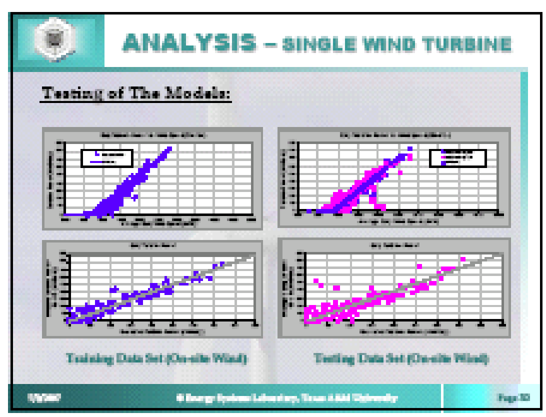


Figure 2-7: Slides Presented at the Wind/Renewables Stakeholder's Meeting, July 2006.

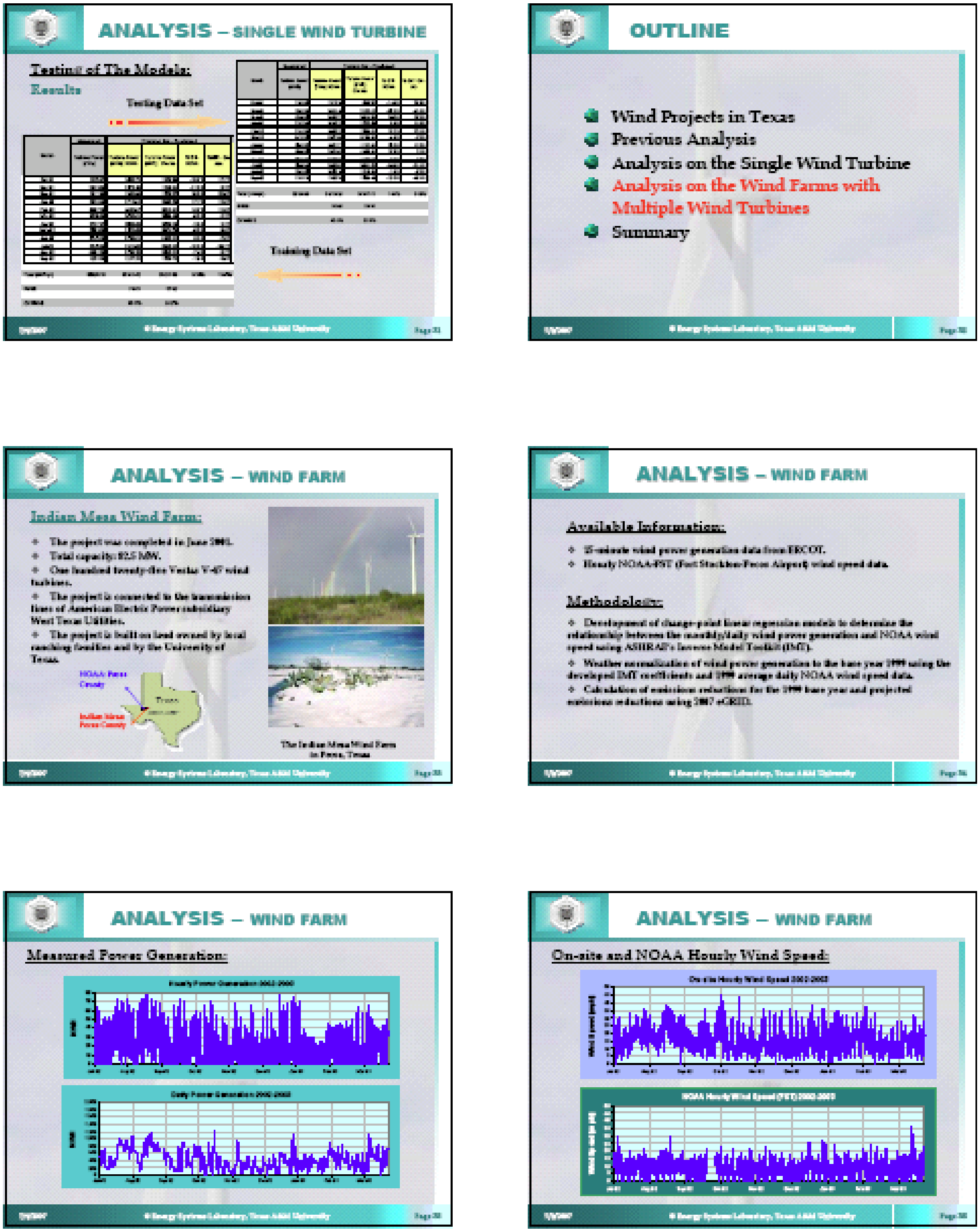
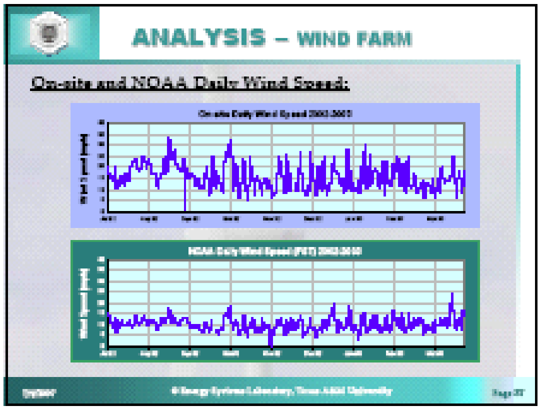
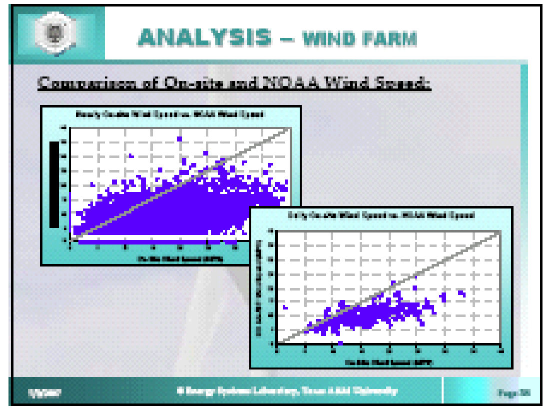
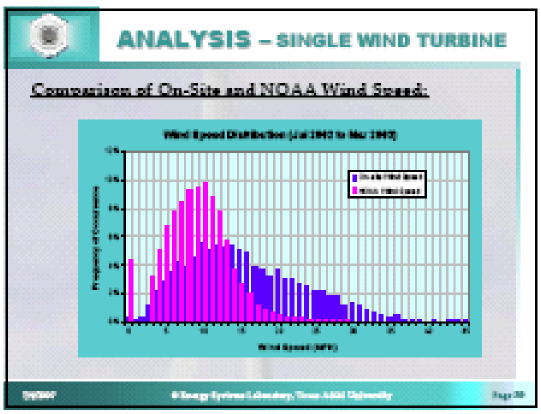
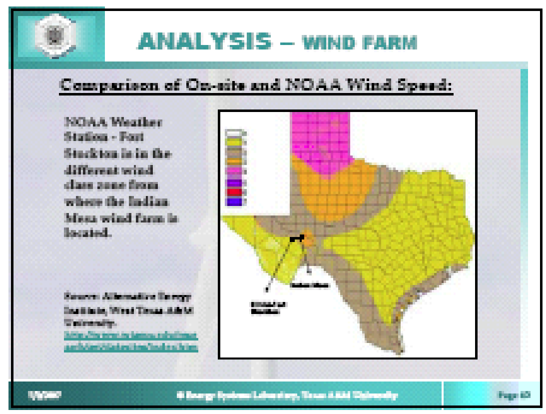


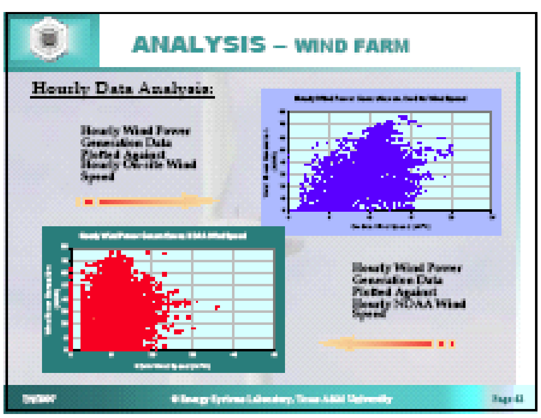
Figure 2-8: Slides Presented at the Wind/Renewables Stakeholder’s Meeting, July 2006.











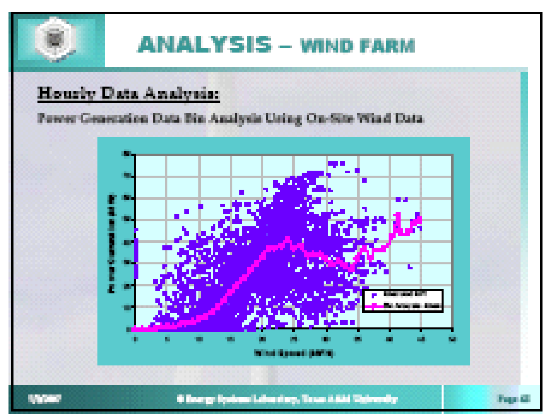
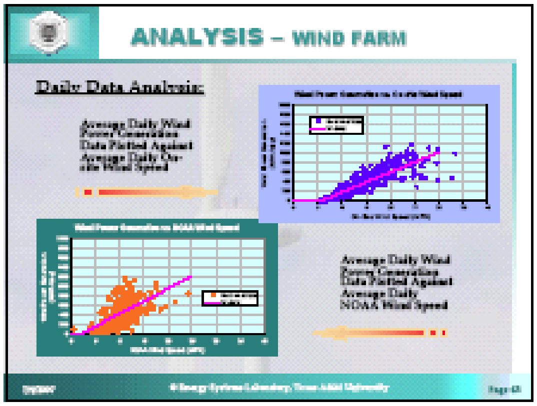
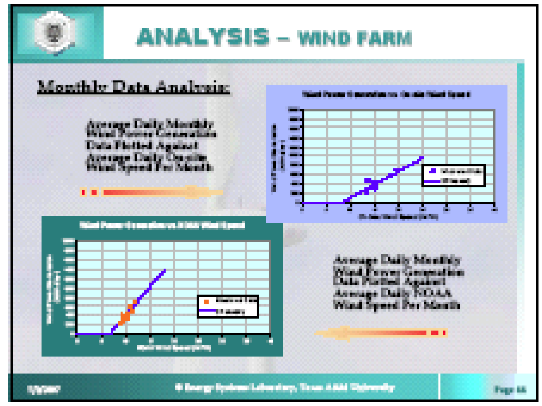
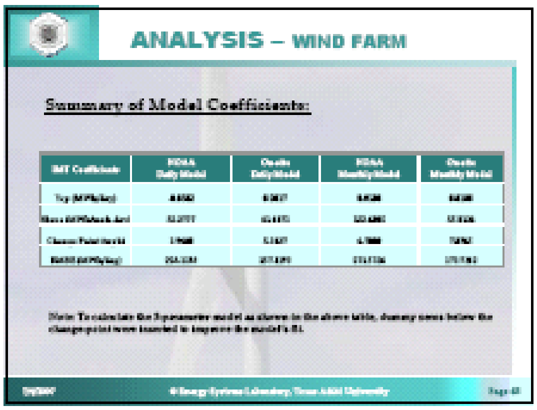
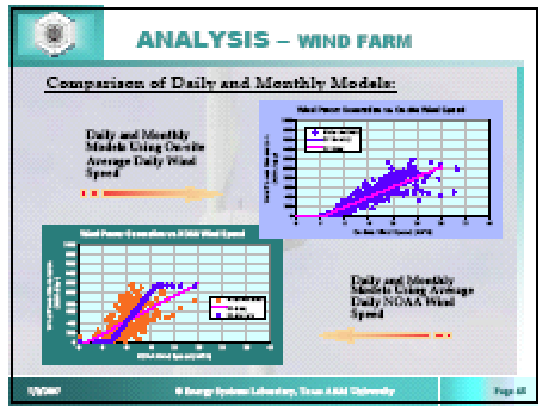


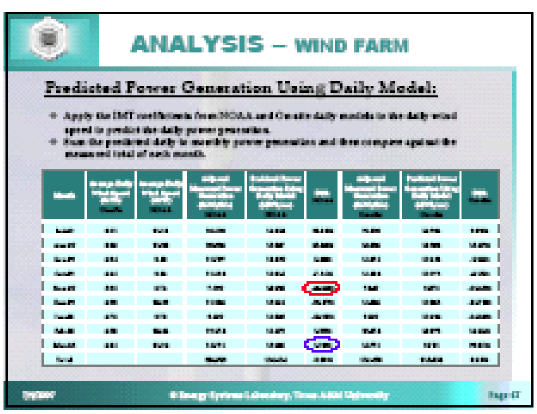
Figure 2-9: Slides Presented at the Wind/Renewables Stakeholder's Meeting, July 2006.











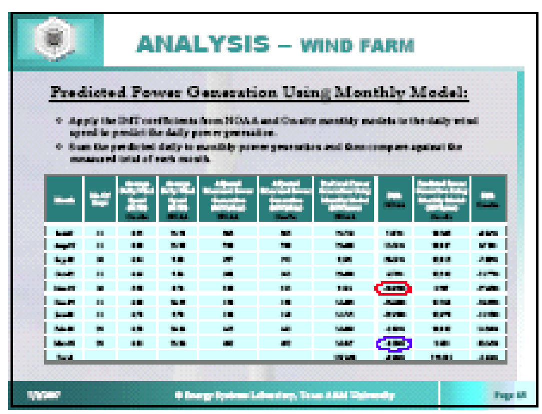
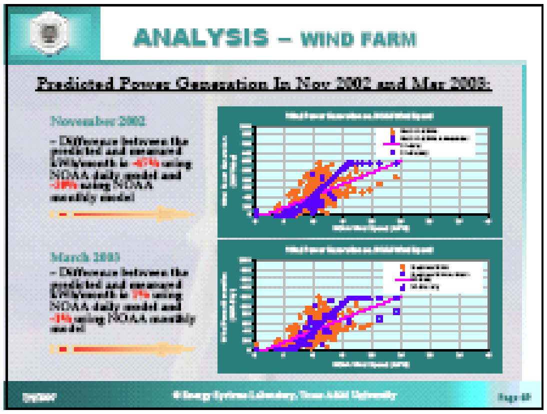
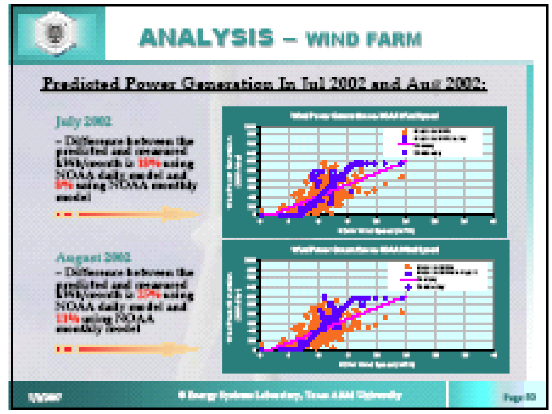
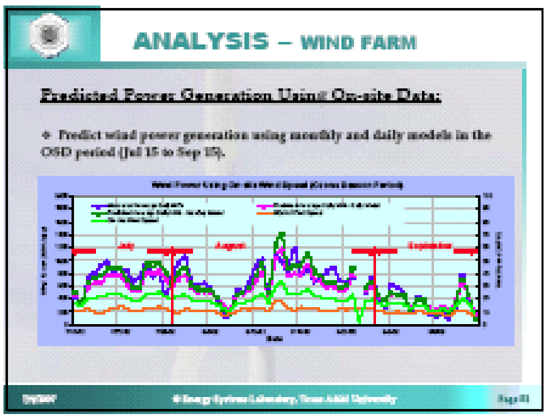
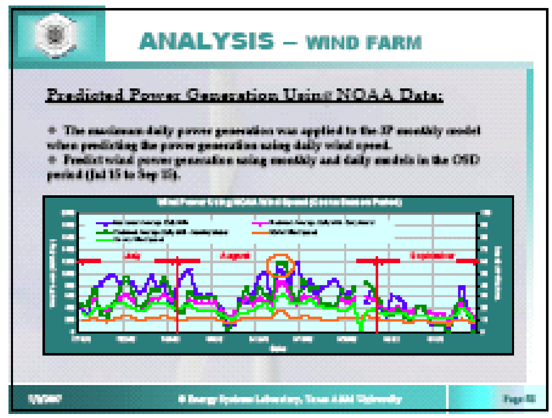


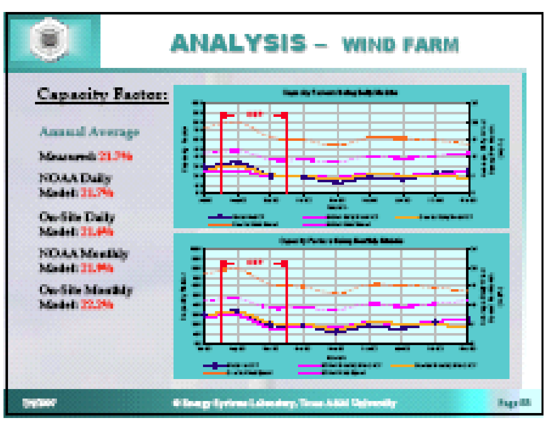
Figure 2-10: Slides Presented at the Wind/Renewables Stakeholder's Meeting, July 2006.











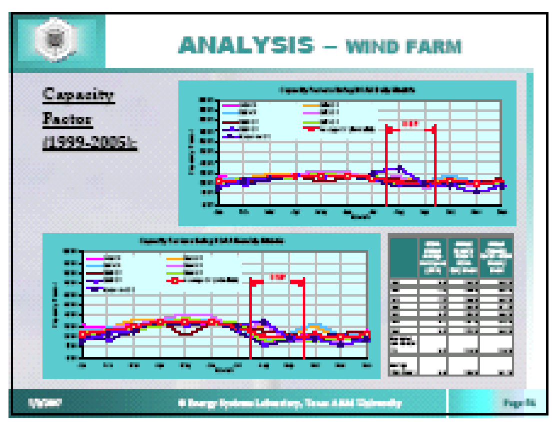


Figure 2-11: Slides Presented at the Wind/Renewables Stakeholder's Meeting, July 2006.

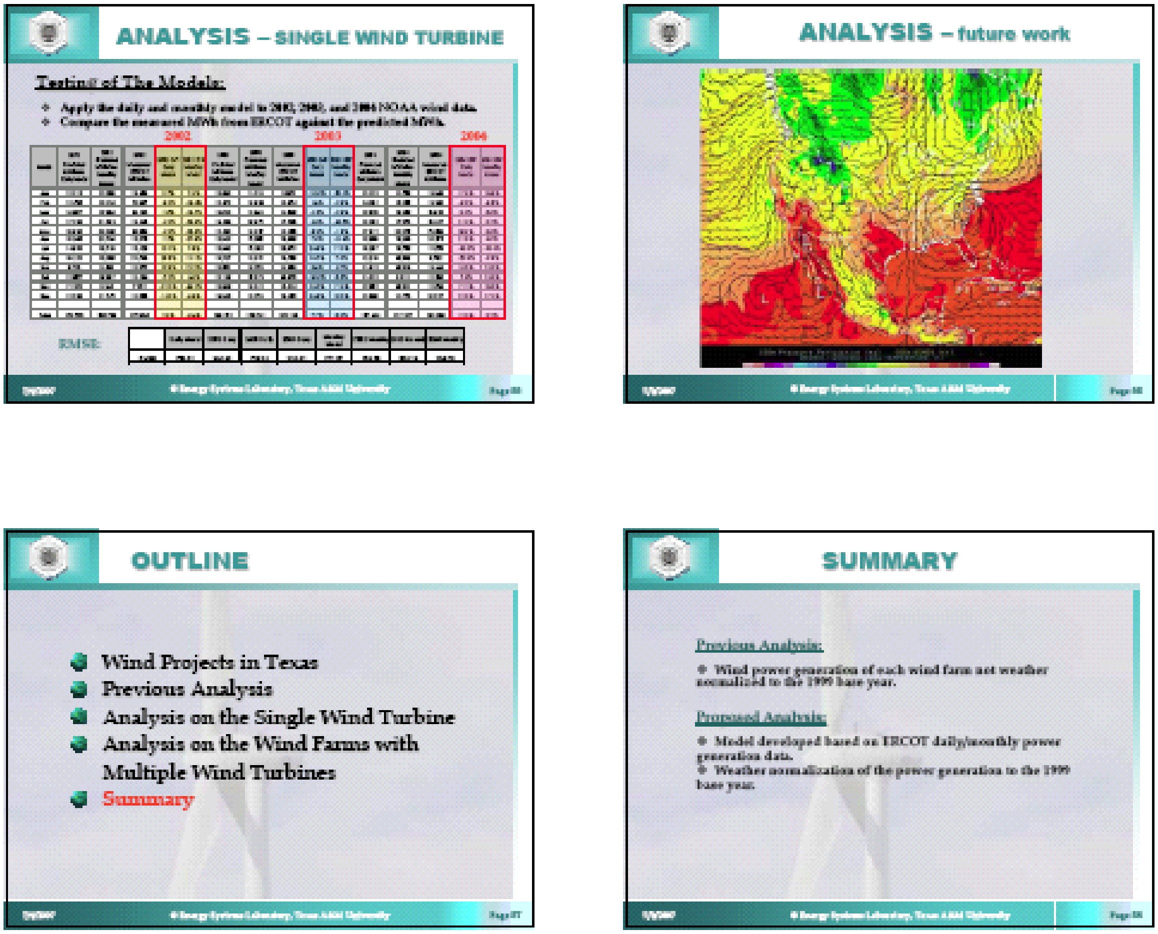


Figure 2-12: Slides Presented at the Wind/Renewables Stakeholder's Meeting, July 2006.

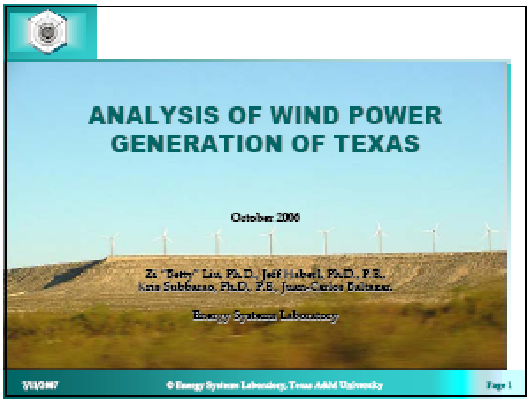
In October 2006, a second conference call was held with the Wind Energy Stakeholder's group. Figure 2-13: through Figure 2-18: present the slides used for this conference call. In this presentation the following topics were discussed:

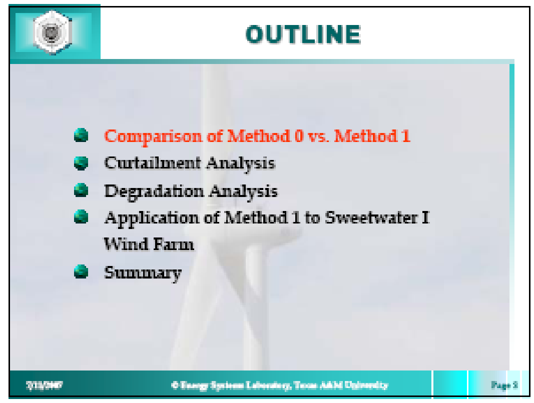
- A comparison of the analysis methods was presented. This includes the Method 0 analysis that was used in the NOx emissions reporting to the TCEQ in June 2006, and the new proposed Method 1 analysis that uses weather-normalized, base year calculations.

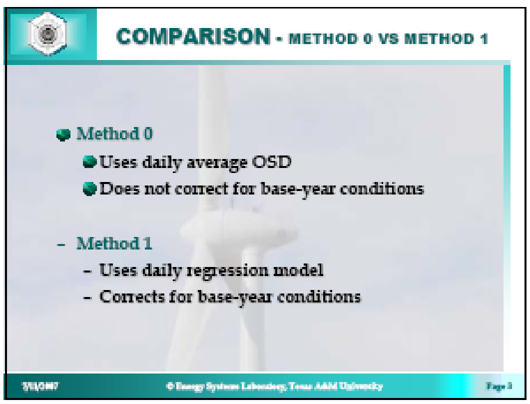
- A presentation of a curtailment analysis. In this analysis a statistical approach was used to determine whether or not any curtailment of electricity generation power could be determined from the recorded data. This analysis is important since curtailment signals are currently not recorded by ERCOT. Yet, if curtailment is left in the data, any statistical analysis based on the data contains the curtailment. TCEQ expressed interested in knowing curtailed and uncurtailed forecasts.

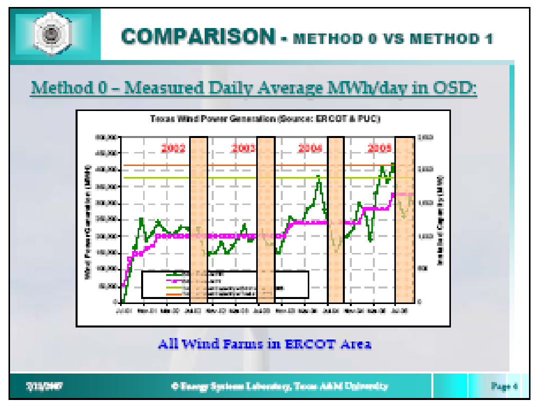
- A presentation of an analysis to determine the degradation of wind farms. This analysis used a statistical approach to review the data from several years from each site to see if the minimum, maximum, and average outputs varied significantly. The goal of the analysis was to determine if the TCEQ could reduce the current 5% degradation factor.

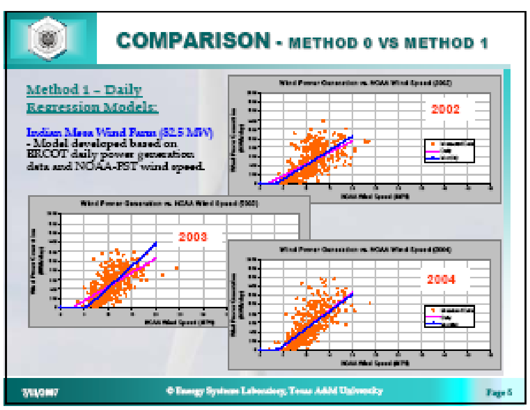
- An analysis that compares the Method 0 and Method 1 analysis to the Sweetwater I wind farm.











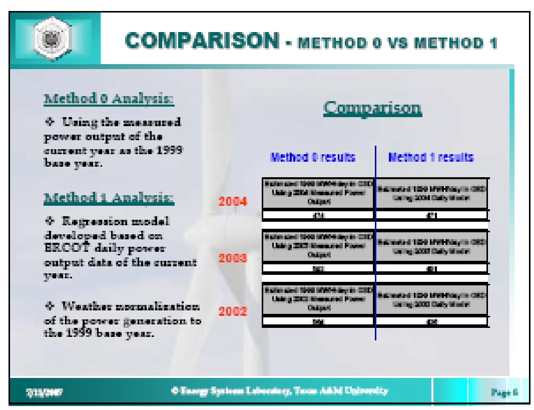
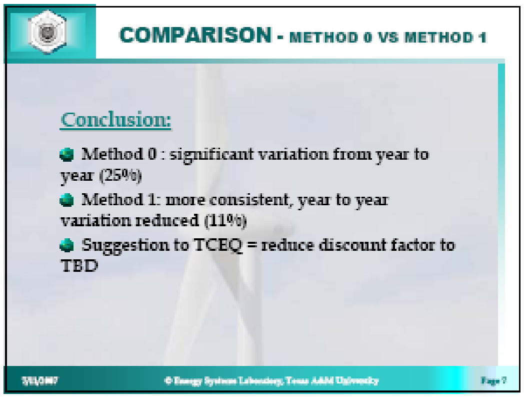
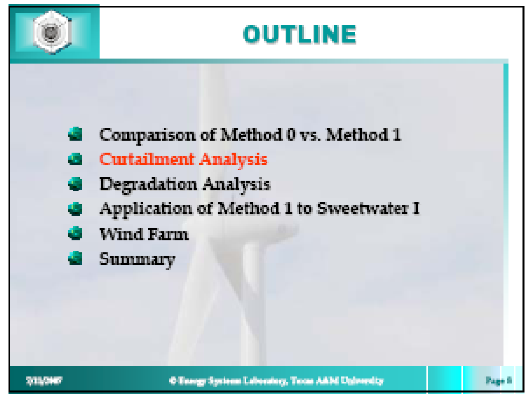
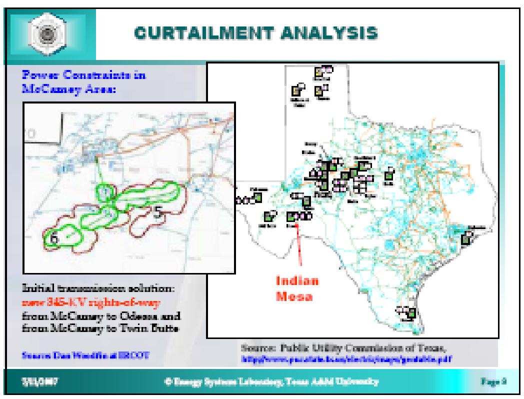
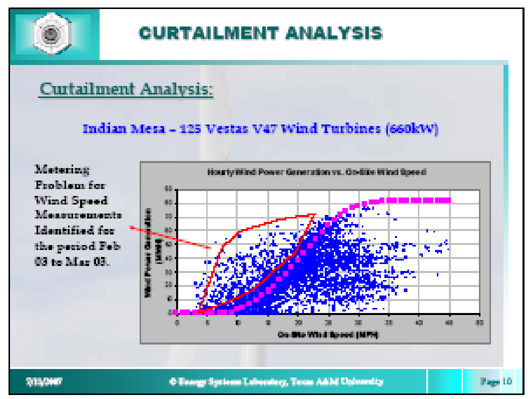


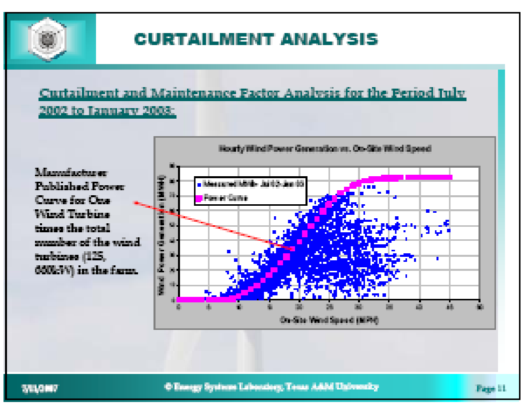
Figure 2-13: Slides Presented at the Wind/Renewables Stakeholder's Meeting, October 2006.











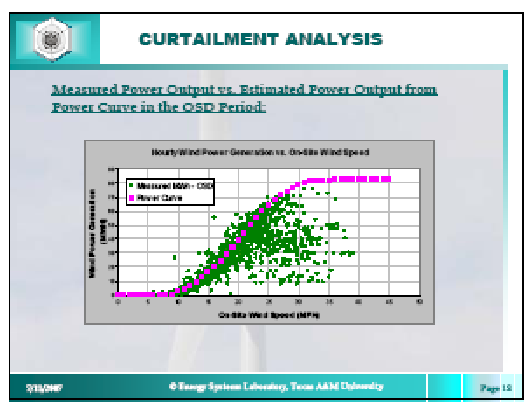
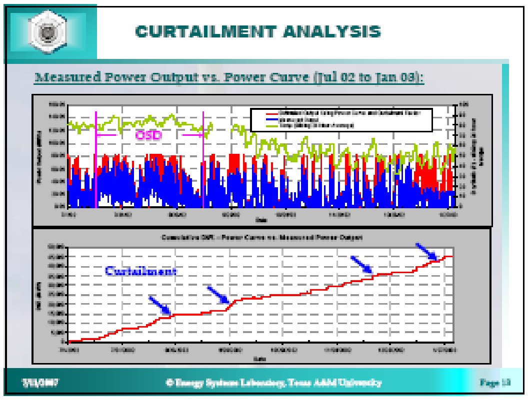
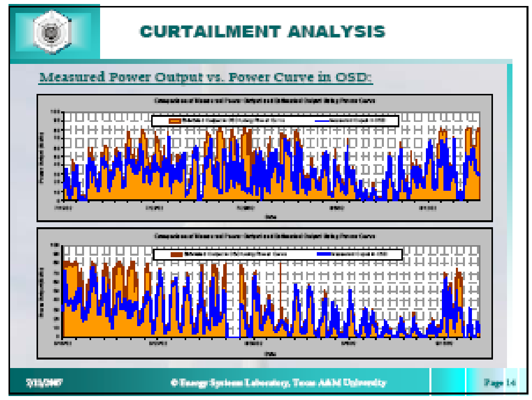
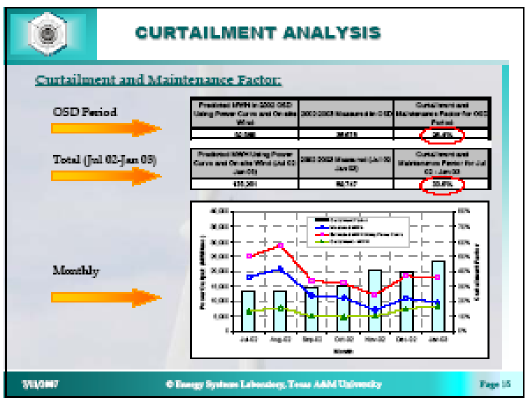
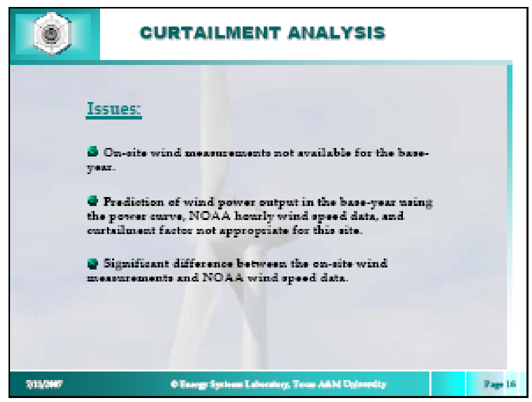


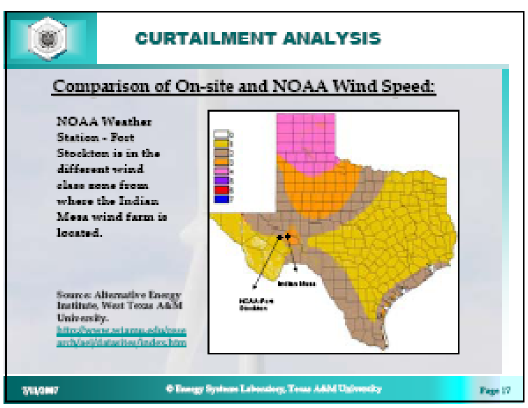
Figure 2-14: Slides Presented at the Wind/Renewables Stakeholder's Meeting, October 2006.











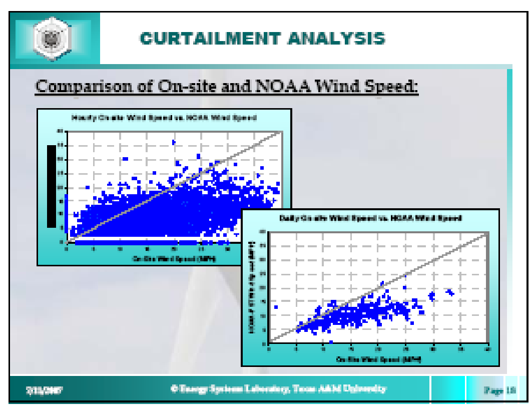
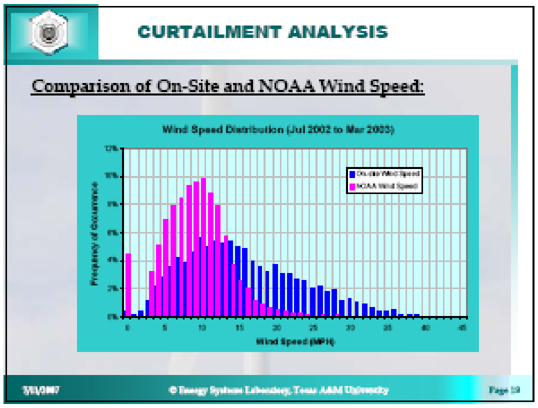
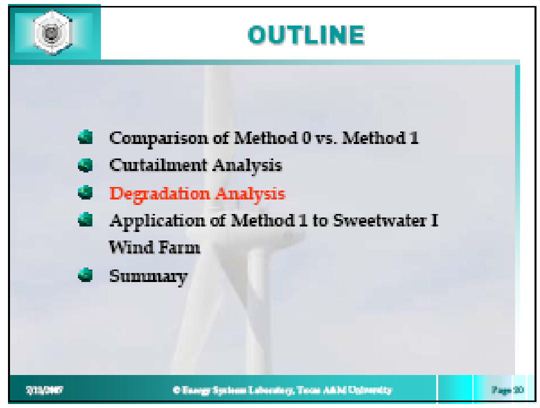
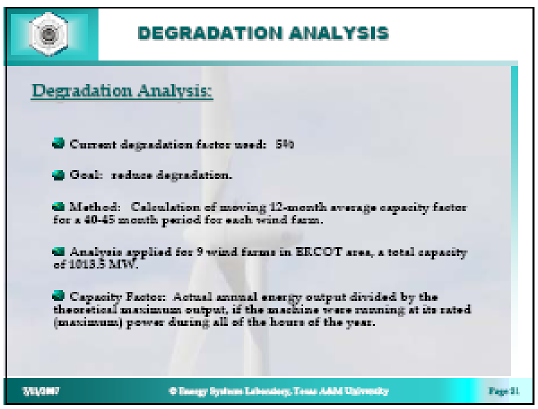
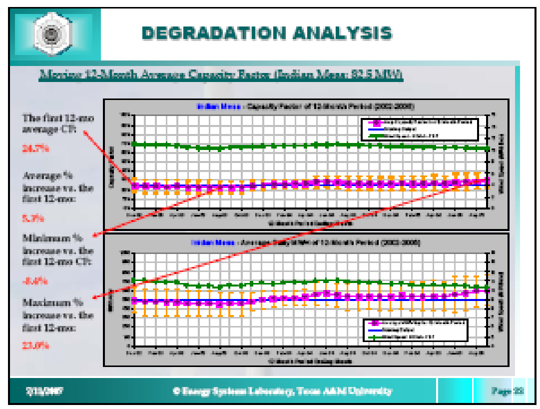


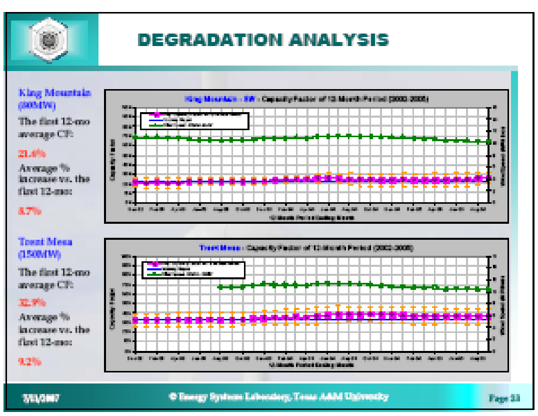
Figure 2-15: Slides Presented at the Wind/Renewables Stakeholder's Meeting, October 2006.











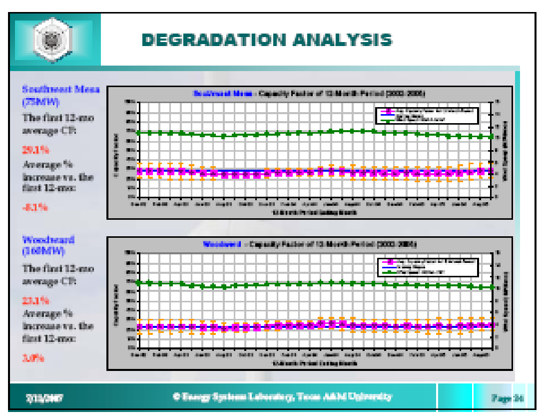
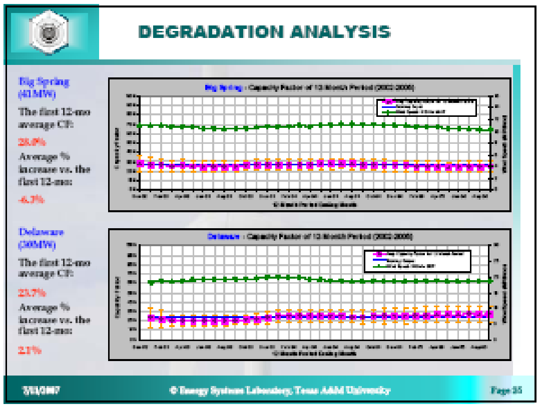
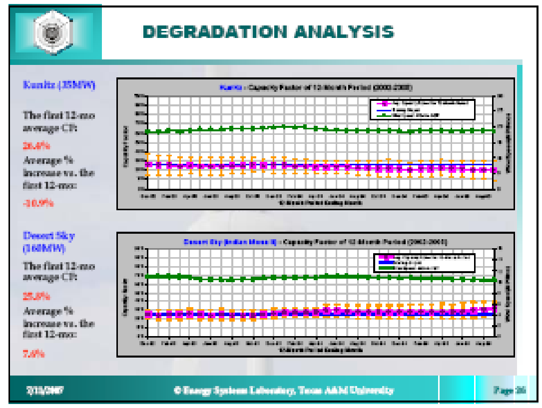
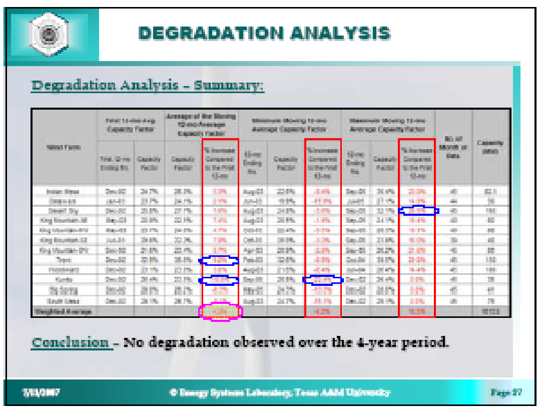
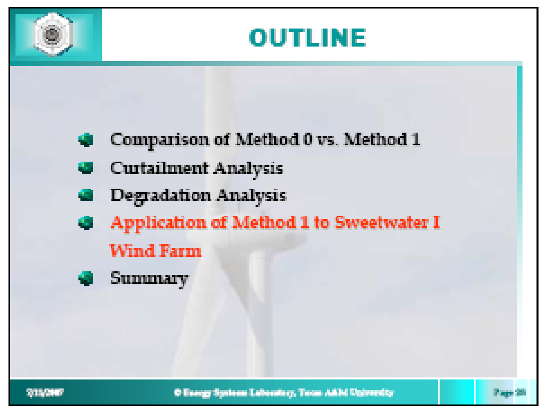


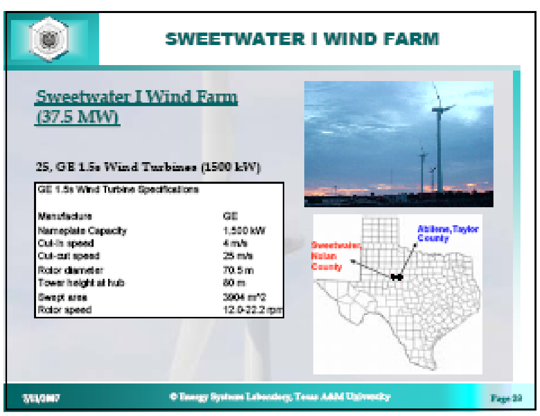
Figure 2-16: Slides Presented at the Wind/Renewables Stakeholder’s Meeting, October 2006.











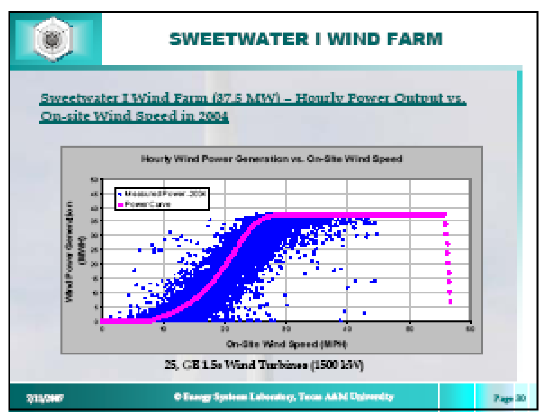
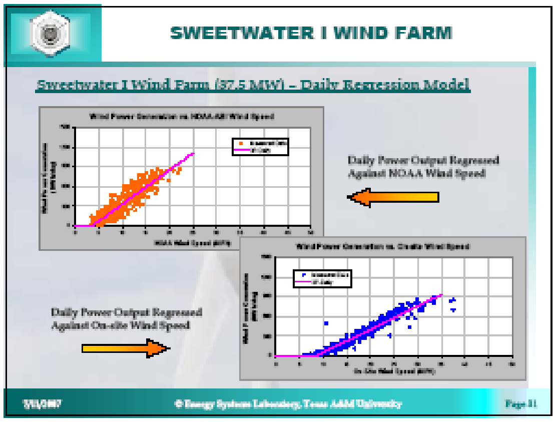
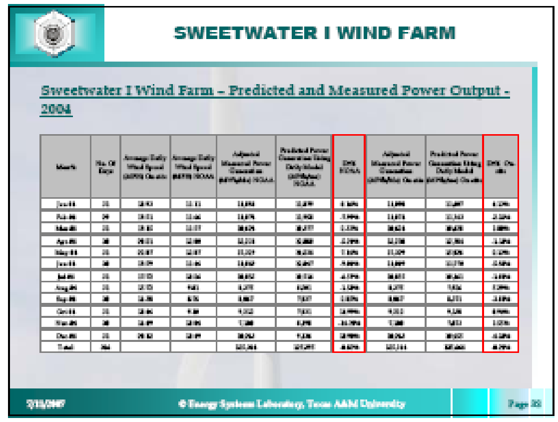
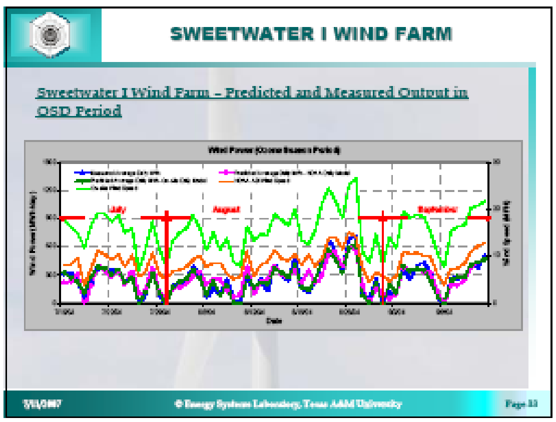
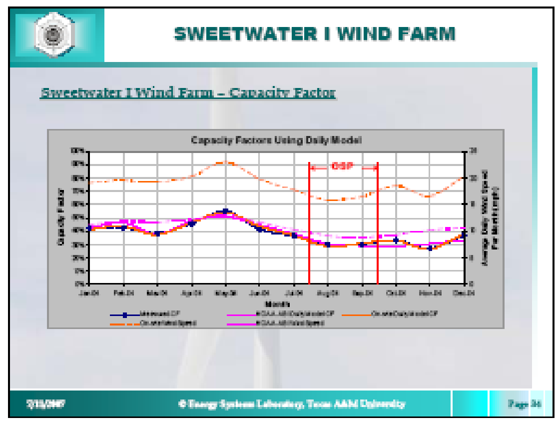


Figure 2-17: Slides Presented at the Wind/Renewables Stakeholder's Meeting, October 2006.









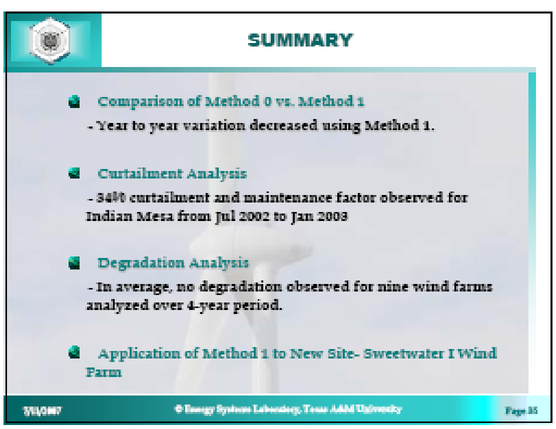
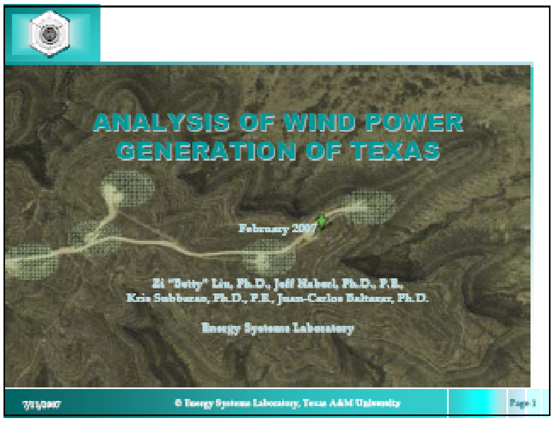
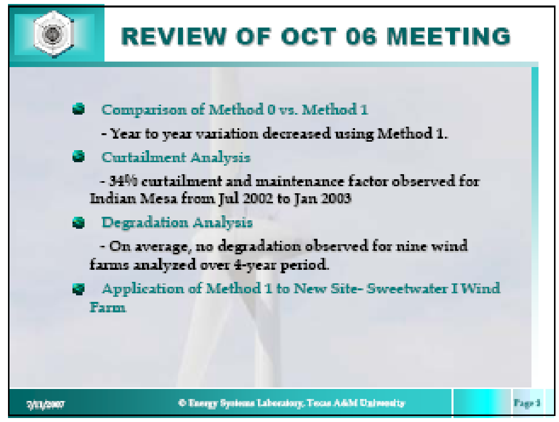


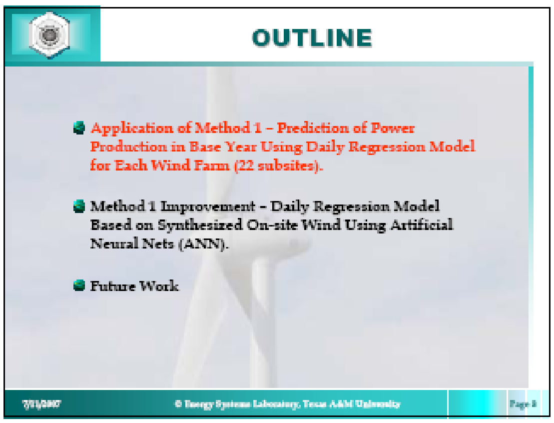
Figure 2-18: Slides Presented at the Wind/Renewables Stakeholder's Meeting, October 2006.

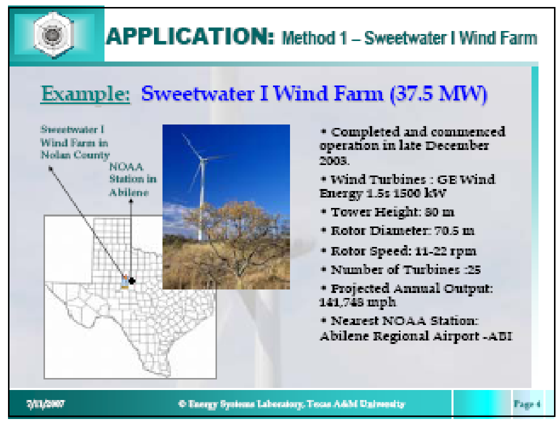
In February 2007, a third conference call was held with the Wind Energy Stakeholder's group. Figure 2-19: through Figure 2-27: show the slides used for this conference call. In this presentation, the following topics were discussed:

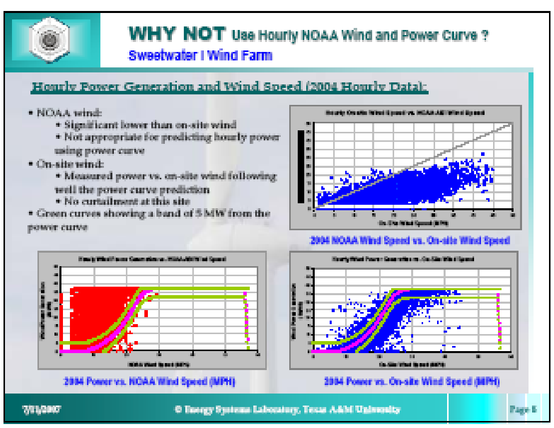
- A review of the October 2006 presentation.
- An Application of the Method 1 approach to predict base year wind production for 22 sites.
- Improvements to the Method 1 analysis using Artificial Neural Networks to improve missing on-site wind date.
- A discussion of future work.











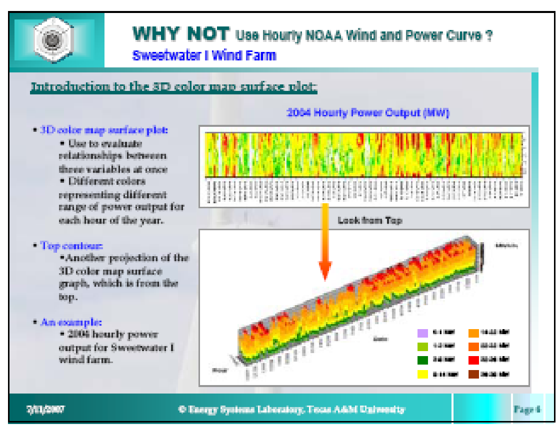
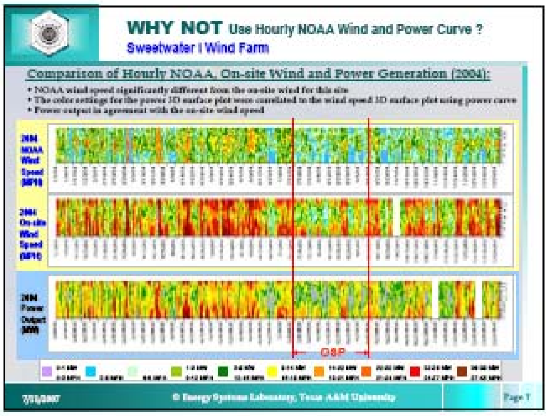
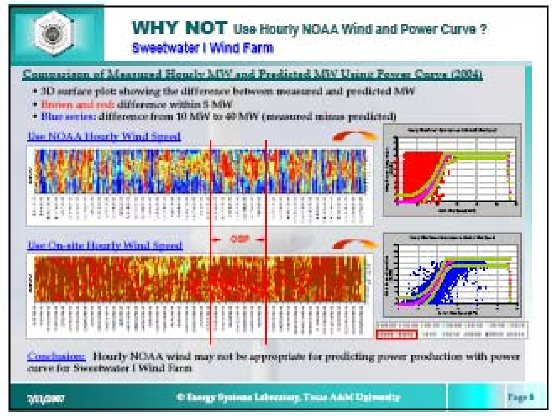
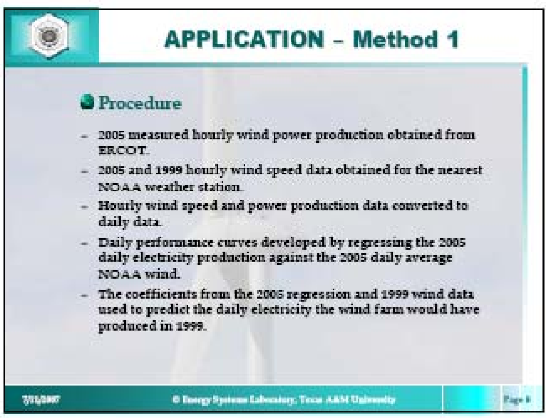
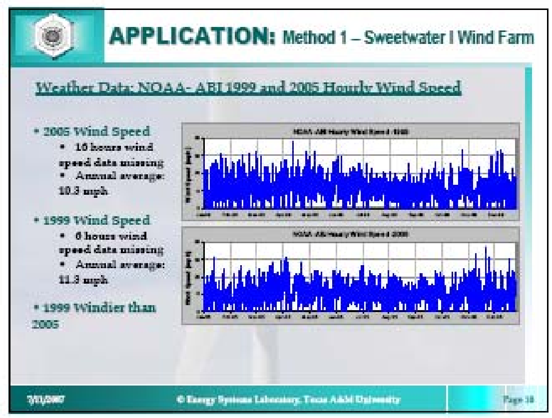


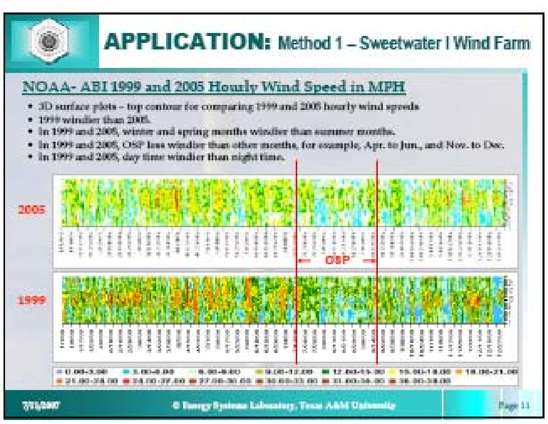
Figure 2-19: Slides Presented at the Wind/Renewables Stakeholder's Meeting, February 2006.











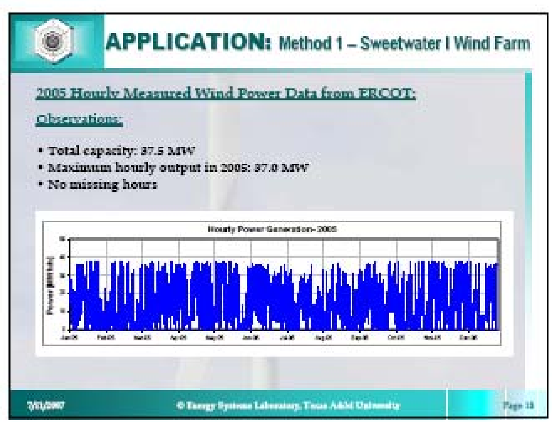


Figure 2-20: Slides Presented at the Wind/Renewables Stakeholder's Meeting, February 2006.

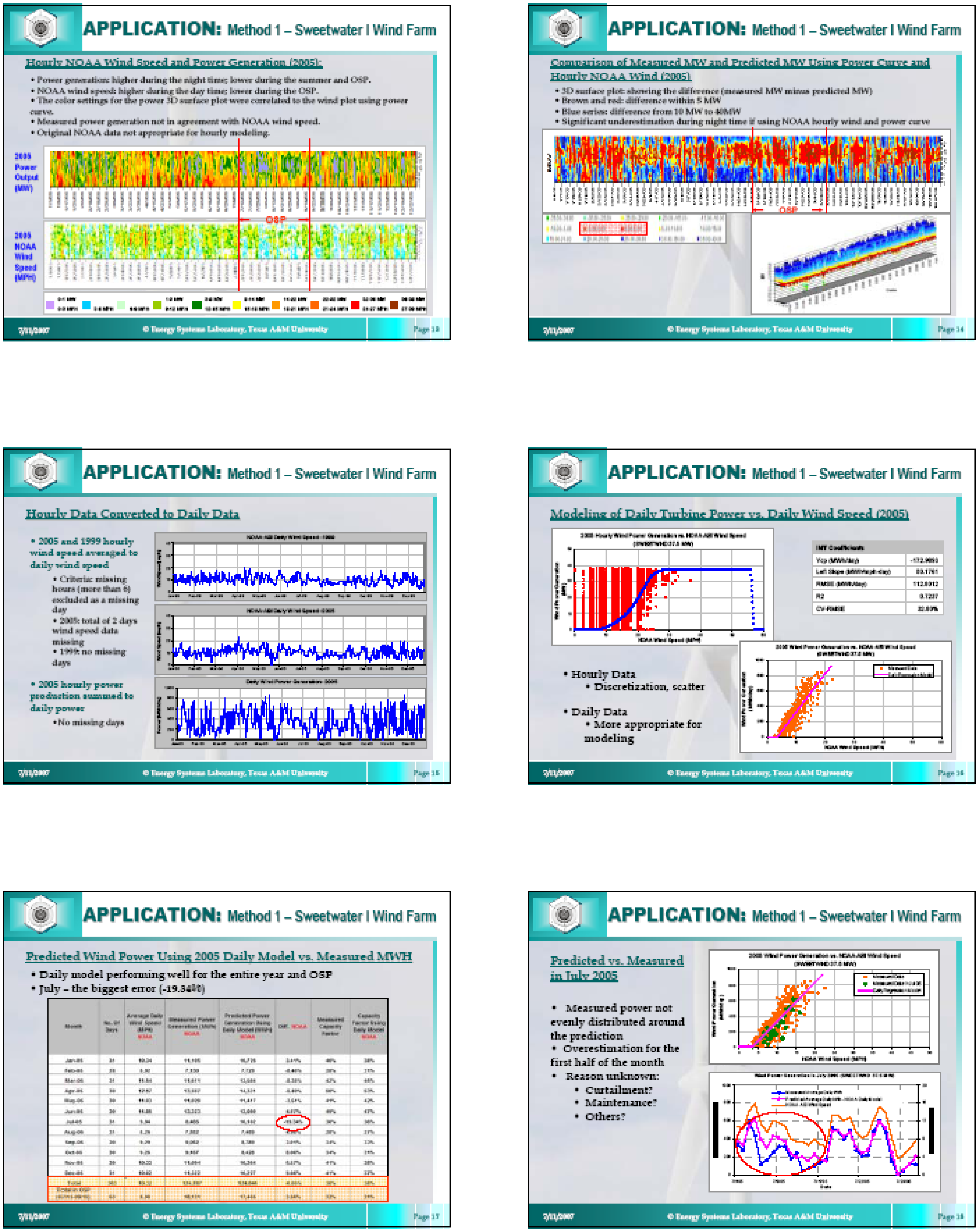
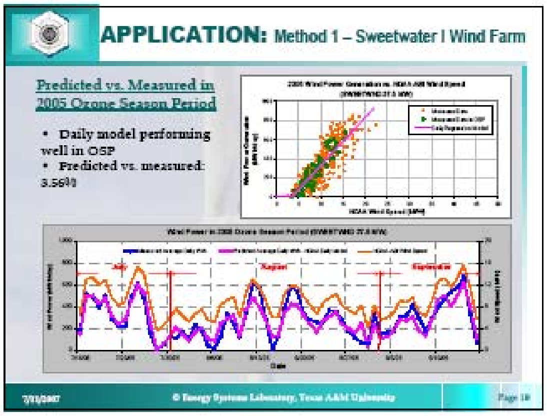
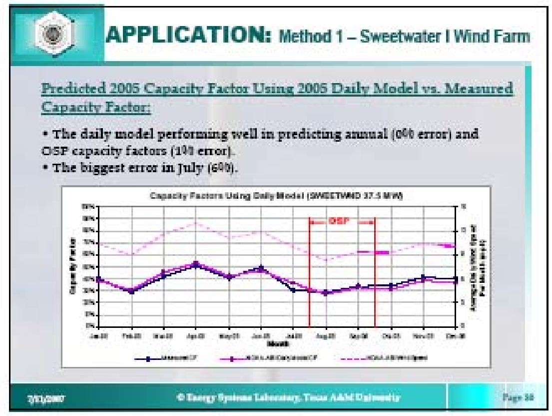
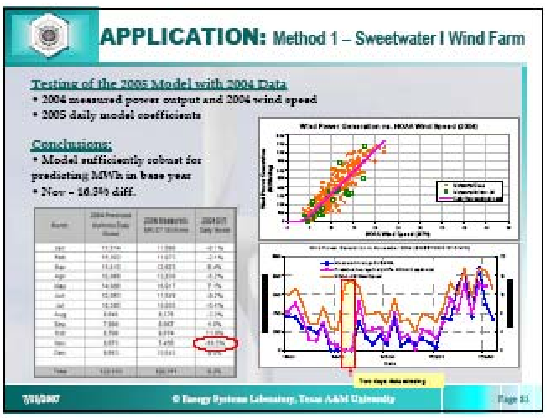
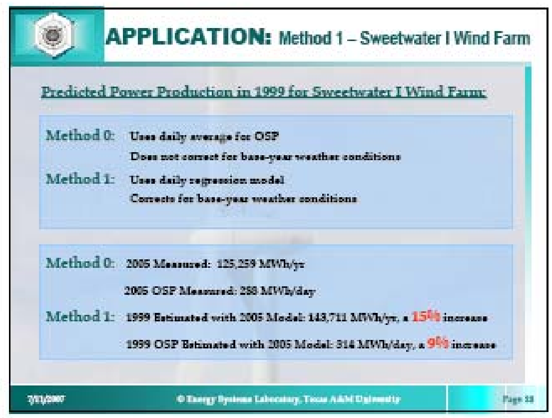


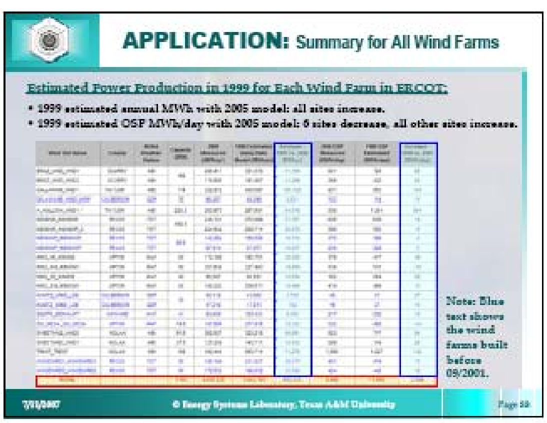
Figure 2-21: Slides Presented at the Wind/Renewables Stakeholder’s Meeting, February 2006.











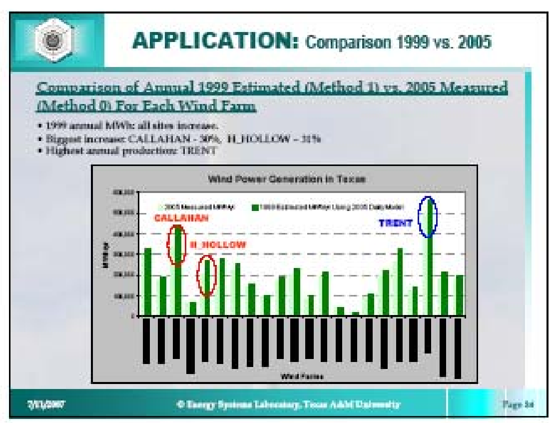
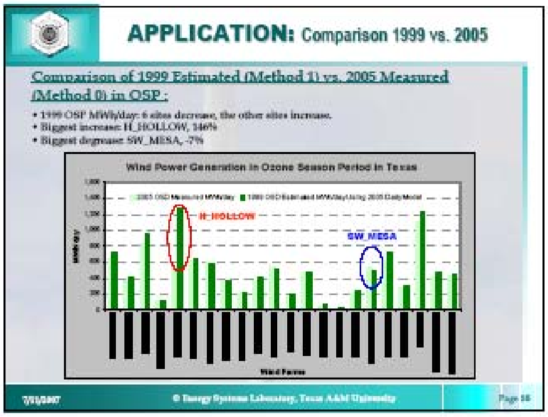
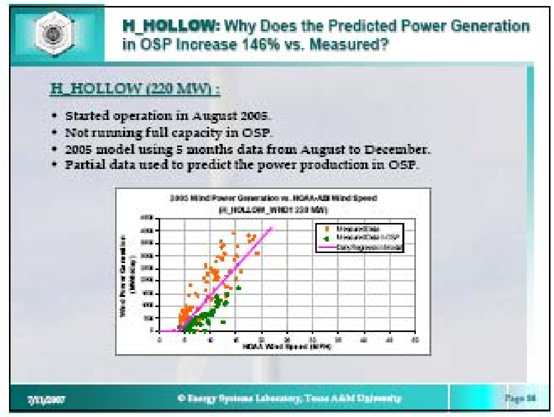
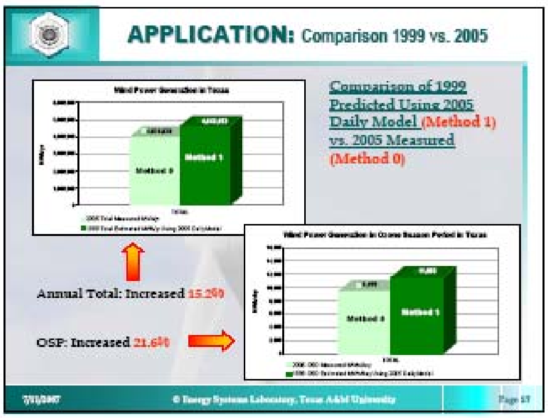
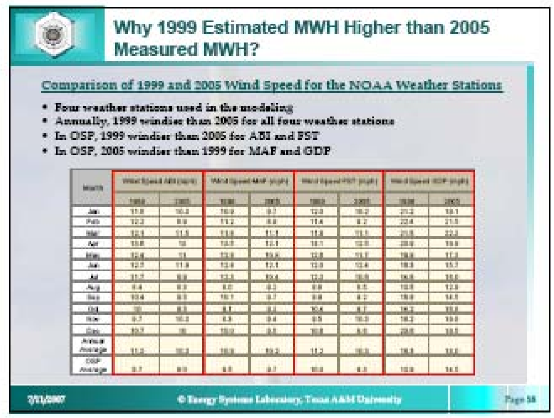


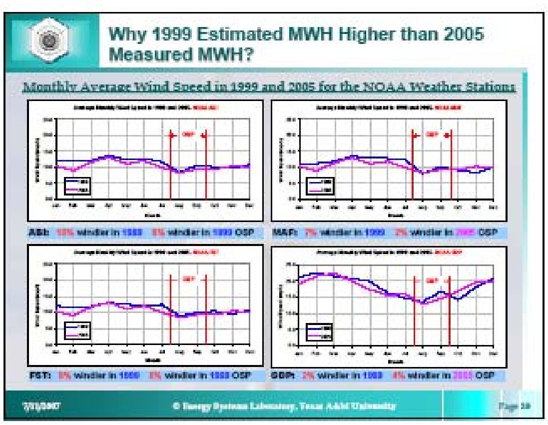
Figure 2-22: Slides Presented at the Wind/Renewables Stakeholder's Meeting, February 2006.











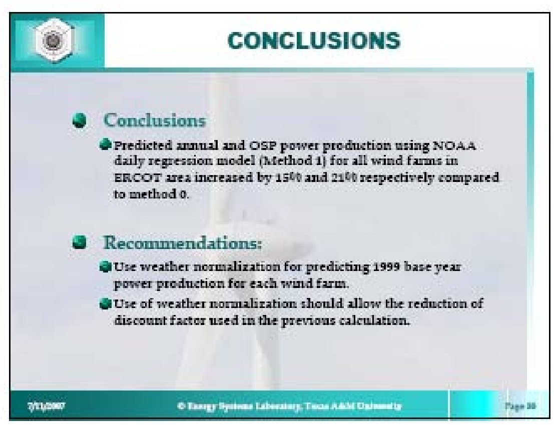
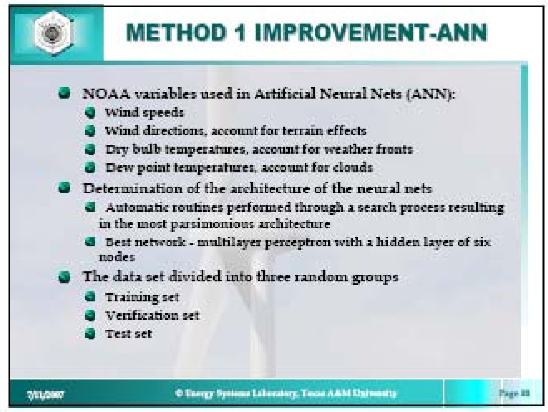
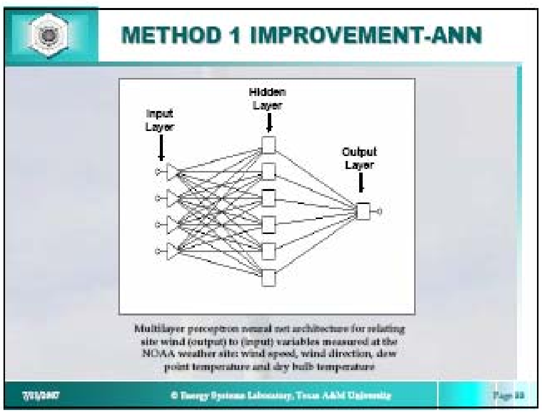
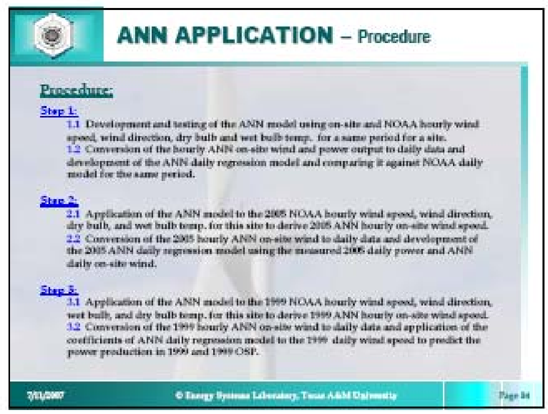
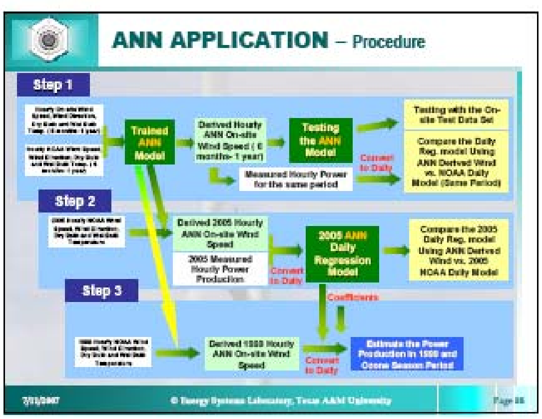


Figure 2-23: Slides Presented at the Wind/Renewables Stakeholder's Meeting, February 2006.









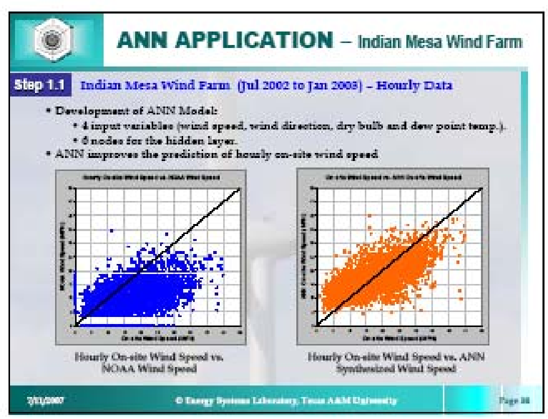
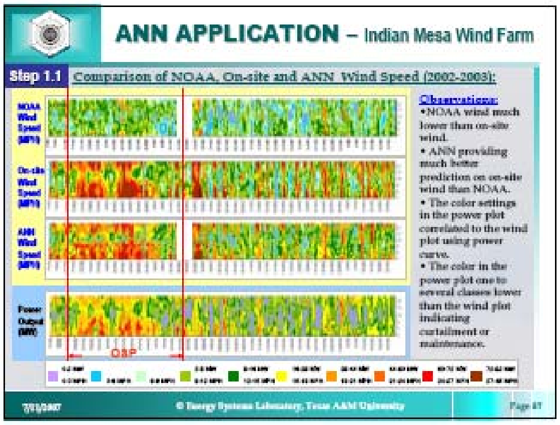
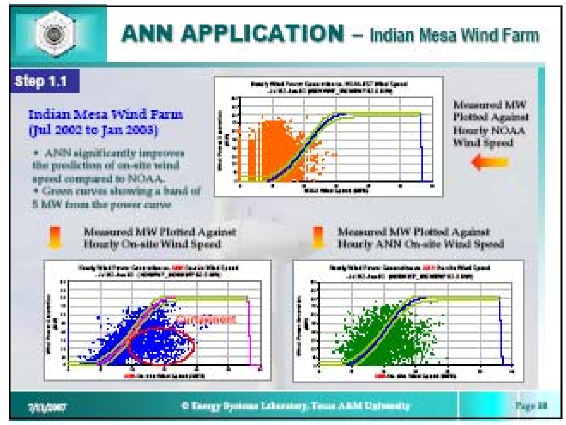
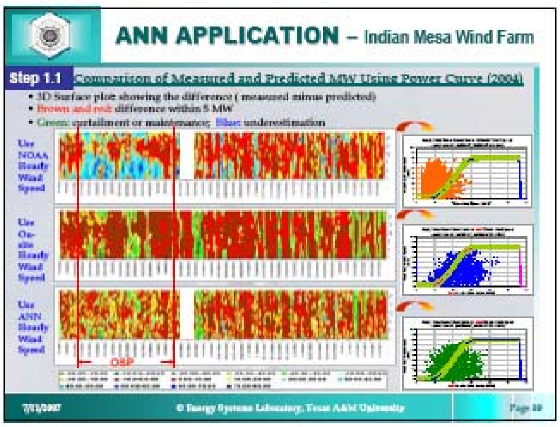
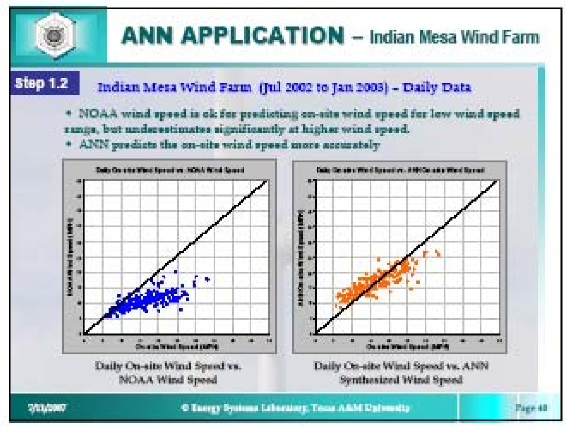


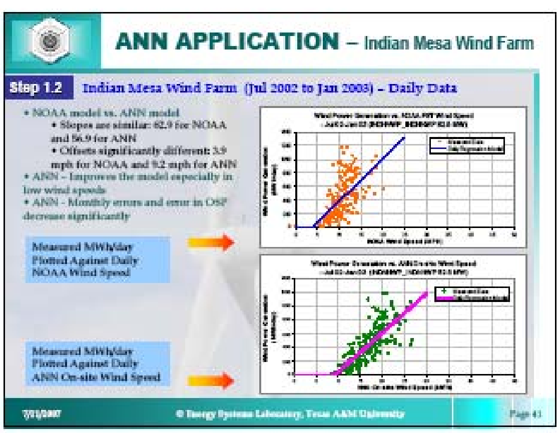
Figure 2-24: Slides Presented at the Wind/Renewables Stakeholder's Meeting, February 2006.











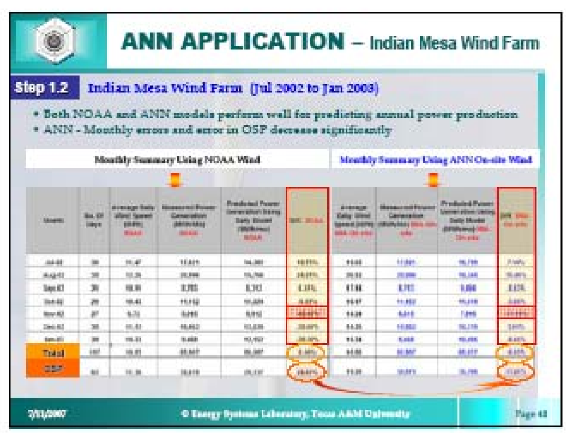
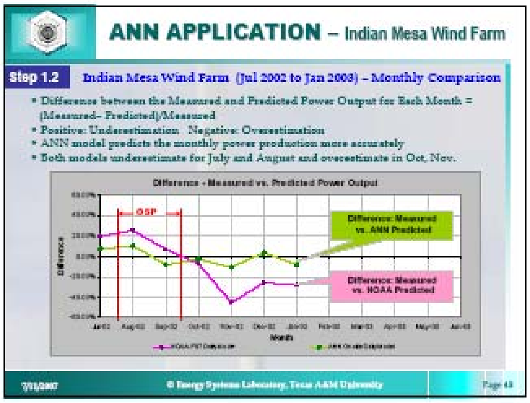
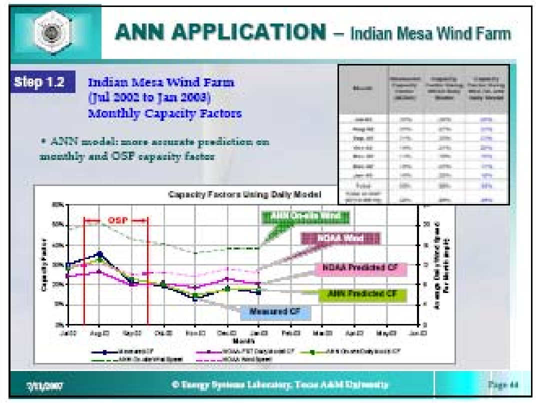
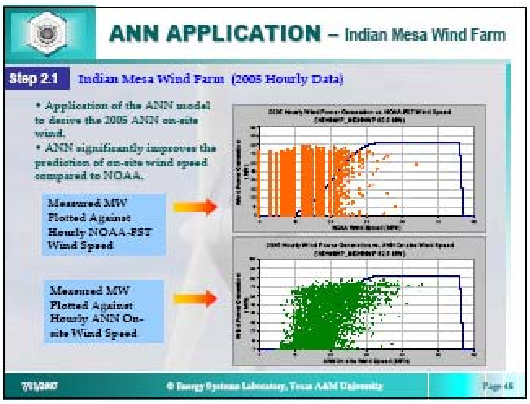
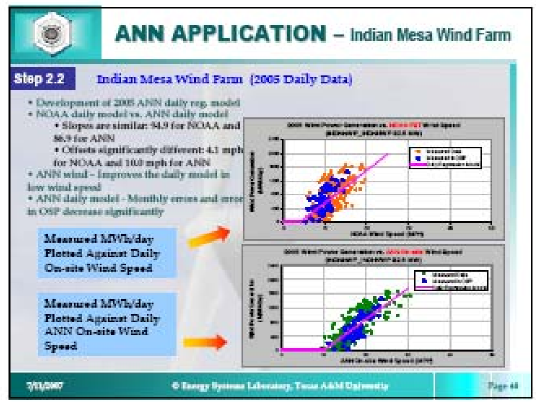


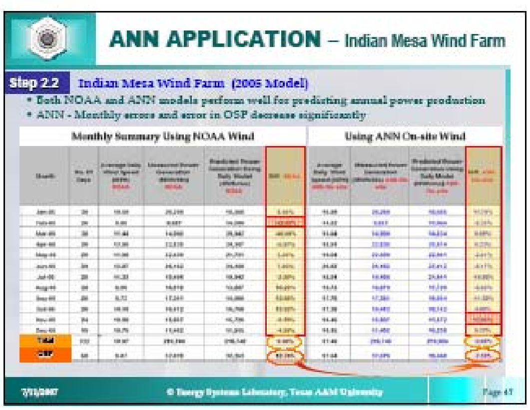
Figure 2-25: Slides Presented at the Wind/Renewables Stakeholder's Meeting, February 2006.











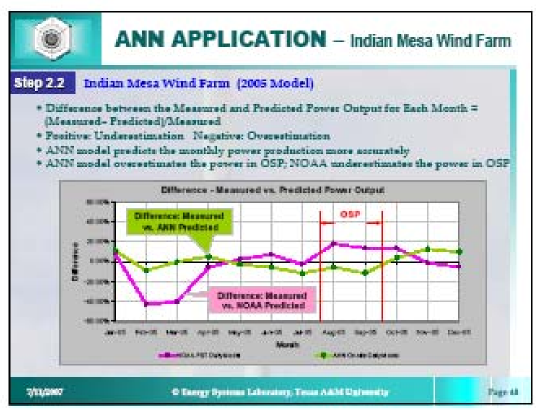
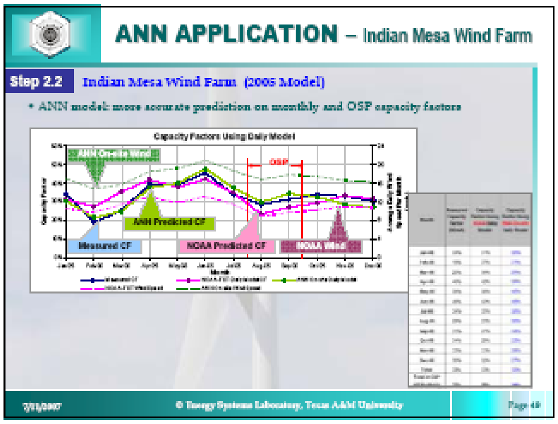
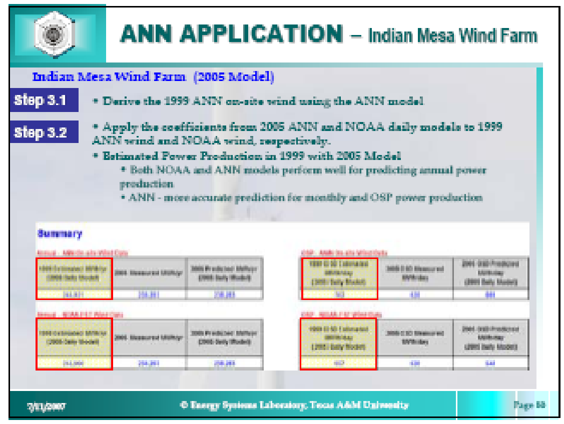
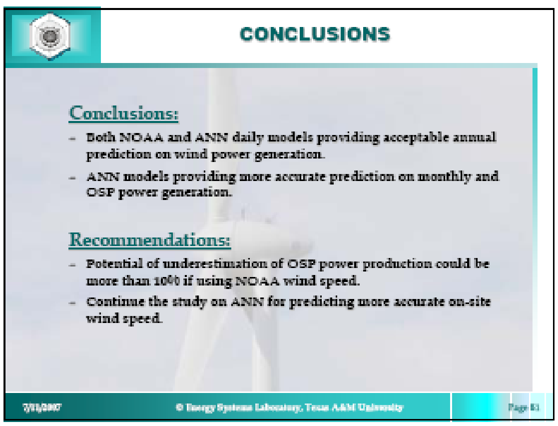


Figure 2-26: Slides Presented at the Wind/Renewables Stakeholder's Meeting, February 2006.







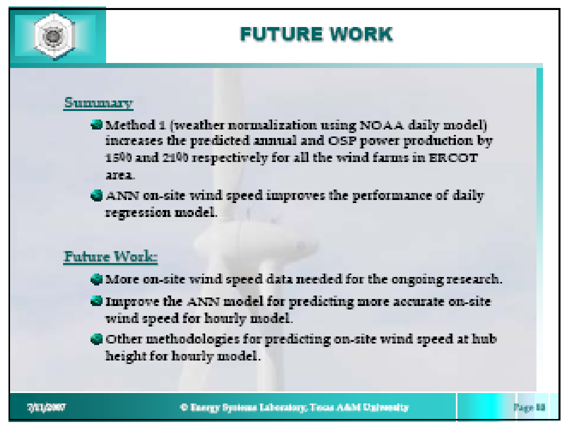


Figure 2-27: Slides Presented at the Wind/Renewables Stakeholder’s Meeting, February 2006.

3 REVIEW OF ERCOT'S RENEWABLE ENERGY CREDIT PROGRAM INFORMATION

3.1 Introduction

In this section, the information posted on ERCOT's Renewable Energy Credit Program site www.texasrenewables.com was reviewed for use in the Laboratory's report to the TCEQ. In particular, information posted under the "Public Reports" tab was downloaded and assembled into an appropriate format for review. This includes ERCOT's 2001 through 2006 reports to the Legislature, which were converted into tabular format for analysis and inserted into this report. Similarly, information from ERCOT's listing of REC generators was inspected to determine how it compared with other sources of information the Laboratory has assembled. Table 3-1 and Table 3-2 contain the list of REC generators that ERCOT has assembled as of August 2007.

3.2 Renewable Introduction

Each year ERCOT is required to report to the Legislature a compiled list of grid-connected sources that generate electricity from renewable energy. Table 3-3 and Table contain the data reported by ERCOT from 2001 through 2006, with partial information reported through 2007. Figure 3-1, Figure 3-2 and Figure 3-3 have been included to better illustrate the annual data collected by ERCOT. In the figures and tables it is clear to see that the electricity generated by wind each year is the largest single source of renewable energy in Texas, which has grown from 565,597 MWh in 2001 to 6,530,928 MWh in 2006. This is followed by landfill gas, which has grown from 29,412 MWh in 2002 to 306,087 MWh in 2006, hydroelectric: 30,639 (2001) to 210,077 (2006), biomass: 39,496 MWh (2003) to 60,569 MWh (2006), and solar: 87 MWh (2002) to 136 MWh (2006).

Table 3-1: ERCOT REC Generator List.

Company Name	Power Generating Company Name	Power Generating Company Code	Generator Site Name	Generator Site Code	Facility Identification Number	Unit Contact Information	Technology Type	Facility Noncompetitive Certification Data
El Paso Electric Company	El Paso Electric	EPE	Hueco Mountain Wind Ranch	EPE1	1	Richard Grenier	Wind	23631
FPL Pecos Wind 1 LP, LLC	FPL Pecos Wind I & II, LP	93	WOODWARD1	WOODWRD 1	2	Jesse Nevarez	Wind	Unknown
Guadalupe-Blanco River Authority	Guadalupe-Blanco River Authority	05-631-1608-3000	DG_Schumansville	DG_Schum	3	Allen Ognoskie	Hydro	20028
Guadalupe-Blanco River Authority	Guadalupe-Blanco River Authority	05-631-1608-3000	DG-MCQUEENEY	DG_MCQUE	4	Allen Ognoskie	Hydro	20028
Trent Wind Farm, L.P.	Trent Wind Farm, L.P.	70	TRENT MESA WIND FARM	TRENT	5	Richard Walker	Wind	24322
FPL Energy Upton Wind I, L.P.	FPL Energy Upton Wind I, LP	94	KING MOUNTAIN SW	KING_SW	6	Jesse Nevarez	Wind	Unknown
FPL Energy Upton Wind II, LP	FPL Energy Upton Wind II, LP	96	KING MOUNTAIN NW	KING_NW	7	Jesse Nevarez	Wind	Unknown
FPL Pecos Wind 2 LP, LLC	FPL Energy Pecos Wind I&II, LP	93	WOODWARD 2	WOODWRD 2	8	Jesse Nevarez	Wind	24296
Delaware Mountain Wind Farm LP	DELAWARE MOUNTAIN WIND FARM LP	16	DELAWARE MOUNTAIN	DELAWARE	9	Linda Brandi	Wind	23705
Indian Mesa, L.P.	NWP INDIAN MESA WIND FARM LP	17	INDIAN MESA NWP	INDNNWP	10	Linda Brandi	Wind	23745
Small Hydro of Texas, Inc.	Small Hydro of Texas, Inc.	71	DG_CUEROCSW	CUECPL	13	Linda A. Parker	Hydro	24191
Upton Wind III, LP	FPL Energy Upton Wind III, LP	96	KING MOUNTAIN NE	KING_NE	14	Jesse Nevarez	Wind	20063
FPL Energy Upton Wind IV, LP	FPL Energy Upton Wind IV, LP	96	KING MOUNTAIN SE	KING_SE	15	Jesse Nevarez	Wind	Unknown
Desert Sky Wind Farm 1 LP	Indian Mesa Power Parners I, L.P.	999	Indian Mesa I Wind Power	INDNENR	16	Richard Walker	Wind	24921
Desert Sky Wind Farm 2 LP	Indian Mesa Power Parners II, L.P.	999	Indian Mesa II Wind Power	INDNENR	17	Richard Walker	Wind	24922
Llano Estacado	Llano Estacado Wind Ranch at White Deer	Shell	White Deer	White Deer Wind	18	Crystal Wuest	Wind	23633
Renewable Ventures	Nuon Renewable Ventures	NRV	Green Mountain Solar at Upper Kirby	USAPV003	19	Nuon Renewable Ventures	Solar	26410
Renewable Ventures	Nuon Renewable Ventures	NRV	Green Mountain Solar at The Winston School	USAPV002	20	Nuon Renewable Ventures	Solar	26411
Viridis Energy, LP Atascocita	Viridis Energy, LP - Atascocita	93-01-87393	ATASCOCITA	HB	29	Mr Luong Nguyen	Landfill gas	26813
Viridis Energy, LP - Coastal Plains	Viridis Energy, LP - Coastal Plains	93-01-16145	COASTAL PLAINS	ALVIN	32	Mr Luong Nguyen	Landfill gas	26812
Viridis Energy, LP - Baytown	Viridis Energy, LP - Baytown	01-62-16561	BAYTOWN	TRM	33	Mr Luong Nguyen	Landfill gas	26811

Table 3-2: ERCOT REC Generator List (cont.).

Company Name	Power Generating Company Name	Power Generating Company Code	Generator Site Name	Generator Site Code	Facility Identification Number	Unit Contact Information	Technology Type	Facility Noncompetitive Certification Data
Viridis Energy, LP - Blue Bonnet	Viridis Energy, LP - Blue Bonnet	93-01-27472	BLUE BONNET	LB	34	Mr Luong Nguyen	Landfill gas	26809
Viridis Energy, LP - Conroe	Viridis Energy, LP - Conroe	Conroe	Conroe	Conroe	35	Mr Luong Nguyen	Landfill gas	26808
Viridis Energy, LP - Security	Viridis Energy, LP - Security	SECURITY	SECURITY	SECURITY	36	Mr Luong Nguyen	Landfill gas	26810
Gas Recovery Systems, Inc.	Gas Recovery Systems	20066	Sunset Farms Electric	Sunset Farms Electric	37	Paul Hesson	Landfill gas	24199
Bio Energy (Austin) LLC	Bio Energy Austin LLC	DG_WALZE	DG_WALZE	DG_WALZE	38	Dennis Bollinger	Biomass	25512
The University of Texas - Houston	University of Texas - Houston	UTHSC	University Center Tower	University Center Tower	42	Rahsaan Arscott	Solar	No. 77027
Sweetwater Wind Power LLC	Sweetwater Wind power LLC	137899477	Sweetwater Wind 1	SWEETWN D	43	Kim Takayesu	Wind	28924
Brazos Wind, LP	Brazos Wiind LP	Brazos Wind	Green Mountain Energy Wind Farm at Brazos	BRAZ_WND 1	44	Scott McBride	Wind	29025
Brazos Wind, LP	Brazos Wind LP	Brazos Wind	Green Mountain Energy Wind Farm at Brazos	BRAZ_WND 2	45	Scott McBride	Wind	29025
Aeolus Wind	Aeolus Wind, LLC	Aeolus Wind, LLC	North Texas	NA	51	Bridget Hutchinson	Wind	NA
Sweetwater Wind Power LLC	Sweetwater Wind Power	Sweet Wind 2	Sweetwater Wind 2	SWEETWN D2	52	Kim Takayesu	Wind	30462
Renovar Arlington, Ltd.	Renovar Arlington, Ltd.	Rnvr-1	Village Creek	Vcreek	53	Lisette Luna	Landfill gas	31083
Renovar Arlington, Ltd.	Renovar Arlington, Ltd.	Rnvr-2	Village Creek	Vcreek	54	Lisette Luna	Landfill gas	31083
Callahan Divide	FPL Energy Callahan Divide	30385	Callahan Wind Energy	30385	55	David Gonzalez	Wind	30385
Buffalo Gap Wind Farm LLC	Buffalo Gap Wind Farm, LLC	Buffalo Gap	Buffalo Gap Wind Farm	Buffalo Gap	56	Gabe Vaca	Wind	31412
Horse Hollow	FPL Energy Horse Hollow Wind	0	Horse Hollow Wind Energy	0	57	Vivian Venegas	Wind	31594
Sweetwater Wind Power LLC	Sweetwater Wind Power	603943148	Sweetwater Wind 3 LLC_AE	SWEETWN D3	58	Kim Takayesu	Wind	31983
Sweetwater Wind Power LLC	Sweetwater Wind Power	603943148-3000	Sweetwater Wind 3 LLC_CPS	SWEETWN D3	59	Kim Takayesu	Wind	31983
American Wind Power Center	American Wind Power Center	Lubbock	AWPC	AWPC#1	60	Coy F. Harris	Wind	32470
Bio Energy (Texas), LLC	Bio Energy (Texas) LLC	32079	Covel Gardens Landfill Gas Power Station	DG_MEDIN	61	John M. Love	Landfill gas	20140
MeadWestvaco Texas LP	MeadWestvaco Texas LP	Evadale Opertions	MeadWestvaco Evadale Pulp and Paper Mill	Evadale Texas	63	Sammy Brunson, Jr	Biomass	31646
G2 Energy (FW Regional)	G2 Energy (FW Regional) LLC	77-998-1765	DG_RDLML_1 Unit	FW Regional	64	John Bean	Landfill gas	32558
JD Wind 1	JD Wind 1	20137	JD Wind 1	JD Wind 1	65	Steve Maller	Wind	32802
JD Wind02	JD Wind 2	20138	JD Wind 2	JD Wind 2	66	Steve Maller	Wind	32803
JD Wind03	JD Wind 3	20139	JD Wind 3	JD Wind 3	67	Steve Maller	Wind	32804
Mesquite Wind, LLC	Mesquite Wind LLC	Horizon Wind	Horizon Wind	Horizon Wind	68	Brian Hayes	Wind	32936
FPL Energy Horse Hollow Wind II, LP	FPL Energy Horse Hollow II, LP	Horse Hollow II	Horse Hollow II	Horse Hollow II	69	John Cote	Wind	32524
Post Wind Farm LP	Post Wind Farm, LP	Post Wind	Post Wind	Post Wind	70	John Cote	Wind	32525
JD Wind 5	JD Wind 5	20154	JD Wind 5	JD Wind 5	71	Steve Maller	Wind	32912

Table 3-3: Electricity Generation by Renewable Sources (MWh, ERCOT: 2001 – 2006 by Quarter).

Technology Type	Year	Quarter1	Quarter2	Quarter3	Quarter4	Total MWh
Biomass						
Hydro						
Landfill gas						
Hydro	2001	0	0	11,293	19,346	30,639
Wind	2001	0	0	201,118	364,479	565,597
Grand Totals		0	0	212,411	383,825	596,236

Technology Type	Year	Quarter1	Quarter2	Quarter3	Quarter4	Total MWh
Biomass						
Hydro	2002	105817	69165	80,154	56,956	312,093
Landfill gas	2002	8216	7073	6,986	7,137	29,412
Solar	2002	0	29	37	21	87
Wind	2002	611708	716896	622,262	500,618	2,451,484
Grand Totals		725,741	793,163	709,439	564,732	2,793,076

Technology Type	Year	Quarter1	Quarter2	Quarter3	Quarter4	Total MWh
Biomass	2003	8876	11253	10,999	8,368	39,496
Hydro	2003	92680	52592	71,699	22,713	239,684
Landfill gas	2003	29995	44629	39,920	39,662	154,206
Solar	2003	32	70	69	49	220
Wind	2003	561994	670248	617,794	665,446	2,515,482
Grand Totals		693,577	778,792	740,481	736,238	2,949,088

Technology Type	Year	Quarter1	Quarter2	Quarter3	Quarter4	Total MWh
Biomass	2004	6274	11459	11,482	7,725	36,940
Hydro	2004	55638	52735	52,350	74,067	234,791
Landfill gas	2004	52801	47964	53,659	49,018	203,443
Solar	2004	31	67	70	44	211
Wind	2004	815010	1014396	610,157	770,066	3,209,630
Grand Totals		929,754	1,126,621	727,718	900,920	3,685,015

Technology Type	Year	Quarter1	Quarter2	Quarter3	Quarter4	Total MWh
Biomass	2005	13921	15069	14,764	14,883	58,637
Hydro	2005	108974	106893	61,189	33,246	310,302
Landfill gas	2005	52118	51193	56,166	54,301	213,777
Solar	2005	46	69	67	46	227
Wind	2005	801232	1246182	869,508	1,304,646	4,221,568
Grand Totals		976,291	1,419,406	1,001,694	1,407,122	4,804,511

Technology Type	Year	Quarter1	Quarter2	Quarter3	Quarter4	Total MWh
Biomass	2006	16327	10479	17,152	16,610	60,569
Hydro	2006	55000	83064	44,870	27,143	210,077
Landfill gas	2006	69191	78650	75,665	82,580	306,087
Solar	2006	26	43	41	26	136
Wind	2006	1478927	1584166	1,376,540	2,091,295	6,530,928
Grand Totals		1,619,471	1,756,402	1,514,268	2,217,654	7,107,797

Technology Type	Year	Quarter1	Quarter2	Quarter3	Quarter4	Total MWh
Biomass	2007	13052	1835	0	0	14,887
Hydro	2007	9192	20433	0	0	29,625
Landfill gas	2007	74600	13329	0	0	87,929
Solar	2007	27	12	0	0	39
Wind	2007	1889198	32042	0	0	1,921,241
Grand Totals		1,986,069	67,651	0	0	2,053,721

Table3-4: Electricity Generation by Renewable Sources (MWh, ERCOT: 2001 – 2006 Annual).

	2001	2002	2003	2004	2005	2006	2007
Wind	565,597	2,451,484	2,515,482	3,209,630	4,221,568	6,530,928	1,921,241
Landfill gas		29,412	154,206	203,443	213,777	306,087	87,929
Hydro	30,639	312,093	239,684	234,791	310,302	210,077	29,625
Biomass			39,496	36,940	58,637	60,569	14,887
Solar		87	220	211	227	136	39
Total (MWh)	596,236	2,793,076	2,949,088	3,685,015	4,804,511	7,107,797	2,053,721

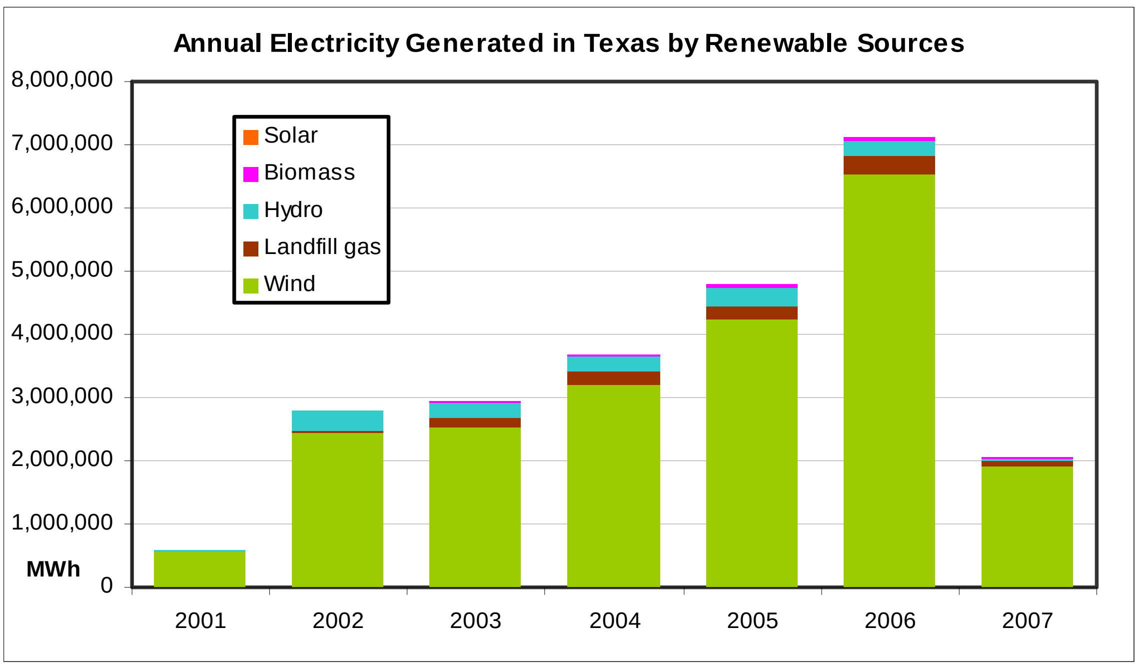


Figure 3-1: Electricity Generation by Renewable Sources (ERCOT: 2001 – 2006 Annual).

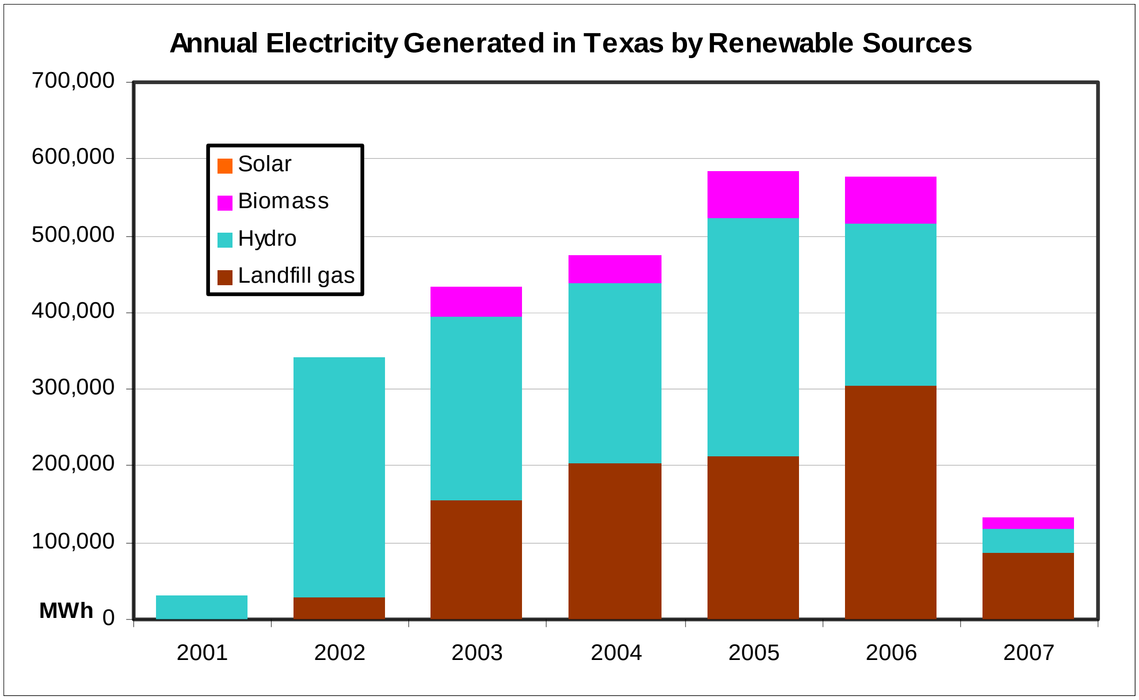


Figure 3-2: Electricity Generation by Renewable Sources Other Than Wind (ERCOT: 2001 – 2006 Annual).

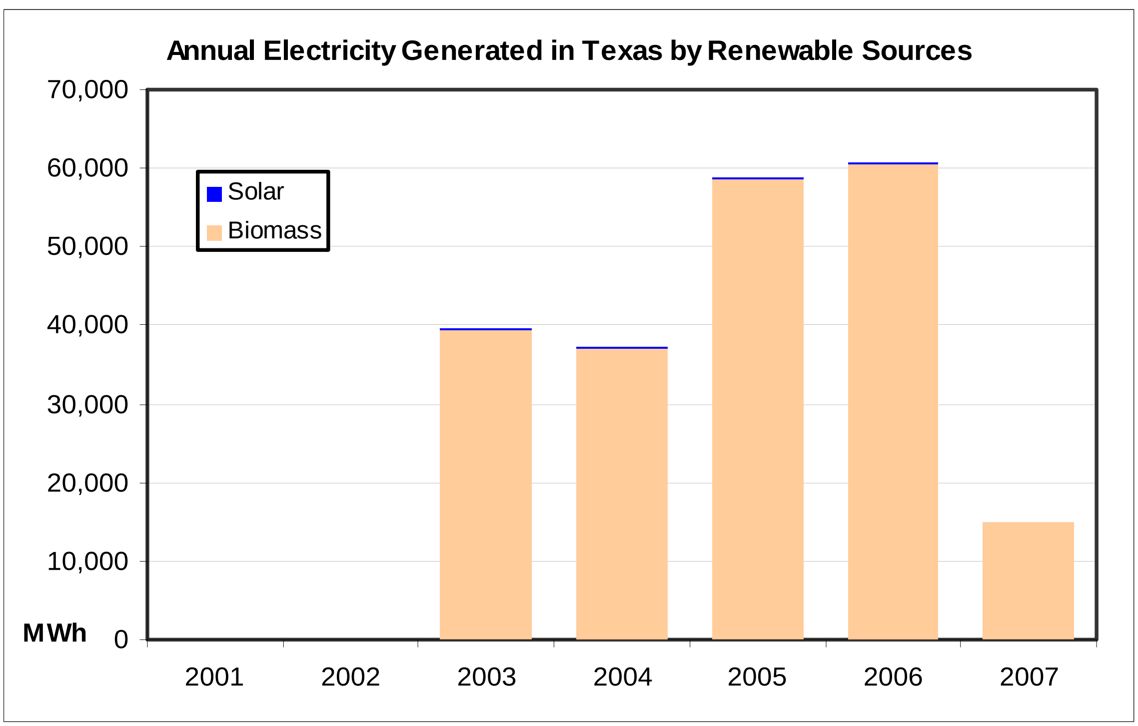


Figure 3-3: Electricity Generation by Renewable Sources from Solar and Biomass (ERCOT: 2001 – 2006 Annual).

4 ANALYSIS ON WIND FARMS USING 2005 DATA

4.1 Introduction

In this section, the weather normalization procedures developed in conjunction with the Stakeholders[5] were applied to several additional wind farms that reported their data to ERCOT during the 2005 measurement period, together with wind data from the nearby NOAA weather stations. In the 2006 Wind and Renewables report to the TCEQ (Haberl et al. 2006), weather normalization analysis methods were reviewed, and an analysis was shown for a single wind turbine in Randall, Texas, as well as an analysis of a wind farm containing multiple turbines at the Indian Mesa facility in Pecos, Texas.

In this section, an analysis of wind data for the Sweetwater I wind farm in Nolan County, Texas is provided, including the processing of weather and power generation data, modeling of daily power generation versus daily wind speed using the ASHRAE Inverse Model Toolkit (IMT) (Haberl et al. 2003; Kissock et al. 2003), prediction of 1999 wind power generation using developed coefficients from 2005 daily model, and the analysis on monthly capacity factors generated using the model.

Then a summary of total predicted wind power production in the base year (1999) for all the wind farms in the ERCOT region using this procedure is presented to show the improved accuracy of using this weather normalization procedure compared to the non-weather normalization procedure reported in the 2006 integrated savings report to the TCEQ (Haberl et al. 2006).

An uncertainty analysis was also performed on all the daily regression models and included in this report to show the accuracy of applying the linear regression models to predict the wind power generation that the wind farms would have had in the base year of 1999.

The detailed analysis for each wind farm is provided in the Appendix to this report. The original data used in the analysis is included in the accompanying CD-ROM with this report.

4.2 Analysis of the Sweetwater I Wind Farm, Nolan County, Texas.

In this section, the Sweetwater I wind farm was used as an example to further analyze the applicability of the procedure of modeling wind power production using 2005 measured wind power data and NOAA wind data, and forecasting the electricity power to the selected base year (1999). Sweetwater I was completed and commenced operation in late December 2003. It is a 37.5-megawatt project using 25 GE Wind turbines located in Nolan County, Texas. The project characteristics are listed in Table 4-1.

[5] See the previous section that describes the conference calls held with the Wind Energy Stakeholder's group to develop the methodologies.

Figure 4-1: The Sweetwater I Wind Farm (37.5 MW).

Table 4-1: Project Characteristics.

Wind Turbines	GE Wind Energy 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

4.2.1 Weather Data, Abilene NOAA Site.

In Figure 4-2, the hourly wind speed data are shown from the NOAA – Abilene Regional Airport (ABI) [6] for the years 1999 and 2005. Figure 4-3 shows the daily wind speed data from NOAA - ABI for the same two years. The annual average daily wind speed of 1999 and 2005 are 11.3 mph and 10.3 mph, respectively.

[6] NOAA wind measurements were taken at a height of 33 ft.

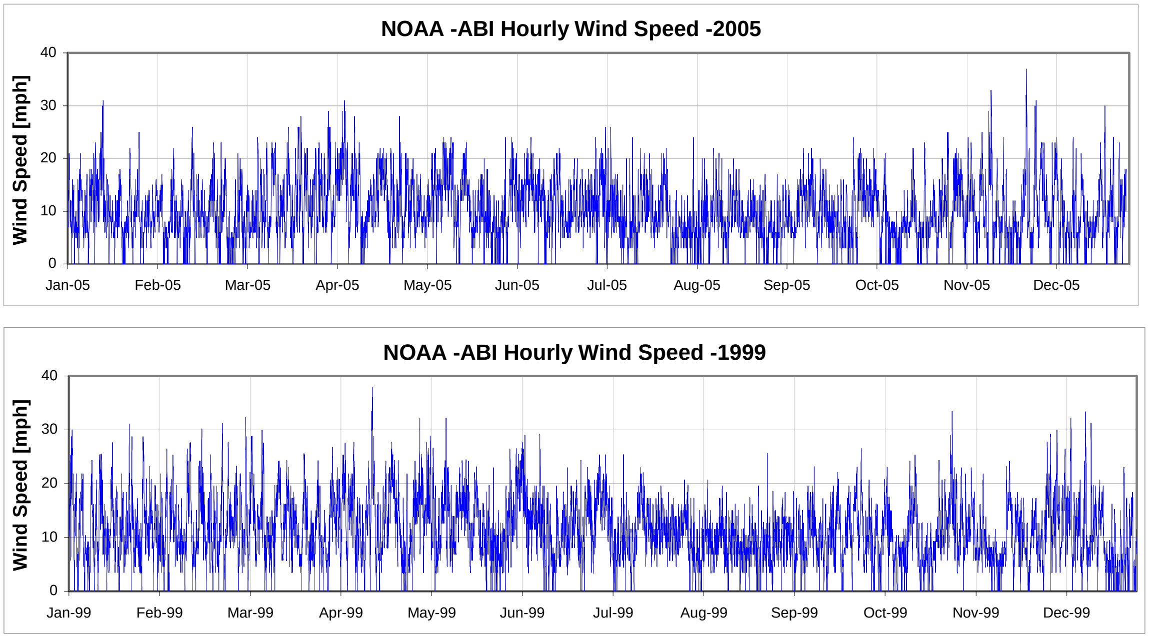


Figure 4-2: Hourly NOAA-ABI Wind Speed (1999 and 2005).

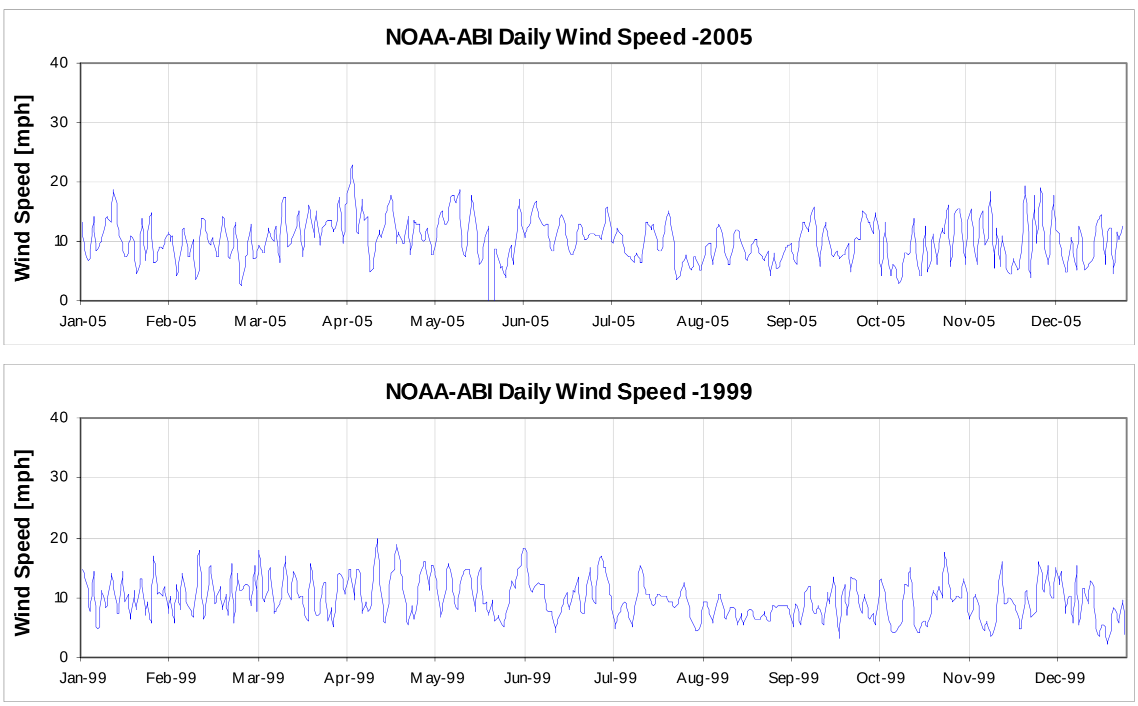


Figure 4-3: Daily NOAA-ABI Wind Speed (1999 and 2005).

4.2.2 Wind Power Data

In Figure 4-4, the hourly electricity produced and measured by ERCOT for this wind farm is shown in time series for the 2005. Figure 4-5 shows the daily turbine power generation totaled from the hourly data. In Figure 4-6, the hourly wind power data were plotted against the hourly NOAA wind measurements. The data show scatter and discretization (i.e., patterning) due to the precision of the measurements. In Figure 4-7, 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. As previously shown for the Randall and Indian Mesa sites, this figure also shows that daily wind power data are suitable for the modeling purpose.

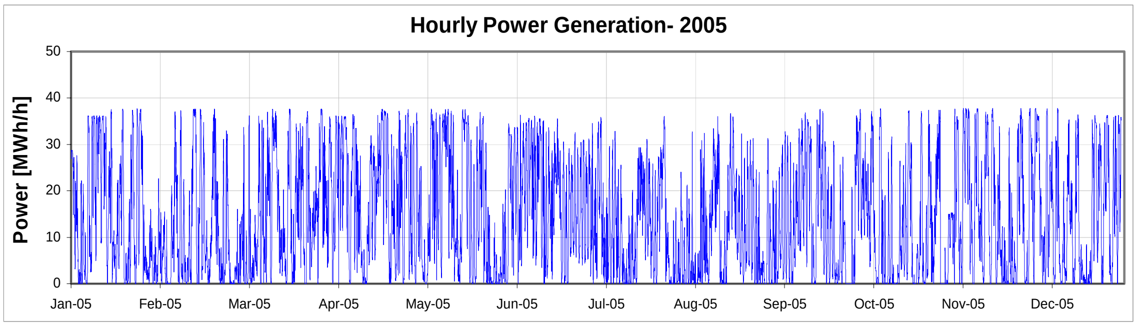


Figure 4-4: Measured Hourly Wind Power (2005), Sweetwater site.

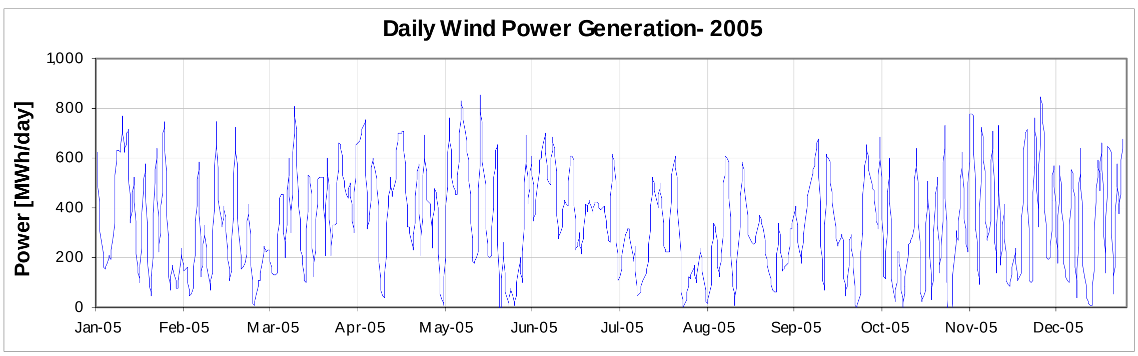


Figure 4-5: Measured Daily Wind Power (2005), Sweetwater site.

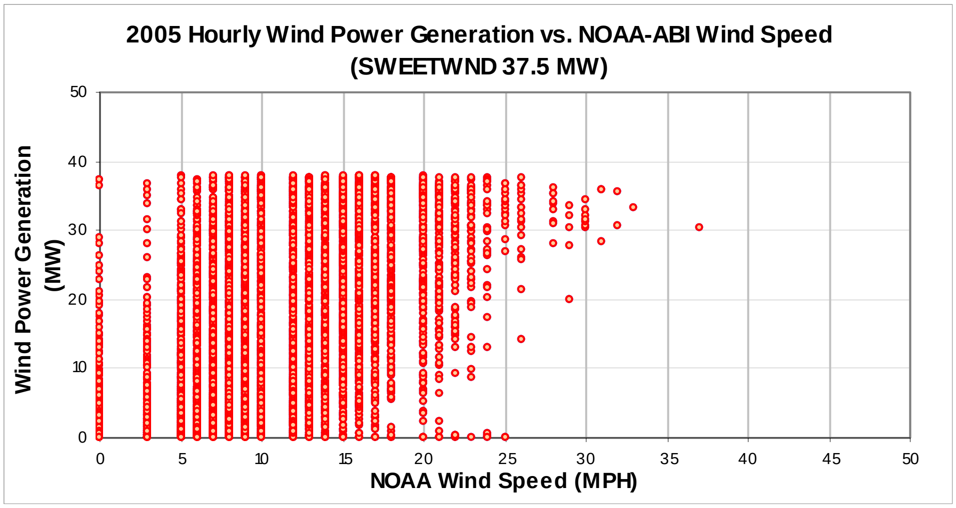


Figure 4-6: Hourly Wind Power vs. NOAA-ABI Wind Speed (2005), Sweetwater site.

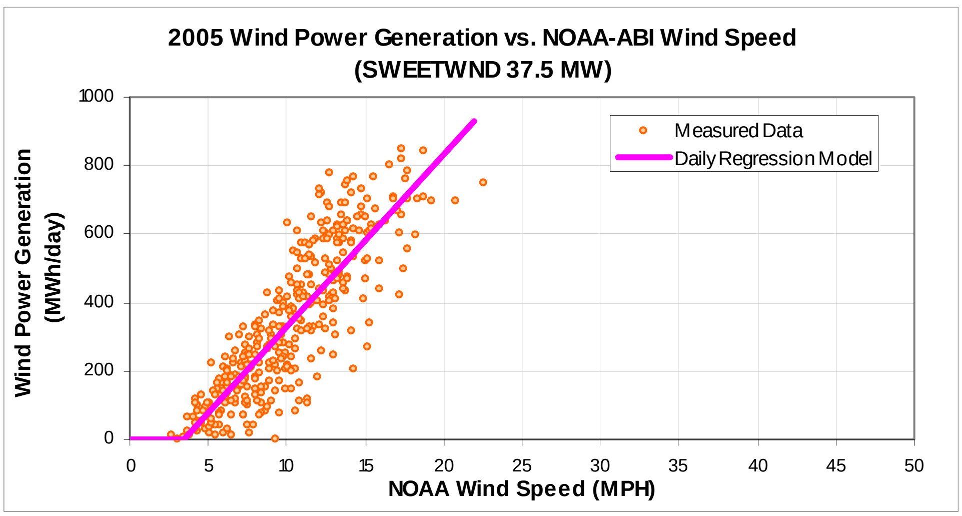


Figure 4-7: Daily Wind Power vs. NOAA-ABI Wind Speed (2005), Sweetwater site.

4.2.3 3D and 2D Surface Plots for Hourly Wind Speed and Wind Power

At the request of the Wind Stakeholders group, the Laboratory looked into ways to better understand the availability of hourly wind power throughout a year. To accomplish this, 3D color maps were developed to view the hourly data from a site. Figure 4-8 shows the 3D color map surface plot for the 2005 hourly wind speed at the Abilene NOAA station (ABI). The 3D color map surface plot was used to view the relationship between three variables, including day of the year, time of day, and the magnitude of the wind speed. To have a clearer view of the difference between the wind speeds in different years, the 3D color map surface plots are created for the years 1999 and 2005 as shown in Figure 4-9. The upper plot in Figure 4-9 shows the projection of the 3D surface graph (Figure 4-8) onto a 2D display for the 2005 hourly wind data. The second plot in Figure 4-9 shows a similar plot for the 1999 hourly wind data. The different colors in the 3D surface plot represent wind speeds for each hour of the year. The change of colors from light blue/green to orange/red and then dark brown indicates the change of low wind speed to high wind speed. In Figure 4-8 and Figure 4-9, it is clear that daytime is windier than nighttime and that summer is the least windy

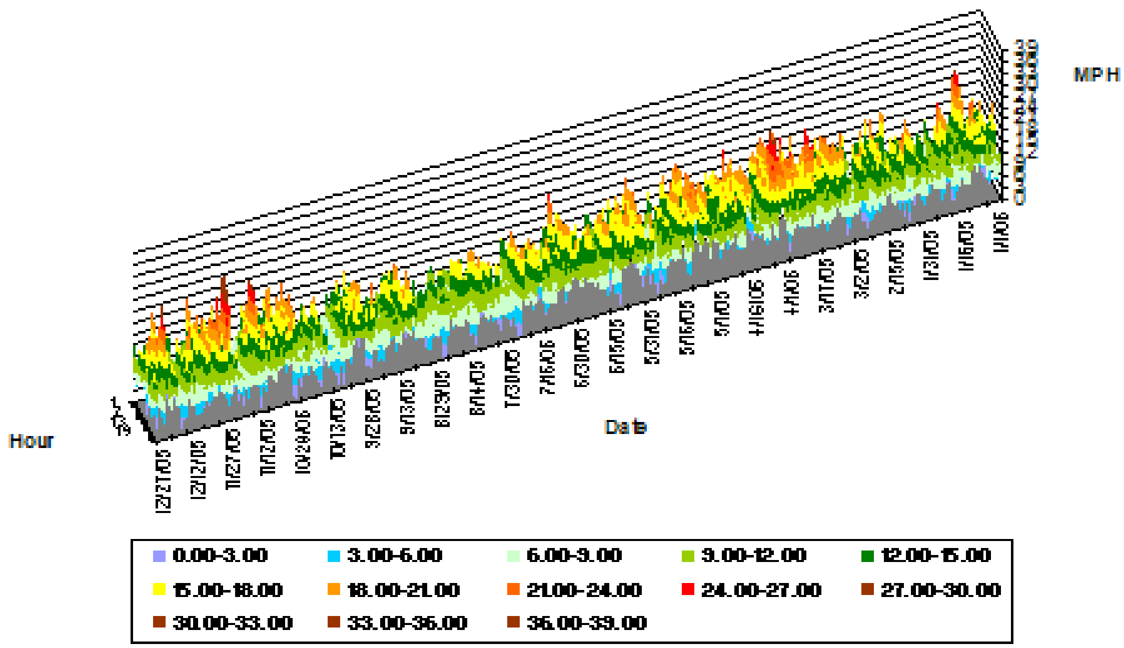


Figure 4-8: 3D Surface Plot for Hourly NOAA-ABI Wind Speed (2005).

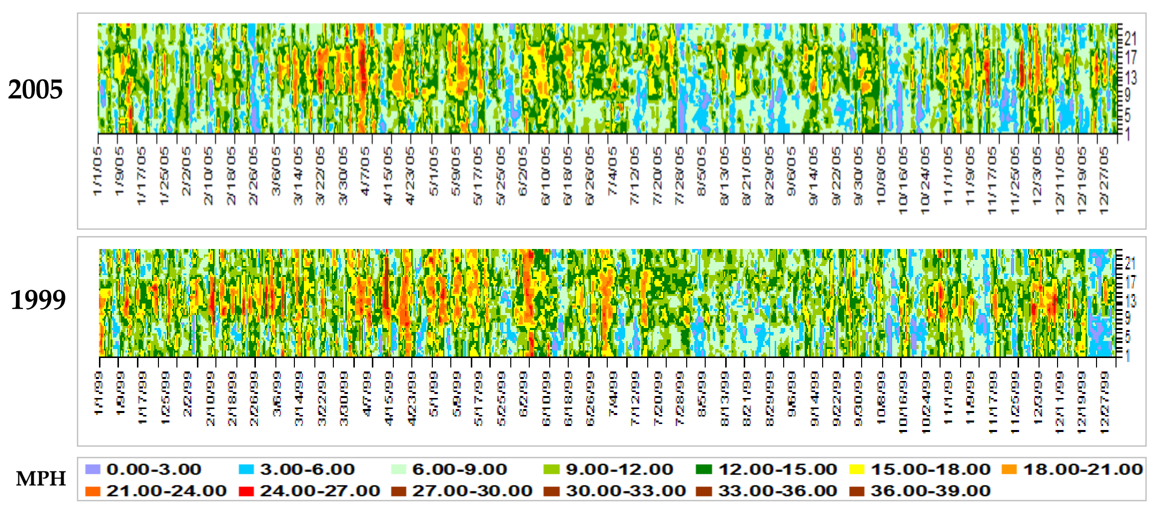


Figure 4-9: 2D Surface Plot for Hourly NOAA-ABI Wind Speed (2005 and 1999).

season in both 1999 and 2005 for this site. It also shows that 1999 is windier than 2005 for this site.

Figure 4-10 shows the 2D surface plot for the measured power production in 2005 for this wind farm. If the NOAA-ABI wind speed could better represent the on-site wind speed, the color distribution pattern of this power production map should be very similar to the upper plot in Figure 4-9 because the color coding for power 2D surface plot is correlated to that of the wind speed based on the power curve. However, it was observed that the color distribution of the power production map is quite different from the NOAA wind speed map. This indicates that hourly NOAA data may not be appropriate for predicting the wind power using a power curve.

Figure 4-11 presents the difference between the measured power and the predicted power using a power curve and NOAA wind speed. The red and dark brown colors indicate the difference within 5 MW. The darker green color represents a larger over-estimation (i.e., the curtailment or maintenance). The blue colors indicate an underestimation of power production. In Figure 4-11, it can be seen that there would be significant underestimation of power during the nighttime if one was using hourly NOAA wind data and the manufacturer's power curve for predicting power output.

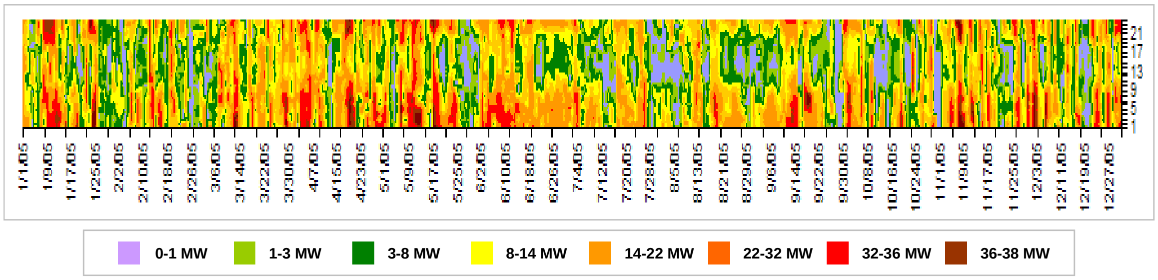


Figure 4-10: 2D Surface Plot for Hourly Wind Power (2005).

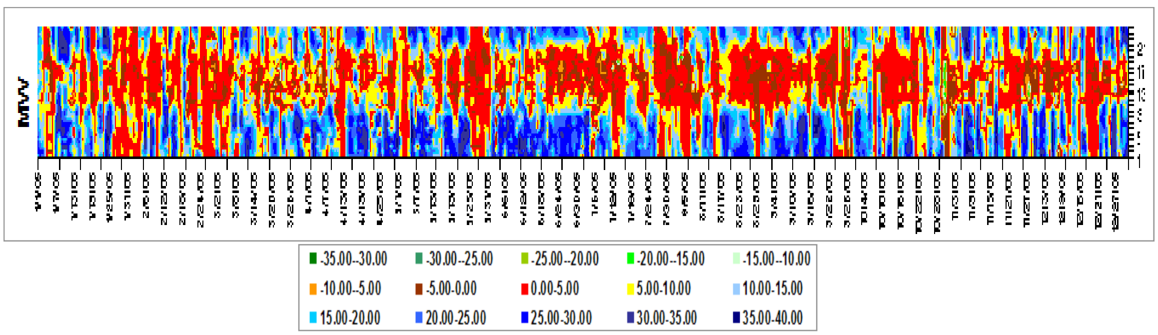


Figure 4-11: 2D Surface Plot for the Difference between Measured Hourly Wind Power and Predicted Hourly Wind Power Using Power Curve and NOAA Wind Speed (2005).

4.2.4 Modeling of Turbine Power vs. Wind Speed

As shown in the previous sections, daily wind power and daily NOAA wind data are more appropriate for modeling the base-year power production than are hourly values. Figure 4-7 shows the application of a three-parameter change-point linear regression to the average daily wind power output versus average daily NOAA wind speeds using ASHRAE's IMT. The summary of the IMT model coefficients from the daily model are listed in Table 4-2. These coefficients show that the NOAA daily model is well described with a root-mean-squared error (RMSE) of 112.80 MWh/day for the 2005 data. In Table 4-3 the predicted monthly electricity production using the 3-parameter, change-point linear daily NOAA model is shown for 2005 to compare against the measured monthly electricity for the same period. Table 4-3 shows that, on average, the model performs well, but still contains month-to-month variations, for example, in July 2005. In this month, the data are unevenly distributed around the model predictions[7] (i.e., Figure 4-12). In the lower half of Figure 4-12, this period of under-prediction can be seen to occur in the first half of the month. The second half of the month shows good agreement with the measured values.

Figure 4-13 shows the predicted electricity production from the wind farm as a time-series trace for the Ozone Season Period (July 15 to September 15) using the NOAA daily model. The measured power output for the same period is also presented for comparison.

[7] In the scatter plot shown in Figure 4-12, this can be seen in the grouping of the July data (green diamonds) versus the other data (yellow squares).

Table 4-2: 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 4-3: 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%

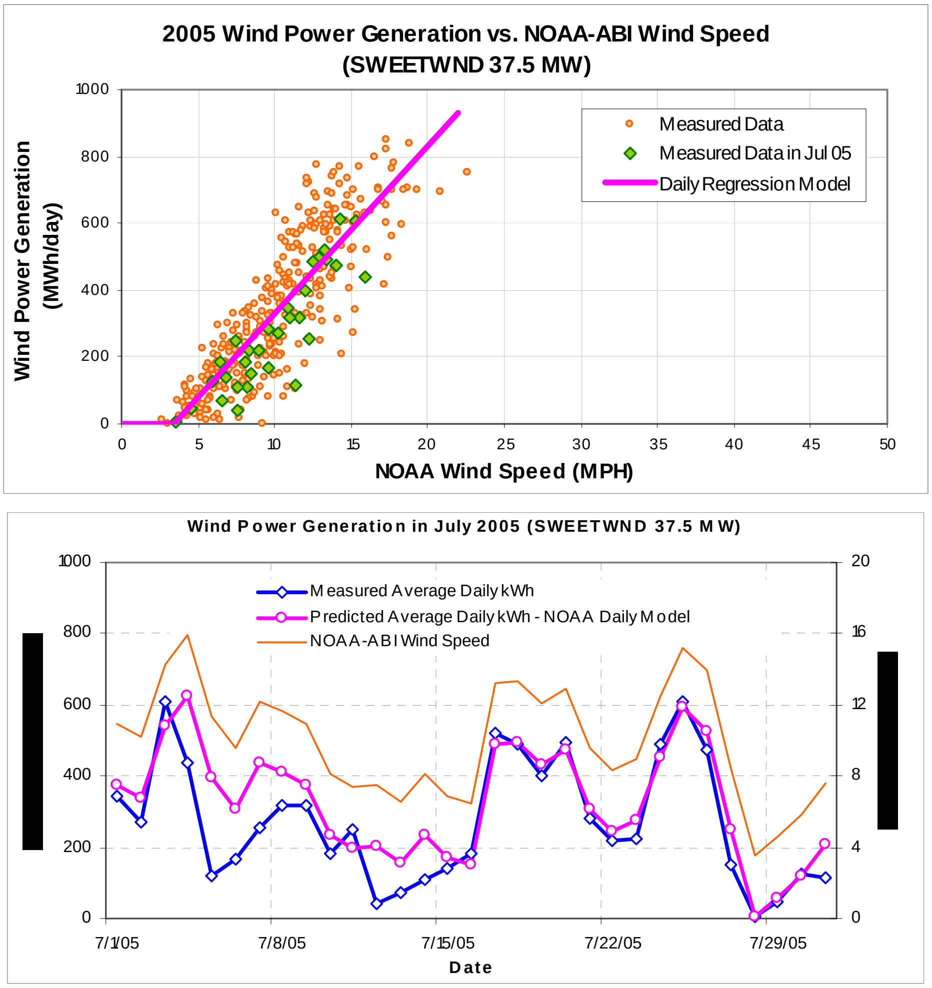


Figure 4-12: Measured Power Production in July 2005.

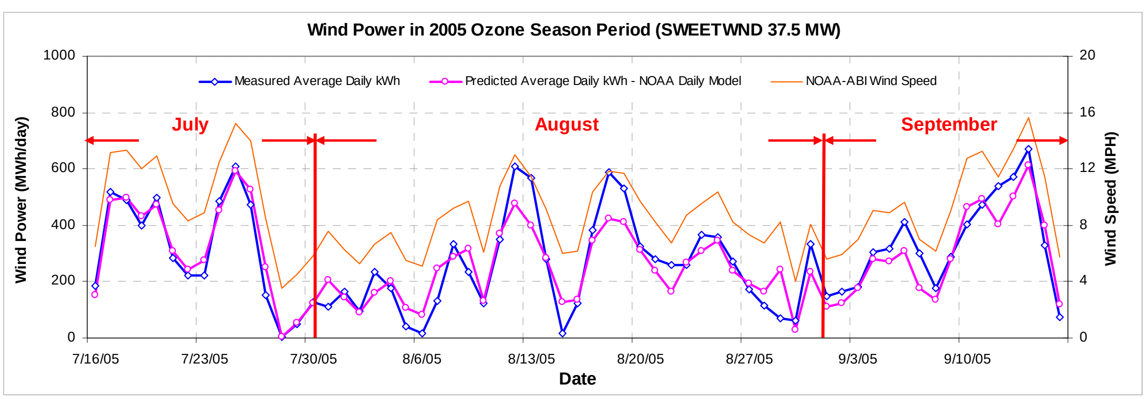


Figure 4-13: Predicted Wind Power in OSP Using NOAA-ABI Wind Speed (2005).

4.2.5 Testing of the Model

To test the performance of the NOAA daily model, the model coefficients were applied to 2004 NOAA daily wind speed to predict the daily wind power that would have been generated in 2004. The predicted daily wind power was then summed to monthly to compare against the monthly measurements from ERCOT, as shown in Table 4-4. The test results show that this model is sufficiently robust to allow for its use in projecting wind production into other weather base years with the largest observed error of 16.3% in November 2004 (Figure 4-14).

4.2.6 Prediction of Wind Power in Base Year 1999

The resultant coefficients (Table 4-2) from the 3-parameter model were next applied to the 1999 average daily NOAA-ABI wind speed to predict the electricity the wind farm would have produced in 1999 (Table 4-5). In Table 4-5 the estimated annual and Ozone Season Day (OSD) values are compared against the measured 2005 values to illustrate the error that would result if one were to simply use the 2005 values without normalization. Table 4-5 shows that the estimated annual power production increased about 15% when compared against 2005. This is because 1999 was much windier than 2005. The average daily power production during the Ozone Season Period also increased (9%).

Table 4-4: 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	-0.1%
Feb	11,303	11,073	-2.1%
Mar	11,813	12,625	6.4%
Apr	12,869	12,238	-5.2%
May	14,886	16,017	7.1%
Jun	12,063	11,049	-9.2%
Jul	10,595	10,055	-5.4%
Aug	8,645	8,375	-3.2%
Sep	7,989	8,067	1.0%
Oct	8,798	9,974	11.8%
Nov	8,673	7,456	-16.3%
Dec	9,553	10,543	9.4%
Total	129,103	129,371	0.2%

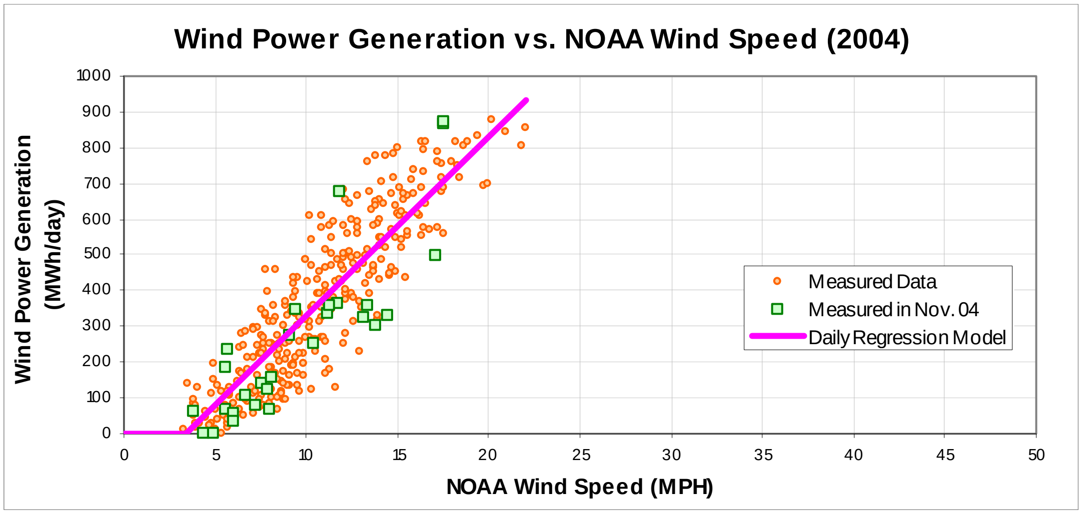


Figure 4-14: Measured Power Production in November 2004.

Table 4-5: Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
143,711	125,249
1999 OSD Estimated MWh/day (2005 Daily Model)	2005 OSD Measured MWh/day
314	288

4.3 Capacity Factor Analysis

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 4-15. Figure 4-16 shows the predicted capacity factors using 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 4-15, the model shows good agreement tracking the measured capacity factor. In comparison, in Figure 4-16, it can be seen that there is more variation in the year to year wind speeds than the uncertainty from the model. Figure 4-16 also shows the importance of weather normalizing the wind speeds back to the base year. Figure 4-17 shows a close up of the wind speeds for 1999 and 2005 for four Texas stations.

As seen in Table 4-6, if predicted with NOAA daily model, the annual capacity factors for these years vary from 38.2% to 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.

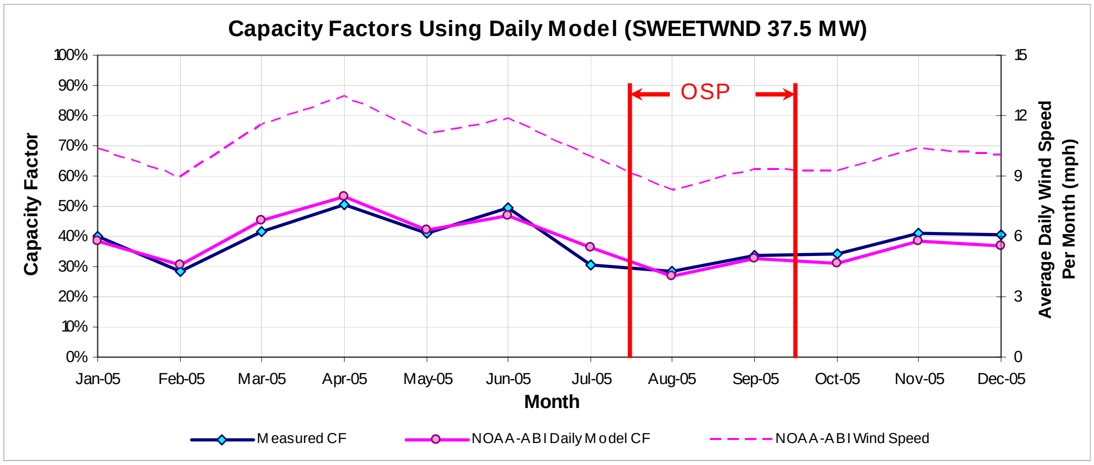


Figure 4-15: Predicted Capacity Factors Using Daily Models (2005).

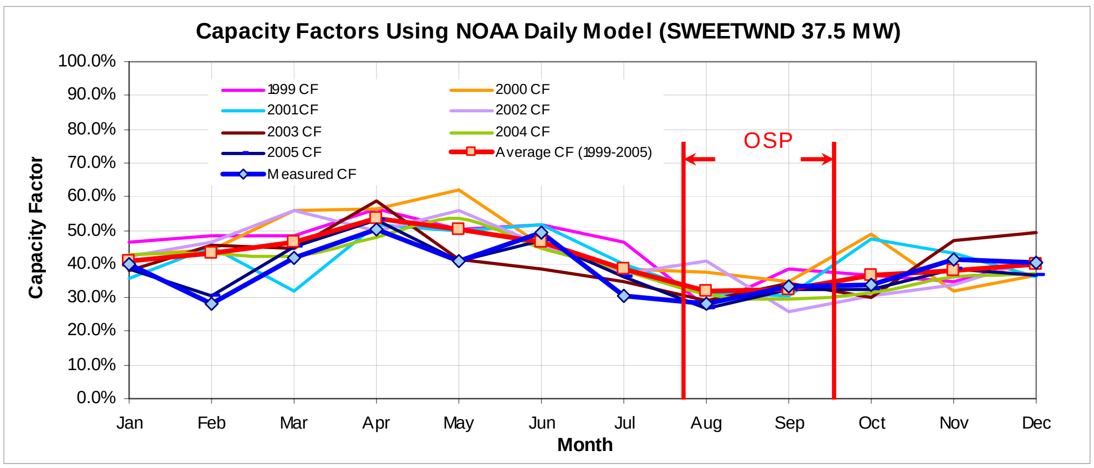


Figure 4-16: Predicted Capacity Factors Using Daily Models (1999-2005).

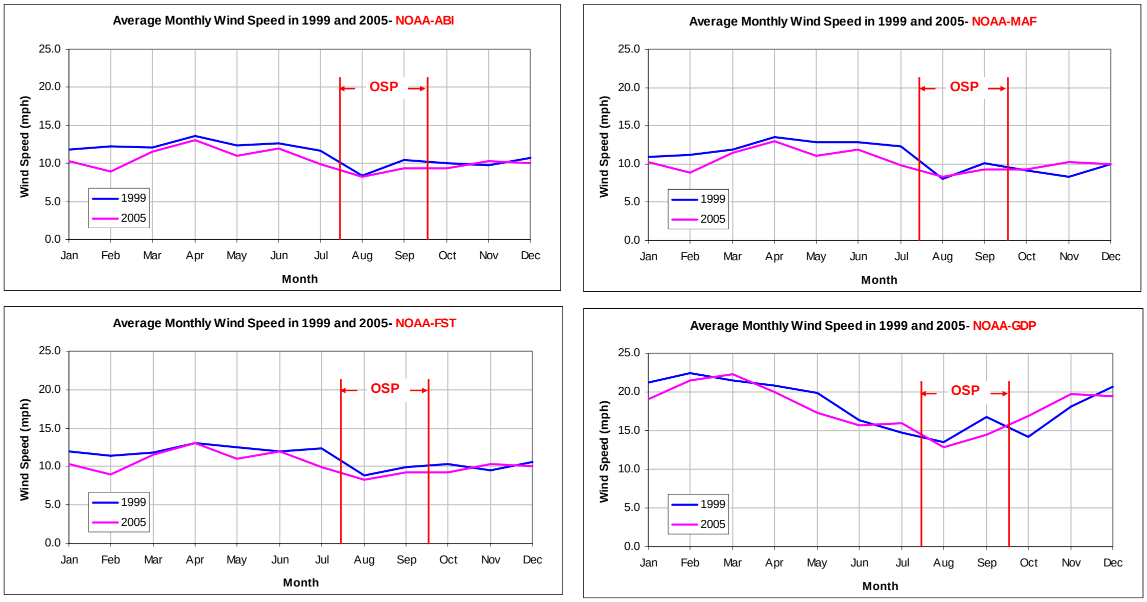


Figure 4-17: 1999 and 2005 Monthly Average Wind Speed for Four NOAA Weather Stations.

Table 4-6: Summary of Predicted Capacity Factors (1999-2005).

	NOAA Annual Average Wind Speed (MPH)	Annual Predicted Capacity Factor - NOAA Daily Model	Predicted Capacity Factor in OSP – NOAA Daily Model
1999	11.3	43.8%	34.9%
2000	11.5	44.5%	35.6%
2001	10.8	41.1%	34.8%
2002	11.0	42.1%	37.2%
2003	10.8	40.9%	31.5%
2004	10.7	39.8%	29.0%
2005	10.3	38.2%	30.8%
Average (1999-2005)	10.9	41.5%	33.4%

4.4 Summary of All Wind Farms in Texas ERCOT Region

Table 4-7 shows the summary of the 2005 measured power production for the wind farms that were operating in 2005 in the Texas ERCOT region and the estimated 1999 power production using daily regression models (Appendix). Table 4-9 and Table 4-10 contain the NOx reductions using the estimated 1999 power production, the 2007 Annual eGRID (Table 4-9), and the Ozone Season Day (OSD) eGRID (Table 4-10).

As shown in Figure 4-18 and Figure 4-19, the estimated power production in 1999 (4,682,682 MWh/yr, or 2,136.7 tons-NOx/yr) increased about 17% when compared to what was measured in 2005 (4,008,696MWh/yr). For the Ozone Season Period, the estimated average daily power production is 9,625

MWh/day (5.17 tons-NOx/OSD), a 7.6% increase from 2005 (8,949 MWh/day). This is due to the fact that of all the four NOAA weather stations involved in the modeling, 1999 has a higher wind than 2005 (Table 4-8 and Figure 4-17). Also, for this period, 1999 is windier than 2005 for the weather stations ABI and FST; however, for MAF and GDP, 2005 is a little windier.

Figure 4-20 presents the comparison of 2005 measured annual power production against the 1999 estimated annual power production for each wind farm. Figure 4-21 shows the difference between the 2005 measured average daily power production and the 1999 estimated average daily power production during the Ozone Season Period 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 low and excluded in the analysis. Therefore, only three months of data were used in the modeling.

This analysis implies that the use of weather normalization for predicting the 1999 base year production based on the 2005 measured power production is more accurate than simply using the measured 2005 power production as the base year power production. Therefore, it is the ESL's recommendation to the TCEQ that the current discount factor be reduced due to the more accurate modeling stated above.

Table 4-7: Summary of Power Production for All Wind Farms.

Wind Unit Name	County	NOAA Weather Station	Capacity (MW)	PCA	2005 Measured (MWh/yr)	1999 Estimated Using Daily Model (MWh/yr)	2005 OSP Measured (MWh/day)	1999 OSP Estimated (MWh/day)
BRAZ_WND_WND1	SCURRY	ABI	160	AEP-West	290,411	331,570	641	724
BRAZ_WND_WND2	SCURRY	ABI		AEP-West	170,608	191,907	368	420
CALLAHAN_WND1	TAYLOR	ABI	114	AEP-West	332,572	433,697	831	955
DELAWARE_WIND_NWP	CULBERSON	GDP	30	TXU	66,267	68,298	103	114
H_HOLLOW_WND1 *	TAYLOR	ABI	213	AEP-West	203,673	328,264		
INDNENR_INDNENR	PECOS	FST	160	AEP-West	246,131	273,888	625	639
INDNENR_INDNENR_2	PECOS	FST		AEP-West	224,842	250,714	585	583
INDNNWP_INDNNWP_J01	PECOS	FST	82.5	AEP-West	142,264	158,580	372	369
INDNNWP_INDNNWP_J02	PECOS	FST		AEP-West	87,914	97,971	230	228
KING_NE_KINGNE	UPTON	MAF	79	AEP-West	172,198	192,701	378	417
KING_NW_KINGNW	UPTON	MAF	79	AEP-West	207,634	227,493	534	515
KING_SE_KINGSE	UPTON	MAF	40	AEP-West	85,097	95,931	182	204
KING_SW_KINGSW	UPTON	MAF	79	AEP-West	190,202	209,671	474	469
KUNITZ_WIND_LGE_J01	CULBERSON	GDP	35	LCRA	42,119	43,855	40	67
KUNITZ_WIND_LGE_J02	CULBERSON	GDP		LCRA	17,210	17,913	16	27
SGMTN_SIGNALMT	HOWARD	MAF	41	TXU	93,939	103,431	217	232
SW_MESA_SW_MESA	UPTON	MAF	75	AEP-West	197,694	217,416	522	488
SWEETWN2_WND2	NOLAN	ABI	91.5	TXU	262,537	323,218	623	717
SWEETWND_WND1	NOLAN	ABI	37.5	LCRA	125,259	143,711	288	314
TRENT_TRENT	NOLAN	ABI	150	TXU	492,444	563,714	1,095	1,227
WOODWRD1_WOODWRD1	PECOS	FST	80	AEP-West	185,149	211,627	401	474
WOODWRD2_WOODWRD2	PECOS	FST	80	AEP-West	172,532	197,112	424	442
TOTAL			1,627		4,008,696	4,682,682	8,949	9,625

* 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.

Table 4-8: Summary of 1999 and 2005 Monthly Average Wind Speed for Four NOAA Weather Stations.

Month	Wind Speed ABI (mph)		Wind Speed MAF (mph)		Wind Speed FST (mph)		Wind Speed GDP (mph)	
	1999	2005	1999	2005	1999	2005	1999	2005
Jan	11.8	10.3	10.9	9.7	12.0	10.2	21.2	19.1
Feb	12.2	8.9	11.2	8.9	11.4	9.2	22.4	21.5
Mar	12.1	11.5	11.8	11.1	11.8	11.1	21.5	22.3
Apr	13.6	13	13.5	12.1	13.1	12.5	20.9	19.9
May	12.4	11	12.8	10.8	12.6	11.7	19.9	17.3
Jun	12.7	11.9	12.8	12.1	12.0	12.4	16.3	15.7
Jul	11.7	9.9	12.3	10.4	12.3	10.6	14.8	16.0
Aug	8.4	8.3	8.0	9.2	8.8	8.5	13.5	12.9
Sep	10.4	9.3	10.1	9.7	9.9	9.2	16.8	14.5
Oct	10	9.3	9.1	9.3	10.4	9.7	14.2	16.8
Nov	9.7	10.3	8.3	9.4	9.5	10.3	18.2	19.8
Dec	10.7	10	10.0	9.5	10.6	8.6	20.6	19.5
Annual Average	11.3	10.3	10.9	10.2	11.2	10.3	18.3	18.0
OSP Average	9.7	9.0	9.5	9.7	10.0	9.3	13.9	14.5

Table 4-9: Annual NOx Reductions Using 1999 Baseyear and 2007 eGRID (25%).

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)	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)
Houston-Galveston Area	Brazoria	0.008831132	22642.18417	0.010890729	0	0.006522185	0	0.003944232	607.8455686	0.065444292	0	0.014877434	0	0.006262315	0	0.004817148	0	0.121274957	0	0.00816387	6482.080254	29732.10999	14.86605499
	Chambers	0.021762222	55796.27029	0.026955801	0	0.016072371	0	0.009076193	1398.732111	0.164940225	0	0.037472294	0	0.015055623	0	0.009553214	0	0.011518588	0	0.015818592	12559.89911	69754.90152	34.87745076
	Fort Bend	0.070431234	180578.9921	0.087239726	0	0.052016606	0	0.029374182	4526.855172	0.533812376	0	0.121275295	0	0.048726002	0	0.030918012	0	0.037278747	0	0.051195276	40648.84464	225754.6919	112.877346
	Galveston	0.033856739	86805.46288	0.041710519	0	0.025004711	0	0.015351589	2365.83333	0.249587379	0	0.056747051	0	0.024143087	0	0.019297151	0	0.567751219	0	0.032836887	26072.35679	115243.653	57.6218265
	Harris	0.068267332	175030.9547	0.084559408	0	0.050418468	0	0.028471701	4387.773868	0.517411736	0	0.117549281	0	0.047228963	0	0.029968099	0	0.03613341	0	0.049622373	39399.96566	218818.6943	109.4093471
	Liberty	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Montgomery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Waller	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beaumont/ Port Arthur Area	Hardin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Orange	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dallas/ Fort Worth Area	Collin	0.002039135	5228.148798	0.003716345	0	0.001505992	0	0.005950953	917.1013185	0.002481478	0	0.000717051	0	0.019166247	0	0.07668094	0	0.00086441	0	0.004000199	3176.142267	9321.392384	4.660696192
	Dallas	0.004539471	11638.77276	0.004683963	0	0.003352602	0	0.00774211	1193.136561	0.002085611	0	0.00068106	0	0.007502816	0	0.026717045	0	0.007524933	0	0.040370454	32053.97908	44885.8884	22.4429442
	Denton	0.00047388	1214.984051	0.000872802	0	0.000349982	0	0.001396994	215.2907205	0.000585443	0	0.000168971	0	0.00454374	0	0.018187155	0	0.000186605	0	0.000849405	674.4244813	2104.699252	1.052349626
	Tarrant	0.012162492	31183.47486	0.012266309	0	0.008982543	0	0.020308652	3129.766379	0.005316504	0	0.001752506	0	0.017326428	0	0.060216761	0	0.020603444	0	0.110647237	87853.46393	122166.7052	61.08335259
	Ellis	0.003279814	8409.130309	0.003307809	0	0.002422289	0	0.005476558	843.9923207	0.001433682	0	0.000472592	0	0.004672353	0	0.016238427	0	0.005556053	0	0.029837824	23691.11298	32944.23561	16.47211781
	Johnson	0.000286058	733.4267674	0.000526868	0	0.000211267	0	0.000843297	129.960535	0.000353404	0	0.000101999	0	0.002742835	0	0.010978701	0	0.000112645	0	0.000512745	407.1172514	1270.504554	0.635252277
	Kaufman	0.006325453	16217.85934	0.006379446	0	0.004671629	0	0.010562096	1627.724656	0.002765	0	0.000911441	0	0.009011105	0	0.031317452	0	0.010715411	0	0.057545265	45690.71043	63536.29442	31.76814721
	Parker	0.000217489	557.6223685	0.000400576	0	0.000160626	0	0.000641157	98.80863987	0.000268692	0	7.75498E-05	0	0.00208537	0	0.008347076	0	8.56434E-05	0	0.000389838	309.5301345	965.9611429	0.482980571
	Rockwall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Henderson	0.000819895	2102.132712	0.000826893	0	0.000605529	0	0.001369042	210.9830388	0.000358395	0	0.00011814	0	0.001168005	0	0.004059317	0	0.001388914	0	0.007458924	5922.356031	8235.471782	4.117735891
	Hood	0.01252711	32118.31973	0.012634039	0	0.009251829	0	0.020917482	3223.593191	0.005475887	0	0.001805044	0	0.017845854	0	0.062021991	0	0.021221112	0	0.113964315	90487.21017	125829.1231	62.91456155
	Hunt	0.006187558	15864.31182	0.006240374	0	0.004569788	0	0.010331844	1592.24044	0.002704724	0	0.000891572	0	0.008814664	0	0.030634735	0	0.010481817	0	0.056290785	44694.65805	62151.21031	31.07560515
El Paso Area	El Paso	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Antonio Area	Bexar	0.033413751	85669.68328	0.051775843	0	0.024677545	0	0.090663423	13972.14016	0.001141841	0	1.143571754	0	0.046873844	0	0.004669544	0	0.000519582	0	0.002503865	1988.058942	101629.8824	50.81494119
	Comal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Guadalupe	0.002000467	5129.00778	0.076378745	0	0.001477434	0	0.133848731	20627.42786	0.001237133	0	0.003554796	0	0.001061766	0	0.001855699	0	0.000401718	0	0.001835165	1457.113528	27213.54917	13.60677459
	Wilson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austin Area	Bastrop	0.004502334	11543.55615	0.171901148	0	0.003325174	0	0.301245466	46424.93871	0.002784342	0	0.008000571	0	0.002389654	0	0.004176513	0	0.000904124	0	0.004130298	3279.43972	61247.93459	30.62396729
	Caldwell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hays	0.002458599	6303.614645	0.093870431	0	0.001815785	0	0.164501762	25351.36657	0.001520452	0	0.004368889	0	0.001304924	0	0.002280677	0	0.000493717	0	0.00225544	1790.810732	33445.79195	16.72289597
	Travis	0.000510007	1307.609528	0.299602906	0	0.000376663	0	0.033939476	5230.412674	0.000334709	0	0.000906121	0	0.000271138	0	0.000471744	0	0.000103327	0	0.000467336	371.0627325	6909.084935	3.454542467
	Williamson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North East Texas Area	Gregg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Harrison	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rusk	0.000685965	1758.748684	0.00069182	0	0.000506616	0	0.001145408	176.5188942	0.000299851	0	9.88414E-05	0	0.000977211	0	0.003396227	0	0.001162035	0	0.006240507	4954.937343	6890.204922	3.445102461
	Smith	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upshur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corpus Christi Area	Nueces	0.22756873	583464.6045	0.004556851	0	0.168069652	0	0.007612767	1173.203538	0.001680888	0	0.001626796	0	0.046792036	0	0.007246366	0	0.001609426	0	0.008283395	6576.982281	591214.7903	295.6073952
	San Patricio	0.050313351	128998.6529	0.001007478	0	0.037158653	0	0.001683113	259.3845022	0.000371629	0	0.00035967	0	0.010345288	0	0.001602105	0	0.000355829	0	0.001831382	1454.110237	130712.1476	65.3560738
Victoria Area	Victoria	0.021836736	55987.31579	0.002215582	0	0.016127403	0	0.003612695	556.7524667	0.001199621	0	0.000555389	0	0.52545648	0	0.032412721	0	0.000476855	0	0.002254849	1790.341221	58334.40947	29.16720474
Other ERCOT counties	Andrews	2.47421E-05	63.43634928	2.49533E-05	0	1.82731E-05	0	4.13138E-05	6.366864311	1.08153E-05	0	3.56511E-06	0	3.5247E-05	0	0.000122499	0	4.19135E-05	0	0.000225089	178.7197561	248.5229697	0.124261485
	Angelina	0.00031082	796.9127459	0.000313473	0	0.000229554	0	0.000519	79.98309137	0.000135867	0	4.47864E-05	0	0.000442787	0	0.001538876	0	0.000526534	0	0.002827658	2245.148928	3122.044766	1.561022383
	Bosque	0.000595392	1526.527939	0.001096604	0	0.000439723	0	0.001755208	270.4951557	0.000735562	0	0.000212298	0	0.005708837	0	0.02285067	0	0.000234455	0	0.001067208	847.359118	2644.382213	1.322191106
	Brazos	0.001939725	4973.271148	0.003572622	0	0.001432574	0	0.005718288	881.2454192	0.002396384	0	0.000691644	0	0.018598805	0	0.074445136	0	0.000763829	0	0.003476855	2760.608925	8615.125492	4.307562746
	Calhoun	0.082699809	212034.4528	0.001655986	0	0.061077496	0	0.002766524	426.3490337	0.000610844	0	0.000591187	0	0.0170045	0	0.002633372	0	0.000584875	0	0.003010234	2390.113862	214850.9157	107.4254579
	Cameron	0.048371747	124020.5639	0.000968599	0	0.297964476	0	0.001618161	249.374792	0.000357288	0	0.00034579	0	0.009946061	0	0.001540279	0	0.000342098	0	0.001760709	1397.995774	125667.9344	62.83396722
	Cherokee	0.003503899	8983.663909	0.003533808	0	0.002587786	0	0.00585073	901.6560658	0.001531635	0	0.00050488	0	0.00499158	0	0.017347879	0	0.005935657	0	0.031876422	25309.75129	35195.07126	17.59753563
	Coke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coleman	0.001298787	3329.966174	2.6007E-05	0	0.000959212	0	4.34478E-05	6.695741383	9.59321E-06	0	9.2845E-06	0	0.000267053	0	4.13567E-05	0	9.18536E-06	0	4.72752E-05	37.53634471	3374.19826	1.68709913
	Crockett	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ector	0.003535748	9065.321038	0.003565928	0	0.002611307	0	0.005903911	909.8516803	0.001545556	0	0.00050947	0	0.005036951	0	0.017505563	0	0.00598961	0	0.032166163	25539.8046	35514.97732	17.75748866
	Fannin	0.007056315	18091.72054	0.007116546	0	0.005211403	0	0.011782473	1815.796954	0.003084477	0	0.001016752	0	0.010052276	0	0.034935966	0	0.011953503	0	0.064194222	50969.95523	70877.47272	35.43873636
	Fayette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Freestone	0.003677178	9427.93388	0.003708565	0	0.00271576	0	0.006140067	946.2457475	0.001607379	0	0.000529848	0	0.005238429	0	0.018205785	0	0.006229194	0	0.033452809	26561.39679	36935.57641	18.46778821
	Frio	0.008588335	22019.67416	0.000871383	0	0.006342868	0	0.001420864	218.9693814	0.000471808	0	0.000218433	0	0.206660746	0	0.012747844	0	0.000187546	0	0.000886827	704.1368167	22942.78036	11.47139018
	Grimes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hardeman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haskell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hidalgo	0.188527456	483366.4867	0.003775086	0	0.139235931	0	0.006306735	971.9308904	0.001392518	0	0.001347706	0	0.03876448	0	0.006003193	0	0.001333316	0	0.006862311	5448.64726	489787.0649	244.8935324
	Howard	0.000555113	1423.257117	0.000559851	0	0.000409976	0	0.000926915	142.8468859	0.000242653	0	7.99868E-05	0	0.000790802	0	0.002748377	0	0.00094037	0	0.005050094	4009.754152	5575.858156	2.787929078
	Jack	0.002121449	5439.192623	0.002139557	0	0.001566784	0	0.003542346	545.9110082	0.000927334	0	0.000305682	0	0.00302217	0	0.010503338	0	0.003593766	0	0.019299698	15323.88276	21308.98639	10.6544932
	Jones	0.040718722	104398.9354	0.000815354	0	0.030072592	0	0.001362147	209.9205323	0.00030076	0	0.000291082	0	0.008372468	0	0.001296587	0	0.000287974	0	0.001482142	1176.815085	105785.671	52.89283549
	Lamar	0.000950838	2437.857905	0.000958954	0	0.000702236	0	0.001587687	244.6784953	0.000415633	0	0.000137007	0	0.001354543	0	0.004707619	0	0.001610734	0	0.008650166	6868.197416	9550.733816	4.775366908
	Limestone	0.000719757	1845.388014	0.000891528	0	0.000531572	0	0.000300183	46.26121885	0.00545518	0	0.001239347	0	0.000497945	0	0.00031596	0	0.000380962	0	0.000523179	415.4020897	2307.051322	1.153525661
	Llano	0.001238174	3174.56039	0.047274044	0	0.000914447	0	0.082844655	12767.18973	0.000765714	0	0.002200214	0	0.000657172	0	0.001148571	0	0.000248641	0	0.001135861	901.8693456	16843.61946	8.421809731
	McLennan	0.024534317	62903.65866	0.024743738	0	0.018119687	0	0.040966843	6313.400186	0.010724513	0	0.003535175	0	0.034951066	0	0.121469933	0	0.041561501	0	0.22319886	177219.0024	246436.0612	123.2180306
	Milam	0.002245405	5757.004888	0.002264571	0	0.001658332	0	0.003749326	577.8086124	0.000981518	0	0.000323543	0	0.003198756	0	0.011117048	0	0.00380375	0	0.02042738	16219.25791	22554.07141	11.2770357
	Mitchell	0.014943169	38312.865	0.015070721	0	0.011036196	0	0.024951762	3845.316062	0.006532002	0	0.002153177	0	0.02128772	0	0.07398395	0	0.025313952	0	0.135944204	107939.1542	150097.3353	75.04866766
	Nolan	0.000564654	1447.718452	0.000569473	0	0.000417022	0	0.000942846	145.3019767	0.000246823	0	8.13615E-05	0	0.000804394	0	0.002795613	0	0.000956532	0	0.005136889	4078.669275	5671.689704	2.835844852
	Palo Pinto	0.003206998	8222.439082	0.005906709	0	0.002368511	0	0.009454195	1456.986068	0.003962005	0	0.001143513	0	0.030749889	0	0.123082087	0	0.001262858	0	0.005748375	4564.186839	14243.61199	7.121805994
	Pecos	4.09677E-05	105.0372368	4.13174E-05	0	3.02565E-05	0	6.84069E-05	10.54218664	1.79079E-05	0	5.90308E-06	0	5.83617E-05	0	0.000202832	0	6.93999E-05	0	0.0003727	295.9222835	411.5017069	0.205750853
	Presidio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Robertson	0.000737708	1891.412543	0.000835096	0	0.00054483	0	0.000735917	113.4121778	0.003149678	0	0.000730875	0	0.00076086	0	0.001866305	0	0.191632518	0	0.003397737	2697.789914	4702.614635	2.351307318
	Taylor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Titus	0.005696437	14605.12426	0.005745061	0	0.004207073	0	0.009511781	1465.86059	0.002490043	0	0.000820806	0	0.008115023	0	0.028203184	0	0.00964985	0	0.051822854	41147.13843	57218.12328	28.60906164
	Tom Green	0.001482448	3800.855971	2.96846E-05	0	0.001094854	0	4.95918E-05	7.642584725	1.09498E-05	0	1.05974E-05	0	0.000304817	0	4.72049E-05	0	1.04843E-05	0	5.39604E-05	42.84435111	3851.342907	1.925671453
	Upton	3.11661E-05	79.90698857	3.14322E-05	0	2.30176E-05	0	5.20405E-05	8.019959526	1.36234E-05	0	4.49076E-06	0	4.43986E-05	0	0.000154304	0	5.27959E-05	0	0.000283531	225.1226256	313.0495737	0.156524787
	Ward	0.018559529	47584.86818	0.01871795	0	0.013707039	0	0.030990277	4775.911641	0.008112796	0	0.002674262	0	0.026439509	0	0.091888626	0	0.03144012	0	0.16884373	134061.2462	186422.026	93.211013
	Webb	0.020014327	51314.83366	0.000400768	0	0.014781473	0	0.000669531	103.1814851	0.000147832	0	0.000143074	0	0.004115289	0	0.000637307	0	0.000141547	0	0.000728512	578.4356911	51996.45084	25.99822542
	Wharton	0.00014434	370.073271	0.000178787	0	0.000106601	0	6.01986E-05	9.277203741	0.001093979	0	0.000248538	0	9.98576E-05	0	6.33625E-05	0	7.6398E-05	0	0.000104918	83.30454571	462.6550205	0.23132751
	Wichita	0.000207633	532.3518251	0.000209406	0	0.000153346	0	0.000346701	53.43012128	9.07612E-05	0	2.99181E-05	0	0.00029579	0	0.001027996	0	0.000351734	0	0.001888925	1499.799239	2085.581185	1.042790592
	Wilbarger	0.028616818	73370.80296	0.000573025	0	0.021134796	0	0.000957307	147.5306042	0.000211372	0	0.00020457	0	0.005884109	0	0.000911232	0	0.000202386	0	0.001041639	827.0569754	74345.39054	37.17269527
	Wise	0.002844488	7292.995852	0.002882008	0	0.002100781	0	0.00476997	735.1001494	0.001256075	0	0.000413241	0	0.004181914	0	0.014614274	0	0.004797945	0	0.025761411	20454.45747	28482.55347	14.24127674
	Young	0.006235856	15988.14319	0.006289085	0	0.004605458	0	0.010412491	1604.668923	0.002725836	0	0.000898531	0	0.008883468	0	0.030873859	0	0.010563634	0	0.056730171	45043.52922	62636.34133	31.31817067
	Total	**1.121837219**	**2876284.056**	**1.172570094**	**0**	**1.090766584**	**0**	**1.189130767**	**183256.9425**	**1.629360006**	**0**	**1.542362643**	**0**	**1.359385821**	**0**	**1.231642808**	**0**	**1.221806085**	**0**	**1.528786947**	**1213850.721**	**4273391.719**	**2136.69586**
Energy Savings by PCA (MWh)		2,563,905				0		154,110		0		0		0		0		0		793,996			

Table 4-10: OSD NOx Reductions Using 1999 Baseyear and 2007 eGRID (OSD).

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)	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)
Houston-Galveston Area	Brazoria	0.00957217	61.83621535	0.011806715	0	0.007069474	0	0.004263638	1.304673142	0.071001767	0	0.016140391	0	0.006781035	0	0.005179719	0	0.126288049	0	0.008771659	15.06093787	78.20182636	0.039100913
	Chambers	0.021881395	141.3538148	0.027103415	0	0.016160386	0	0.009125896	2.792524079	0.165843463	0	0.037677498	0	0.01513807	0	0.009605529	0	0.011581666	0	0.015905217	27.30925842	171.4555973	0.085727799
	Fort Bend	0.055695513	359.7930108	0.068987309	0	0.041133619	0	0.023228475	7.107913198	0.422127404	0	0.095901908	0	0.038531479	0	0.024449302	0	0.029479235	0	0.040484129	69.51124963	436.4121736	0.218206087
	Galveston	0.027555985	178.0116644	0.033893644	0	0.020351324	0	0.012791501	3.914199378	0.201446635	0	0.045812515	0	0.019823685	0	0.01677514	0	0.594656509	0	0.028709453	49.29412998	231.2199938	0.115609997
	Harris	0.077360573	499.7493019	0.09582276	0	0.057134232	0	0.032264145	9.87282841	0.586331222	0	0.1332069	0	0.053519883	0	0.033959864	0	0.040946397	0	0.056232096	96.55050942	606.1726397	0.30308632
	Liberty	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Montgomery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Waller	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beaumont/ Port Arthur Area	Hardin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Orange	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dallas/ Fort Worth Area	Collin	0.001763649	11.39317185	0.003151138	0	0.001302533	0	0.005050143	1.545343672	0.002085751	0	0.00060408	0	0.015958397	0	0.063788818	0	0.000846136	0	0.004013208	6.890677386	19.82919291	0.009914596
	Dallas	0.005045553	32.59427172	0.005305276	0	0.003726366	0	0.008757286	2.679729613	0.002413087	0	0.000782263	0	0.009310387	0	0.033672029	0	0.008209179	0	0.044002183	75.55174906	110.8257504	0.055412875
	Denton	0.000635758	4.106995501	0.001170951	0	0.000469535	0	0.001874207	0.573507338	0.000785431	0	0.000226691	0	0.006095882	0	0.024399888	0	0.00025035	0	0.001139562	1.956628471	6.63713131	0.003318566
	Tarrant	0.015572243	100.5966914	0.015705165	0	0.011500796	0	0.026002176	7.95666599	0.006806985	0	0.002243821	0	0.022183886	0	0.077098512	0	0.026379614	0	0.141667156	243.2425069	351.7958644	0.175897932
	Ellis	0.003502824	22.62824059	0.003532723	0	0.002586991	0	0.005848935	1.789774095	0.001531165	0	0.000504725	0	0.004990048	0	0.017342555	0	0.005933836	0	0.031866639	54.71501985	79.13303454	0.039566517
	Johnson	0.000337176	2.178157169	0.000621017	0	0.00024902	0	0.000993991	0.304161307	0.000416556	0	0.000120226	0	0.003232969	0	0.012940552	0	0.000132774	0	0.00060437	1.037703677	3.520022152	0.001760011
	Kaufman	0.006492753	41.94318138	0.006548174	0	0.004795187	0	0.01084145	3.317483707	0.002838131	0	0.000935547	0	0.009249437	0	0.032145758	0	0.01099882	0	0.059067263	101.4184904	146.6791555	0.073339578
	Parker	0.000475952	3.074647333	0.000876616	0	0.000351511	0	0.0014031	0.429348609	0.000588002	0	0.000169709	0	0.0045636	0	0.01826665	0	0.000187421	0	0.000853118	1.464803774	4.968799717	0.0024844
	Rockwall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Henderson	0.000950271	6.138750988	0.000958382	0	0.000701818	0	0.001586741	0.48554272	0.000415385	0	0.000136926	0	0.001353736	0	0.004704812	0	0.001609773	0	0.00864501	14.84348201	21.46777572	0.010733888
	Hood	0.012327882	79.6381176	0.012433111	0	0.00910469	0	0.020584816	6.2989537	0.0053888	0	0.001776337	0	0.017562038	0	0.061035609	0	0.020883617	0	0.112151856	192.5647364	278.5018077	0.139250904
	Hunt	0.006351211	41.02882472	0.006405424	0	0.004690653	0	0.010605108	3.245162933	0.00277626	0	0.000915153	0	0.0090478	0	0.031444984	0	0.010759047	0	0.057779603	99.20757867	143.4815663	0.071740783
El Paso Area	El Paso	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Antonio Area	Bexar	0.031128114	201.087615	0.048234164	0	0.0229895	0	0.084461674	25.84527234	0.001063735	0	1.065346769	0	0.043667482	0	0.004350128	0	0.000484041	0	0.002332591	4.005058002	230.9379454	0.115468973
	Comal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Guadalupe	0.002007611	12.96916445	0.076651484	0	0.00148271	0	0.134326688	41.10396658	0.00124155	0	0.00356749	0	0.001065557	0	0.001862326	0	0.000403153	0	0.001841718	3.162229761	57.2353608	0.02861768
	Wilson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austin Area	Bastrop	0.004469515	28.87306426	0.170648096	0	0.003300936	0	0.299049574	91.50916953	0.002764046	0	0.007942252	0	0.002372235	0	0.004146069	0	0.000897533	0	0.00410019	7.04002663	127.4222604	0.06371113
	Caldwell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hays	0.002469353	15.95201946	0.094281013	0	0.001823727	0	0.165221279	50.55771148	0.001527102	0	0.004387998	0	0.001310631	0	0.002290653	0	0.000495876	0	0.002265306	3.889529727	70.39926066	0.03519963
	Travis	0.000507609	3.279155024	0.298194277	0	0.000374892	0	0.033779905	10.33665081	0.000333135	0	0	0	0.000269863	0	0.000469526	0	0.000102841	0	0.000465139	0.79864284	14.41444867	0.007207224
	Williamson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North East Texas Area	Gregg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Harrison	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rusk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Smith	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upshur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corpus Christi Area	Nueces	0.223524525	1443.968434	0.00447587	0	0.165082827	0	0.007477478	2.288108245	0.001651016	0	0.001597886	0	0.045960479	0	0.007117588	0	0.001580824	0	0.008136188	13.96983409	1460.226377	0.730113188
	San Patricio	0.055330886	357.4375245	0.001107949	0	0.040864326	0	0.001850962	0.566394477	0.00040869	0	0.000395538	0	0.01137698	0	0.001761876	0	0.000391315	0	0.002014018	3.458069301	361.4619883	0.180730994
Victoria Area	Victoria	0.020604752	133.1066983	0.002090584	0	0.015217528	0	0.003408874	1.043115579	0.001131941	0	0.000524055	0	0.495811308	0	0.030584062	0	0.000449952	0	0.002127635	3.653149685	137.8029636	0.068901482
Other ERCOT counties	Andrews	2.56527E-05	0.165716204	2.58716E-05	0	1.89456E-05	0	4.28342E-05	0.013107275	1.12134E-05	0	3.69632E-06	0	3.65442E-05	0	0.000127007	0	4.3456E-05	0	0.000233373	0.400701298	0.579524777	0.000289762
	Angelina	0.00032149	2.07682647	0.000324234	0	0.000237435	0	0.000536817	0.164265984	0.000140531	0	4.63239E-05	0	0.000457988	0	0.001591705	0	0.000544609	0	0.002924729	5.021760355	7.262852808	0.003631426
	Bosque	0.000939453	6.068864336	0.001730301	0	0.000693828	0	0.002769496	0.8474658	0.001160623	0	0.000334979	0	0.009007821	0	0.036055459	0	0.000369939	0	0.001683919	2.891289446	9.807619583	0.00490381
	Brazos	0.001913926	12.36396421	0.003525105	0	0.00141352	0	0.005642234	1.726523488	0.002364512	0	0.000682445	0	0.018351436	0	0.073454996	0	0.00075367	0	0.003430612	5.890360578	19.98084828	0.009990424
	Calhoun	0.088525246	571.8730896	0.001772635	0	0.065379841	0	0.0029614	0.90618846	0.000653873	0	0.000632831	0	0.01820231	0	0.002818869	0	0.000626074	0	0.003222277	5.532650154	578.3119282	0.289155964
	Cameron	0.054672288	353.1829777	0.001094762	0	0.285623104	0	0.001828931	0.559652735	0.000403825	0	0.00039083	0	0.011241561	0	0.001740904	0	0.000386657	0	0.001990046	3.416908212	357.1595387	0.178579769
	Cherokee	0.003512995	22.69394859	0.003542982	0	0.002594504	0	0.005865919	1.79497125	0.001535611	0	0.000506191	0	0.005004538	0	0.017392915	0	0.005951066	0	0.031959174	54.8739016	79.36282145	0.039681411
	Coke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coleman	0.001355099	8.753941785	2.71346E-05	0	0.001000801	0	4.53316E-05	0.013871471	1.00092E-05	0	9.68705E-06	0	0.000278632	0	4.31498E-05	0	9.58362E-06	0	4.9325E-05	0.084690989	8.852504245	0.004426252
	Crockett	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ector	0.003629264	23.4450427	0.003660242	0	0.002680373	0	0.006060061	1.854378819	0.001586434	0	0.000522944	0	0.005170172	0	0.017968562	0	0.006148027	0	0.033016916	56.69004495	81.98946647	0.040994733
	Fannin	0.007628516	49.28021455	0.007693632	0	0.005633999	0	0.012737922	3.897804206	0.003334599	0	0.001099201	0	0.010867422	0	0.037768948	0	0.012922821	0	0.069399776	119.1594152	172.337434	0.086168717
	Fayette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Freestone	0.003774434	24.3828444	0.003806652	0	0.002787588	0	0.006302464	1.928553971	0.001649892	0	0.000543862	0	0.005376978	0	0.018687305	0	0.006393948	0	0.034337593	58.95764675	85.26904513	0.042634523
	Frio	0.014763838	95.374395	0.001497957	0	0.010903753	0	0.002442547	0.747419315	0.000811065	0	0.000375499	0	0.355261637	0	0.021914272	0	0.000322402	0	0.001524506	2.617576315	98.73939063	0.049369695
	Grimes	0.000554424	3.58158047	0.001021149	0	0.000409467	0	0.001634436	0.500137553	0.000684949	0	0.00019769	0	0.005316025	0	0.021278368	0	0.000218322	0	0.000993776	1.70631361	5.788031632	0.002894016
	Hardeman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haskell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hidalgo	0.239736996	1548.700992	0.004800509	0	0.177056459	0	0.008019827	2.454067155	0.001770766	0	0.001713782	0	0.049294041	0	0.007633834	0	0.001695483	0	0.008726314	14.98308093	1566.13814	0.78306907
	Howard	0.000585081	3.779622393	0.000590075	0	0.000432108	0	0.000976955	0.298948132	0.000255752	0	8.43049E-05	0	0.000833494	0	0.002896748	0	0.000991136	0	0.005322723	9.139115937	13.21768646	0.006608843
	Jack	0.002177558	14.06702562	0.002196145	0	0.001608224	0	0.003636037	1.112627291	0.000951861	0	0.000313767	0	0.003102103	0	0.010781137	0	0.003688816	0	0.01981015	34.01402697	49.19367988	0.02459684
	Jones	0.042500124	274.5507992	0.000851025	0	0.031388236	0	0.00142174	0.43505241	0.000313918	0	0.000303816	0	0.008738755	0	0.001353312	0	0.000300572	0	0.001546985	2.656172408	277.642024	0.138821012
	Lamar	0.00107998	6.976673809	0.001089199	0	0.000797614	0	0.001803327	0.551817981	0.000472084	0	0.000155616	0	0.001538517	0	0.005347007	0	0.001829503	0	0.00982503	16.86957695	24.39806874	0.012199034
	Limestone	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Llano	0.00124346	8.032750996	0.047475864	0	0.000918351	0	0.083198331	25.45868932	0.000768983	0	0.002209607	0	0.000659977	0	0.001153474	0	0.000249702	0	0.00114071	1.958599905	35.45004022	0.01772502
	McLennan	0.023031368	148.7826401	0.023227961	0	0.017009692	0	0.038457253	11.76791956	0.01006754	0	0.003318614	0	0.032809997	0	0.114028801	0	0.039015483	0	0.209525912	359.7559905	520.3065502	0.260153275
	Milam	0.001652492	10.67509896	0.001666598	0	0.001220439	0	0.002759294	0.844343841	0.000722342	0	0.000238109	0	0.002354105	0	0.008181524	0	0.002799346	0	0.015033406	25.81235821	37.33180101	0.018665901
	Mitchell	0.016961453	109.5709865	0.017106233	0	0.012526789	0	0.028321847	8.666485242	0.00741424	0	0.002443993	0	0.024162925	0	0.083976519	0	0.028732956	0	0.154305373	264.9423262	383.179798	0.191589899
	Nolan	0.000603273	3.897142877	0.000608422	0	0.000445544	0	0.001007331	0.30824338	0.000263704	0	8.69262E-05	0	0.00085941	0	0.002986817	0	0.001021953	0	0.005488224	9.423280127	13.62866638	0.006814333
	Palo Pinto	0.003074879	19.86372039	0.00566337	0	0.002270935	0	0.00906471	2.773801285	0.003798781	0	0.001096403	0	0.029483083	0	0.118011463	0	0.001210832	0	0.005511559	9.463346343	32.10086801	0.016050434
	Pecos	4.22618E-05	0.273011109	4.26225E-05	0	3.12122E-05	0	7.05678E-05	0.021593734	1.84736E-05	0	6.08954E-06	0	6.02052E-05	0	0.000209239	0	7.15921E-05	0	0.000384473	0.660140067	0.95474491	0.000477372
	Presidio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Robertson	0.000359257	2.320803338	0.000406685	0	0.000265328	0	0.000358385	0.109665944	0.001533867	0	0.00035593	0	0.000370532	0	0.000908875	0	0.09332343	0	0.00165467	2.841067775	5.271537057	0.002635769
	Taylor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Titus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tom Green	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upton	3.2238E-05	0.208257159	3.25131E-05	0	2.38092E-05	0	5.38302E-05	0.016472039	1.40919E-05	0	4.6452E-06	0	4.59255E-05	0	0.000159611	0	5.46116E-05	0	0.000293282	0.503565204	0.728294402	0.000364147
	Ward	0.019807626	127.9572619	0.0199767	0	0.014628815	0	0.033074321	10.12074233	0.008658368	0	0.002854101	0	0.028217522	0	0.098067981	0	0.033554415	0	0.180198187	309.4002865	447.4782907	0.223739145
	Webb	0.014180046	91.60309479	0.000283942	0	0.010472596	0	0.000474359	0.145154002	0.000104738	0	0.000101367	0	0.002915661	0	0.000451529	0	0.000100285	0	0.000516147	0.886224384	92.63447318	0.046317237
	Wharton	0.00015439	0.997359308	0.000191235	0	0.000114024	0	6.43902E-05	0.019703394	0.001170153	0	0.000265844	0	0.000106811	0	6.77744E-05	0	8.17175E-05	0	0.000112223	0.192687711	1.209750413	0.000604875
	Wichita	0.000219843	1.420185419	0.000221719	0	0.000162364	0	0.000367089	0.112329152	9.60984E-05	0	3.16774E-05	0	0.000313184	0	0.001088447	0	0.000372417	0	0.002000002	3.434004208	4.966518779	0.002483259
	Wilbarger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Wise	0.002918471	18.85332213	0.002955932	0	0.002155421	0	0.004892446	1.497088501	0.001287753	0	0.000423725	0	0.004280539	0	0.014952843	0	0.004924352	0	0.026440527	45.39838528	65.74879591	0.032874398
	Young	0.00549666	35.50842479	0.005543579	0	0.004059529	0	0.009178198	2.808528509	0.002402716	0	0.000792019	0	0.007830425	0	0.027214083	0	0.009311425	0	0.050005398	85.85926772	124.176221	0.062088111
	Total	**1.143037355**	**7384.021312**	**1.154658244**	**0**	**1.089429227**	**0**	**1.180868675**	**361.3458145**	**1.539350626**	**0**	**1.443063194**	**0**	**1.48172714**	**0**	**1.269705424**	**0**	**1.151968562**	**0**	**1.517782624**	**2606.032765**	**10351.39989**	**5.175699945**
Energy Savings by PCA (MWh)		6,460.00		0.00		0		306.00		0.00		0.00		0		0		0.00		1717.00			

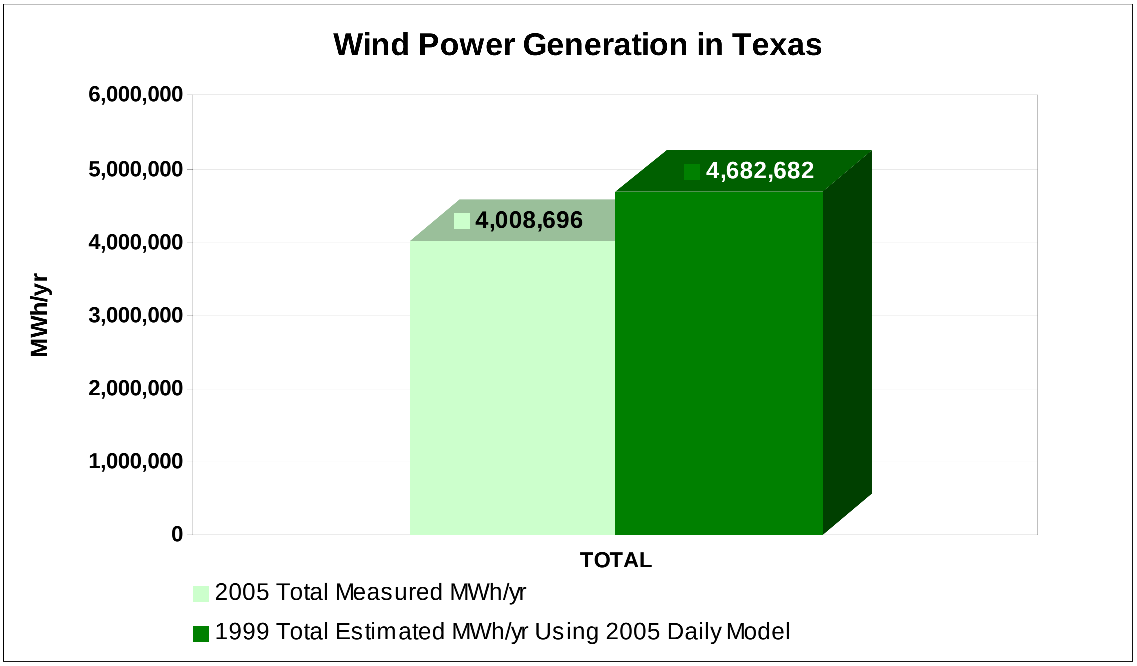


Figure 4-18: Comparison of Total 2005 Measured and 1999 Estimated Power Production.

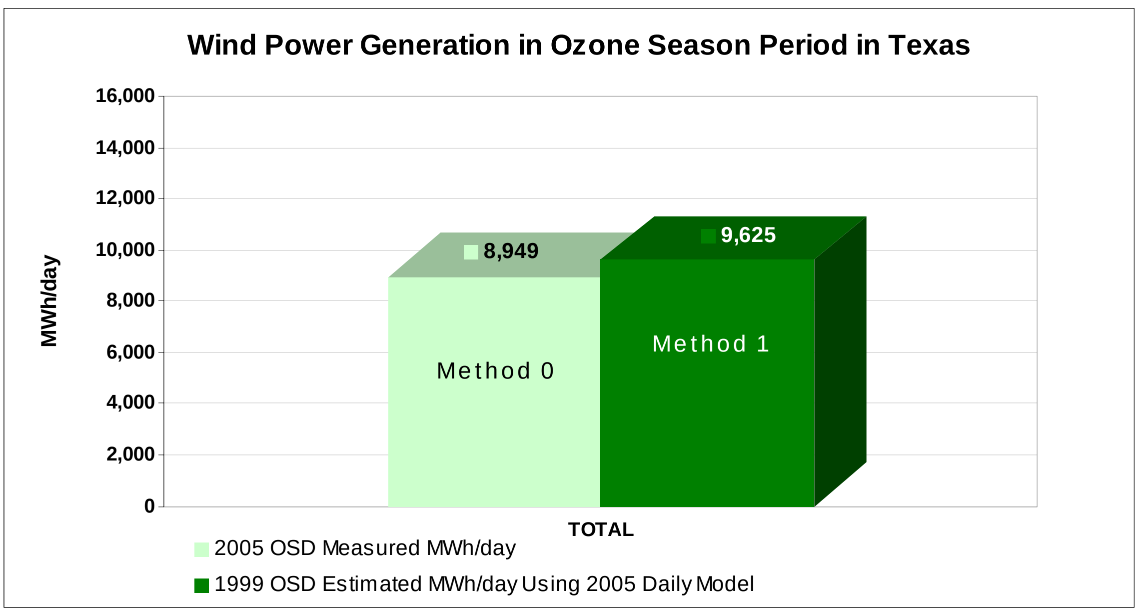


Figure 4-19: Comparison of Total 2005 OSD Measured and 1999 OSD Estimated Power Production.

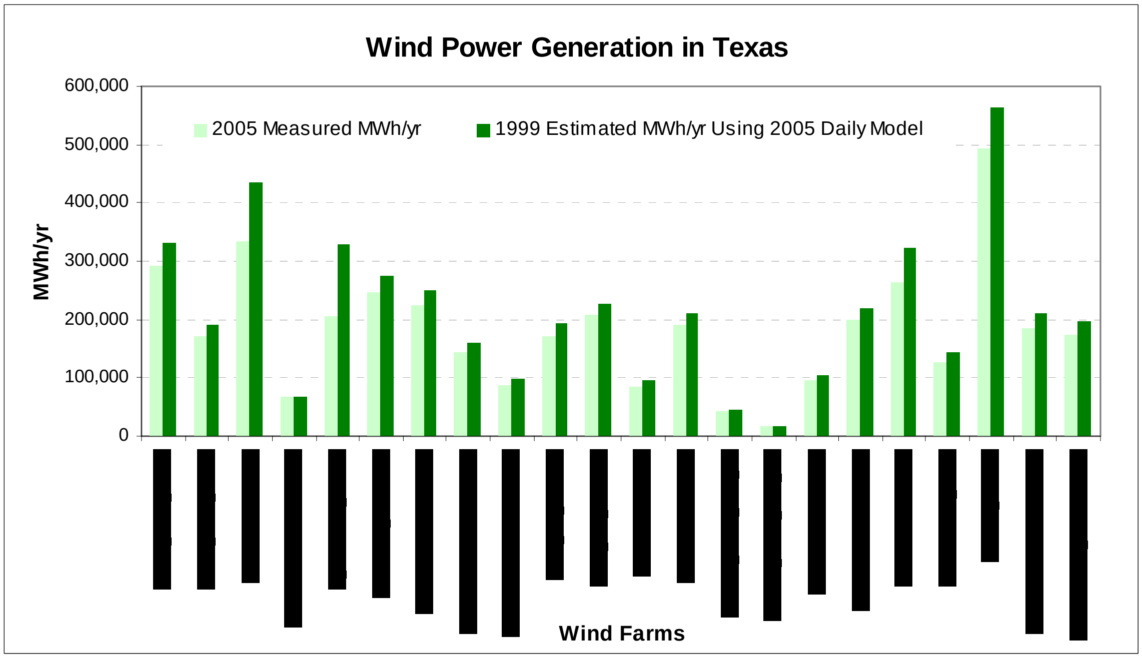


Figure 4-20: Comparison of 2005 Measured and 1999 Estimated Power Production for Each Wind Farm.

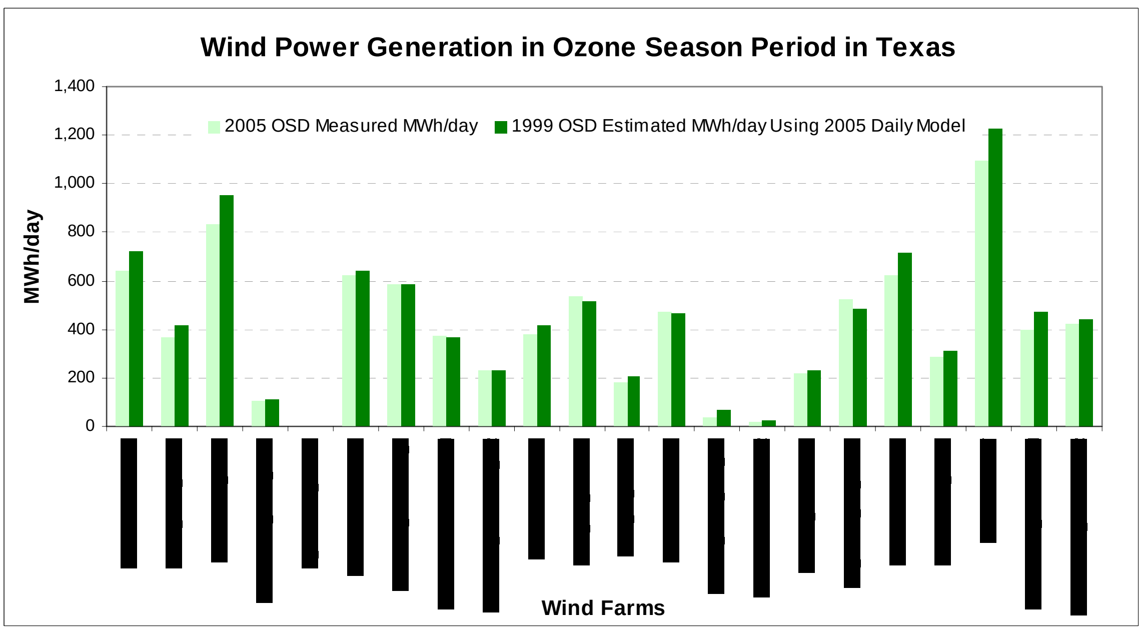


Figure 4-21: Comparison of 2005 OSD Measured and 1999 OSD Estimated Power Production for Each Wind Farm.

4.5 Uncertainty Analysis on the 2005 Daily Regression Models

One of the advantages of using regression models is that it allows for an uncertainty analysis to be calculated, which can be used to assess the accuracy of the model. This section of the report presents an uncertainty analysis for the daily regressions that were applied to the 2005 data.

Assuming that the daily energy production of a wind farm data can be related linearly with the daily average wind speed (see Figure 4-22), it is expressed as:

$$\hat{E}_i = c_o + c_1 V_i \qquad (1)$$

Where V is the daily average wind speed, $\hat{E}$ is the daily total energy production, and c_o and c_1 are the resultant coefficients of a linear regression. The subscript *i* represents any day over the modeling period.

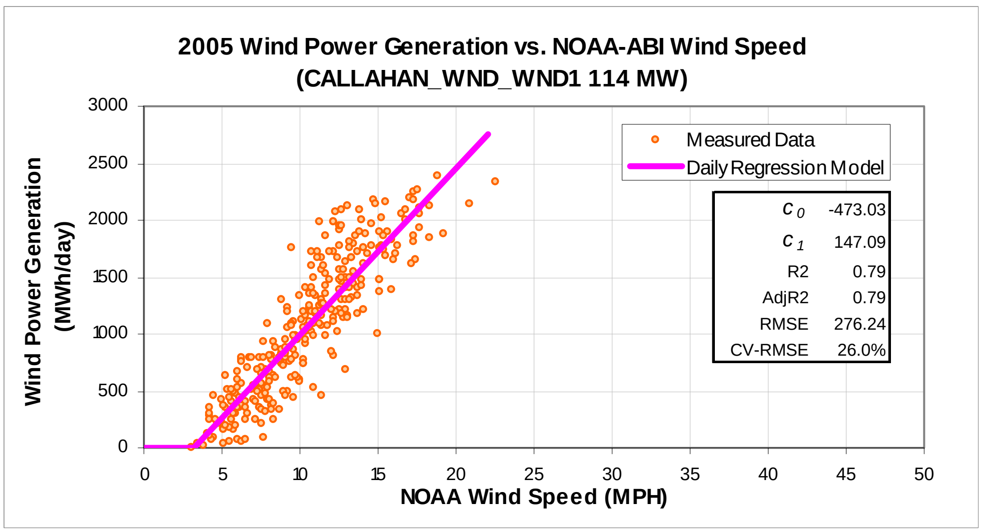


Figure 4-22: Linear Model Representation of the Daily Wind Power Generation on the Year 2005 for the Callahan Divide Wind Farm.

The primary purpose of modeling in this analysis is to back-cast the wind power production or predict the power production in another weather year that would have occurred if the turbines had been installed and operating. This allows for the evaluation of the NOx reductions during the base-year weather conditions. Unfortunately, any prediction intrinsically contains an uncertainty, which is related to the prediction variance. Thus, the prediction uncertainty, $\sigma^2\left(\hat{E}_{pred,j}\right)$, assuming no autocorrelation effects in the data used to generate the linear model, can be presented for a particular observation, *j*, during any time at a particular condition is represented as follows:

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

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

$$MSE\left(\hat{E}_i\right)=\left[\frac{1}{n-(k+1)}\right]\sum_{i=1}^{n}\left(E_i-\hat{E}_i\right)^2 \qquad (3)$$

Where *n* is the number of days in the period used for the developed model, *k* is the number of regressor 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 Equation 2 accounts for the increase in the variance of the energy prediction for any particular observation, *j*, which is different from 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, *m* days, is then the sum of all the wind energy predicted $\hat{E}_{pred,j}$ in each individual observation.

Assuming that

$$\sum_{j=1}^{m}\sigma^2\left(\hat{E}_{pred,j}\right)=\sigma^2\left(\sum_{j=1}^{m}\left(\hat{E}_{pred,j}\right)\right)=\sigma^2\left(\hat{E}_{pred,total}\right) \qquad (4)$$

and the total prediction variance or uncertainty, is obtained through

$$\sigma^2\left(\hat{E}_{pred,total}\right)=MSE\left(\hat{E}_i\right)\cdot m\cdot\left[1+\frac{1}{n}+\frac{\sum_{j=1}^{m}\left(V_j-\overline{V}_n\right)^2}{m\sum_{i=1}^{n}\left(V_i-\overline{V}_n\right)^2}\right] \qquad (5)$$

Thus, it is observable 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 4-11 presents all the statistical related parameters for the daily linear models of all the Wind Farms in Texas. Table 4-12 shows the uncertainty of applying the linear models to predict the energy generation that they could have had in the year 1999. Also, in the same table is included the uncertainty related to the predicted wind generated for all the same Wind Farms in the 1999 Ozone Season Period (OSP), which considers the period of July 15 though September 15 – about 63 days.

Table 4-11: Statistical Parameters of the Determined 2005 Daily Power Production Linear Models.

Wind Farm	c_o	c_1	$AdjR^2$	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%	153
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	192.0	49.40%	364
INDNNWP_INDNNWP2	-101.55	33.07	0.44	118.6	49.40%	364
KUNITZ_WIND_LGE	-101.97	12.10	0.60	63.8	54.90%	349
KUNITZ_WIND_LGE2	-41.55	4.94	0.60	26.0	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	219.0	43.30%	364
WOODWRD2_WOODWRD2	-350.53	79.59	0.66	182.6	38.70%	364

Table 4-12. 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	12,548.8	331,569.7	3.8%	63	5,208.3	45,616.9	11.4%
BRAZ_WND_WND2	365	7,148.0	191,906.8	3.7%	63	2,966.7	26,458.3	11.2%
CALLAHAN_WND1	365	10,363.9	433,697.0	2.4%	63	4,301.0	60,172.8	7.1%
H_HOLLOW_WND1 *	365	23,948.8	626,846.0	3.8%	63	9,917.3	85,292.3	11.6%
INDNENR_INDNENR	363	11,154.7	273,888.0	4.1%	63	4,642.3	40,255.8	11.5%
INDNENR_INDNENR_2	365	10,903.7	249,340.2	4.4%	63	4,525.4	36,733.3	12.3%
KING_NE_KINGNE	365	6,721.3	192,700.7	3.5%	63	2,788.8	26,265.9	10.6%
KING_NW_KINGNW	365	9,111.7	227,493.1	4.0%	63	3,780.6	32,451.2	11.7%
KING_SE_KINGSE	365	3,492.1	95,930.8	3.6%	63	1,448.9	12,878.0	11.3%
KING_SW_KINGSW	365	7,905.5	209,670.8	3.8%	63	3,280.1	29,520.7	11.1%
SWEETWN2_WND2	365	8,894.8	323,217.8	2.8%	63	3,691.4	45,167.7	8.2%
SWEETWND_WND1	365	4,231.0	143,710.9	2.9%	63	1,756.0	19,793.7	8.9%
TRENT_TRENT	365	16,486.7	563,713.8	2.9%	63	6,842.6	77,287.0	8.9%
DELAWARE_WIND_NWP	365	2,864.2	68,298.4	4.2%	61	1,170.7	7,200.7	16.3%
INDNNWP_INDNNWP	363	7,182.7	157,710.7	4.6%	63	2,989.2	23,239.2	12.9%
INDNNWP_INDNNWP2	363	4,435.5	97,434.0	4.6%	63	1,845.9	14,354.0	12.9%
KUNITZ_WIND_LGE	365	2,393.2	43,855.5	5.5%	60	970.1	4,200.6	23.1%

KUNITZ_WIND_LGE2	365	975.6	17,913.4	5.4%	60	395.5	1,717.3	23.0%
SGMTN_SIGNALMT	365	4,360.7	103,431.4	4.2%	63	1,809.3	14,601.7	12.4%
SW_MESA_SW_MESA	365	9,106.2	217,415.7	4.2%	63	3,778.3	30,764.5	12.3%
WOODWRD1_WOODWRD1	363	8,193.2	210,467.7	3.9%	63	3,409.8	29,881.5	11.4%
WOODWRD2_WOODWRD2	363	6,828.9	196,032.2	3.5%	63	2,842.0	27,851.3	10.2%

5 REPORTING NOX EMISSIONS CREDITS TO THE TCEQ (PRELIMINARY)

5.1 Introduction

In January 2005, the Laboratory was asked to propose a method by which the NOx emissions savings from the energy-efficiency programs from multiple Texas State Agencies working under SB 5 and SB 7 could be reported in a combined format to allow the TCEQ to consider the combined savings for SIP planning purposes. This required that the analysis should include the cumulative savings estimates from all projects through 2013 for both the annual and Ozone Season Day (OSD) NOx reductions. The NOx emissions reductions from all these programs were calculated using the emissions factors for 2007 from the U.S.E.P.A. The different programs included in this cumulative analysis are:

- ESL-Single-family
- ESL-Multi-family
- PUCT-SB 7
- PUCT-SB 5
- SECO
- Wind-ERCOT

The Laboratory's single- and multi-family programs include the energy savings attained by constructing new residences according to the IECC 2000/2001 building code. The baseline for comparison for the code programs is the published data on residential construction characteristics by the National Association of Home Builders (NAHB) for 1999. Annual MWh (electric) and MBtu (natural gas) savings are from the Laboratory's Annual Reports to the TCEQ.

The PUCT's SB 5 and SB 7 programs include their incentive and rebates programs managed by the different Utilities for Texas. These include the Residential Energy Efficiency Programs as well as the Commercial & Industrial Standard Offer Programs (C&I SOP). The energy-efficiency measures include high-efficiency HVAC equipment, variable-speed drives, increased insulation levels, infiltration reduction, duct sealing, Energy Star Homes, etc. Annual MWh savings, according to the utilities (or Power Control Authorities –PCAs), were reported for the different programs completed in the years 2001, 2002, 2003 and 2004. The PUCT also reported the savings from the SB 5 grant program which was conducted in 2002 and 2003.

The Texas State Energy Conservation Office (SECO) funds energy-efficiency programs directed towards school districts, government agencies, city and county governments, private industries and residential energy consumers. For the 2004 reporting year, SECO submitted annual energy savings values for 149 projects which included projects funded by SECO and by Energy Service projects.

The wind-ERCOT project includes NOx emissions savings from the current installed green power generation capacity in west Texas. For projections through 2013, two annual growth factors were available: 17% annual growth through 2009 to reach a production level of 3700 MW in 2009, and 22.7% annual growth to reach a production level of 7000 MW in 2015.

5.2 Description of Analysis Method.

Annual and Ozone Season Day (OSD) NOx emissions reductions were calculated for 2004 and cumulatively from 2005 up to 2013 using assumed growth factors. The following factors were used to adjust the cumulative savings for future predictions:

<u>Annual Degradation Factor:</u>
This factor was used to account for the decrease in efficiency of the measures installed as the equipment wears down and degrades. An annual degradation factor of 5% was used for all the programs. This value was taken from a study by Kats et al. 1996.

Transmission and Distribution Loss:
This factor adjusts the reported savings to account for the loss in energy resulting in the transmission and distribution of the power from the electricity producers to the electricity consumers. For this calculation, the energy savings reported at the consumer level are increased by 7% to give credit for the actual power produced that gets lost in the transmission and distribution system on its way to the customer. In the case of Wind-ERCOT, The T&D losses were assumed to cancel out since wind energy is displacing the actual power produced by the conventional power plants, therefore, no net increase or decrease in T&D losses.

Initial Discount Factor:
This factor was used to discount the reported savings for the assumptions and methods employed in the calculation procedures. For the Laboratory's single family and multi-family code compliance program, the discount factor was assumed to be 20%. For PUCT's SB 5 and SB 7 programs and Wind-ERCOT, the discount factor was taken as 25%. For the savings in the SECO program, the discount factor was 60%.

Growth Factor:
The growth factors were used to account for several different factors. First, in the case of wind energy, the factor accounted for the increased number of wind turbines which are being installed every year in the western portion of the state. Three different scenarios were studied for wind energy projections:

- No annual growth;
- 17% growth factor, on the basis that the installed wind power generation capacity will grow to 3700 MW until 2009 from the current installed level of 2000 MW. For this growth scenario, the 17% growth will achieve 3700 MW by 2009; after that, the wind power generation will be fixed at the production level achieved in 2009; and
- 22.7% growth factor, on the basis that the installed wind power generation capacity will grow to 7000 MW in 2015.

In the numbers shown in this report, a 17% growth factor was assumed for the wind energy savings.

Also included are growth factors for single-family (3.25%) and multi-family residential (1.54%) construction. These values represent the average growth rate for these housing types from the U.S. Census data for Texas.

Figure 5-1 shows the overall information flow that was used to calculate the NOx emissions savings from the annual and OSD MWh numbers from all programs. For the Laboratory's single-family and multi-family code-implementation programs, the annual and ozone season savings were calculated from DOE-2 hourly simulation models based on Chapter 4 of IECC 2000/2001. The base case is taken as the average characteristics of single- and multi-family residences for Texas published by the National Association of Home Builders for 1999. The OSD consumption is the average daily consumption between July 15 and September 15, 1999.

The annual MWh numbers from PUCT programs are calculated through deemed savings tables and spreadsheets created for the utilities incentive programs by Frontier Associates in Austin, Texas.

The SECO MWh savings were submitted as annual savings by project, i.e., no break down by project type. A description of the measures completed for the project was also submitted for information purposes.

The electricity production used for the Wind-ERCOT data is from the actual on-site metered data measured at 15-minute intervals.

5.3 Preliminary 2006 TCEQ Integrated NOx Emissions Savings: Cumulative Annual (Tons/yr) savings from EE/RE programs in Texas (2006 – 2020).

The preliminary 2006 NOx emissions savings are reported in Table 5-1 and Table 5-2, as well as in Figure 5-2 through Figure 5-4. These values represent the electricity and NOx emissions savings that are reported to the TCEQ through the integrated NOx emissions savings reporting procedures, which were previously described. Table 5-1 contains the values used for growth, discount, and degradation, as well as the associated notes. Table 5-2 contains the electricity savings reported by ERCOT for the years 1999 through 2005, and as projected for the years 2006 through 2020. Figure 5-2 displays the values tabulated in Table 5-1 and Table 5-2.

Figure 5-3 displays the cumulative annual NOx emissions reductions across all programs reporting to TCEQ (i.e., PUC, SECO, ERCOT and ESL). In the upper graph of Figure 5-3, the values are displayed as a stacked bar chart with the salmon colored portion representing the cumulative NOx emissions reductions from wind energy using the Legislative goals for future electricity generation from wind energy. The lower portion of Figure 5-3 displays the individual portions of the cumulative annual NOx emissions reductions. In the lower portion of Figure 5-3, the salmon colored line and symbol represent the wind energy portion.

Figure 5-4 displays the cumulative OSD NOx emissions reductions across all programs reporting to TCEQ (i.e., PUC, SECO, ERCOT and ESL). In the upper graph of Figure 5-4, the values are displayed as a stacked bar chart with the salmon colored portion representing the cumulative NOx emissions reductions from wind energy using the Legislative goals for future electricity generation from wind energy. The lower portion of Figure 5-4 displays the individual portions of the cumulative annual NOx emissions reductions. In the lower portion of Figure 5-4, the salmon colored line and symbol represent the wind energy portion.

Table 5-1: 2006 TCEQ Integrated NOx Emissions Savings: values used for growth, discount, and degradation, including notes.

Energy Savings Summary

Base year	1999
Projection year	2020

ADJUSTMENT FACTORS

	ESL-Single Family[16]	ESL-Multifamily[16]	ESL-Commercial[16]	Federal Buildings[15]	Furnace Pilot Light Program[15]	PUC (SB7)[15]	PUC (SB5 Grant Program)[15]	SECO[15]	Wind-ERCOT[8]	SEER13 Single Family	SEER13 Multifamily
Annual Degradation Factor [11]	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
T&D Loss [9]	7.00%	7.00%	7.00%	7.00%	0.00%	7.00%	7.00%	7.00%	0.00%	7.00%	7.00%
Initial Discount Factor [12]	20.00%	20.00%	20.00%	20.00%	20.00%	25.00%	25.00%	60.00%	25.00%	20.00%	20.00%
Growth Factor	3.25%	1.54%	3.25%	0.00%	0.00%	0.00%	0.00%	0.00%	According to SB	N.A.	N.A.
Weather Normalized	Yes	Yes	Yes	No	No	No	No	No	See note 7	Yes	Yes

Notes :

1) 2007 annual eGrid with 25% capacity factor has been used for the calculation of annual NOx emission reductions.

2) 2007 Ozone Season Day (OSD) eGrid with 25% capacity factor has been used for the calculation of OSD NOx emission reductions.

3) If the base year is 1999 then all the savings from all the projects are counted from 2000. For base year 2000, the savings are counted from 2001 and so on.

4) For PUC, SECO and Federal Buildings energy efficiency programs, the OSD energy consumption is the average daily of the annual energy consumption.

Season
(July 15th to September 15th)

[6) The annual and OSD energy savings for the commercial building stock in Texas are calculated from the following sources:]
a) U.S. Department of Energy (DOE). 2004. Building Energy Standards Program: Determination Regarding Energy Efficiency Improvements
in the Energy Standard for Buildings, Except Low-Rise Residential Buildings, ASHRAE/IESNA Standard 90.1-1999.
Docket No. (Docket No. EE-DET-02-001). Washington, D.C. <http://www.energycodes.gov/implement/pdfs/FR_com_notice.pdf>
b) McGraw-Hill Construction Dodge. 2005. MarkeTrack: McGraw-Hill Construction Analytics. McGraw-Hill Construction Information Group, 148 Princeton-Hightstown Rd., Hightstown, N.J. <http://dodge.construction.com>

7) For Wind-ERCOT (2005), the OSD energy consumption is the average daily consumption of the measured data in the months of July, August and September of 2005

8) For the Wind calculation there are two scenarios for the growth in Wind energy:
a) annual growth rates from 0% to 25%
b) Annual growth rates mimicking the yearly goals set forth by the Senate Bill 20, Section 39.904, Utilities Code.

9) T&D losses for Wind-ERCOT are 0.00% or negative since Wind is displacing the power produced by conventional plants which already have a T&D Loss associated with them.

10) For the Furnace Pilot Light program, annual and OSD gas (Mbtu) savings have been calculated. 0.092 lbs of NOx /MBtu is being used to calculate the NOx emissions reduction

11) The 5% annual degradation factor for all programs has been taken from:
Kats, G.H. et al. (1996) "Energy Efficiency as a Commodity," ACEEE Summer Study on Energy Efficiency in Buildings.

12) The initial discount factor for each program should be chosen to reflect the accuracy of the reported numbers.

edited.

14) NOx emissions savings from PUC- SB7 and PUC-SB5 grants program for El Paso electric, Entergy and Xcel Energy are not included since they are
not part of the eGrid currently being used to calculate the NOx reductions.

15) The growth factor for Federal Buildings, Furnace pilot lights, PUC(SB7), PUC(SB5) and SECO is 0%, since it is being assumed that the future year
savings will be at the same level as 2005

16) Growth factors for single-family (3.25%) and multi-family residential (1.54%) construction values represent the average growth rate for these housing types from the U.S. Census data for Texas

Table 5-2: 2006 TCEQ Integrated NOx Emissions Savings: Cumulative Annual (MWh/yr) and OSD (MWh/day) savings from electricity generated by wind farms in Texas (2006 – 2020).

Energy savings summary: (program wise)

Base year	**1999**
Projection year	**2020**

Adjustment factors

Annual degradation factor[5]	5.00%
T&D loss	0.00%
Initial discount factor[6]	25.00%
Growth factor	According to SB 20, section 39.904

Energy Savings Summary

Year	Total Energy Savings	
	Electricity	
	Annual (MWh)	Ozone Season Day (MWh/day)
1999	0	0.00
2000	0	0.00
2001	461,407	1,673.88
2002	1,606,875	4,424.13
2003	1,626,532	4,385.11
2004	2,150,286	4,376.68
2005	2,912,683	6,871.40

Future Projection (year)	Total Cumulative Energy Savings	
	MWh	Ozone Season Day (MWh/day)
2006	4,782,508	10,304.91
2007	5,023,145	10,003.28
2008	4,820,640	10,434.72
2009	5,705,725	12,350.57
2010	6,533,348	14,142.04
2011	7,303,511	15,809.12
2012	8,016,212	17,351.83
2013	9,273,739	20,088.47
2014	9,269,232	20,064.11
2015	9,383,227	20,310.86
2016	9,461,078	20,479.38
2017	9,954,593	21,547.64
2018	9,960,154	21,559.68
2019	10,138,098	21,944.85
2020	10,268,312	22,226.71

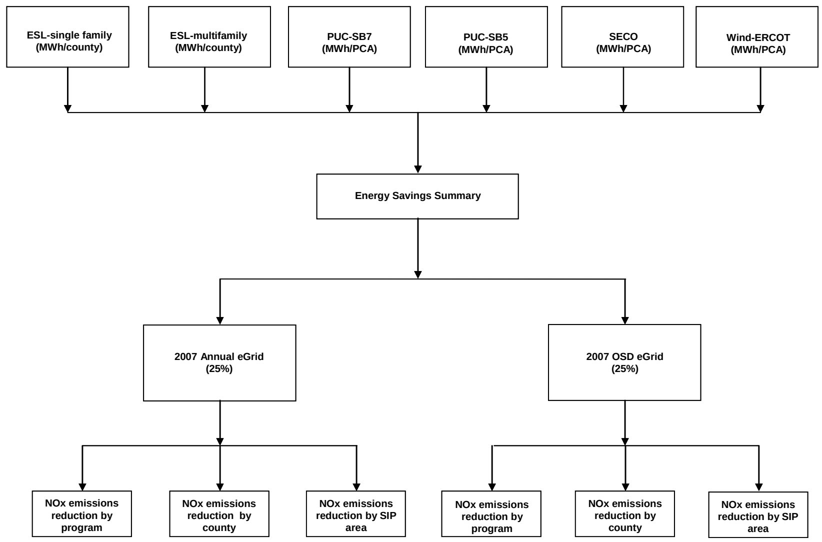


Figure 5-1: Process Flow Diagram of the NOx Emissions Reduction Calculations.

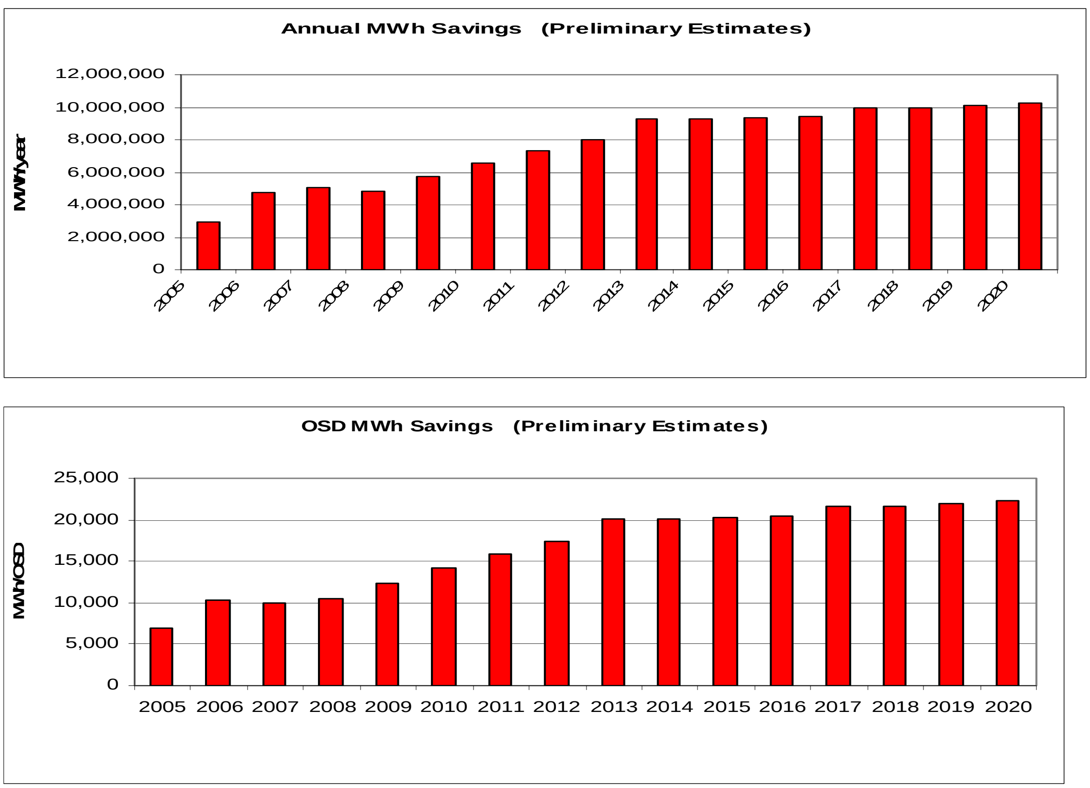
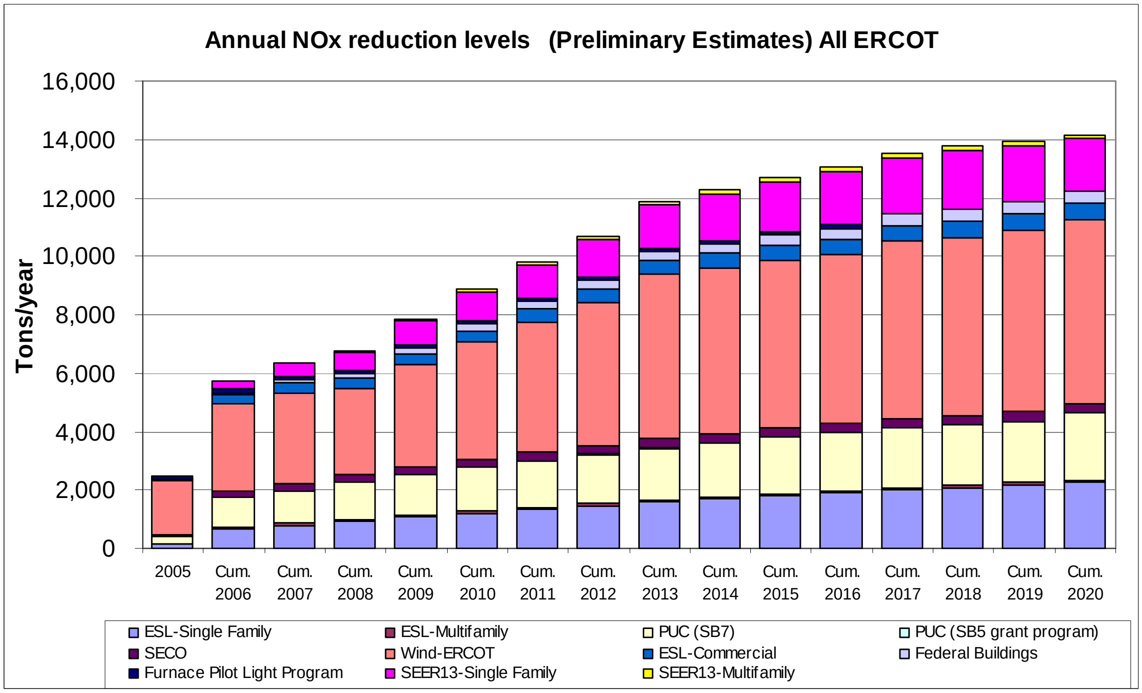


Figure 5-2: 2006 TCEQ Integrated NOx Emissions Savings: Cumulative Annual (MWh/yr) and OSD (MWh/day) savings from electricity generated by wind farms in Texas (2006 – 2020).



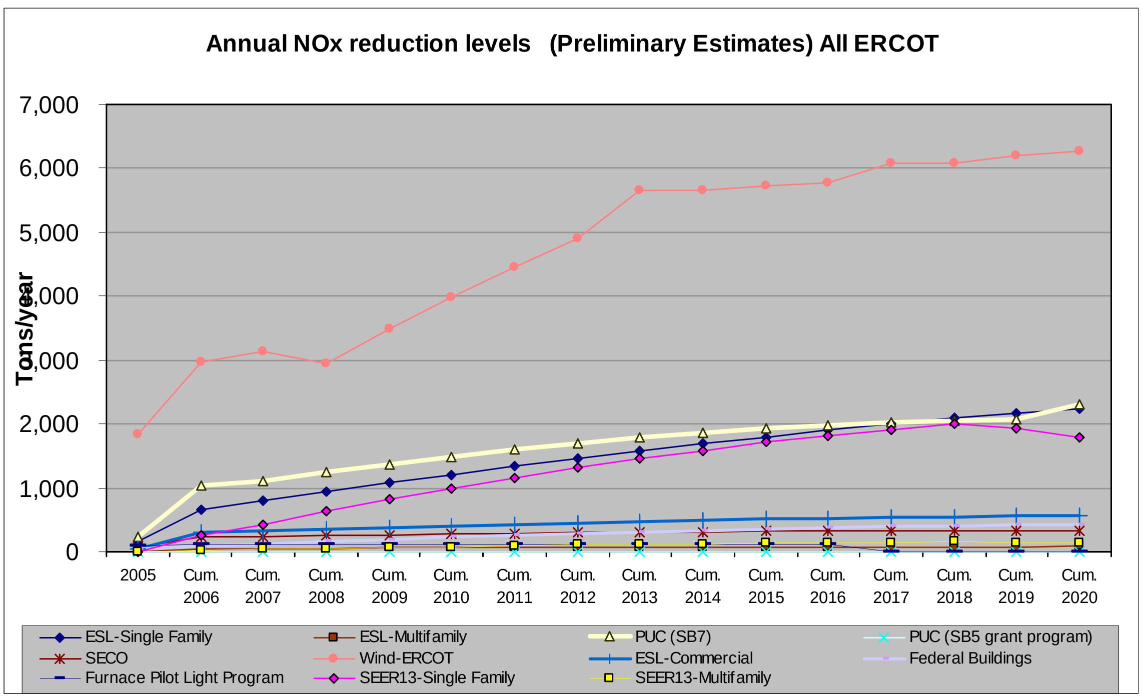
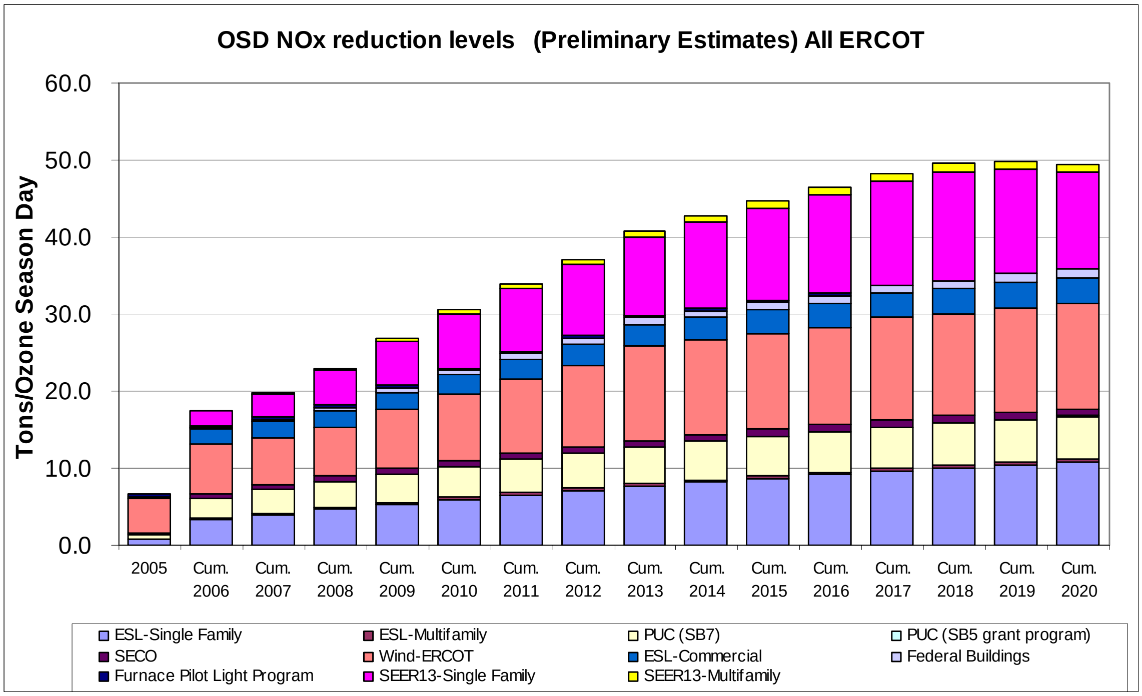


Figure 5-3: 2006 TCEQ Integrated NOx Emissions Savings: Cumulative Annual (Tons/yr) savings from EE/RE programs in Texas (2006 – 2020).



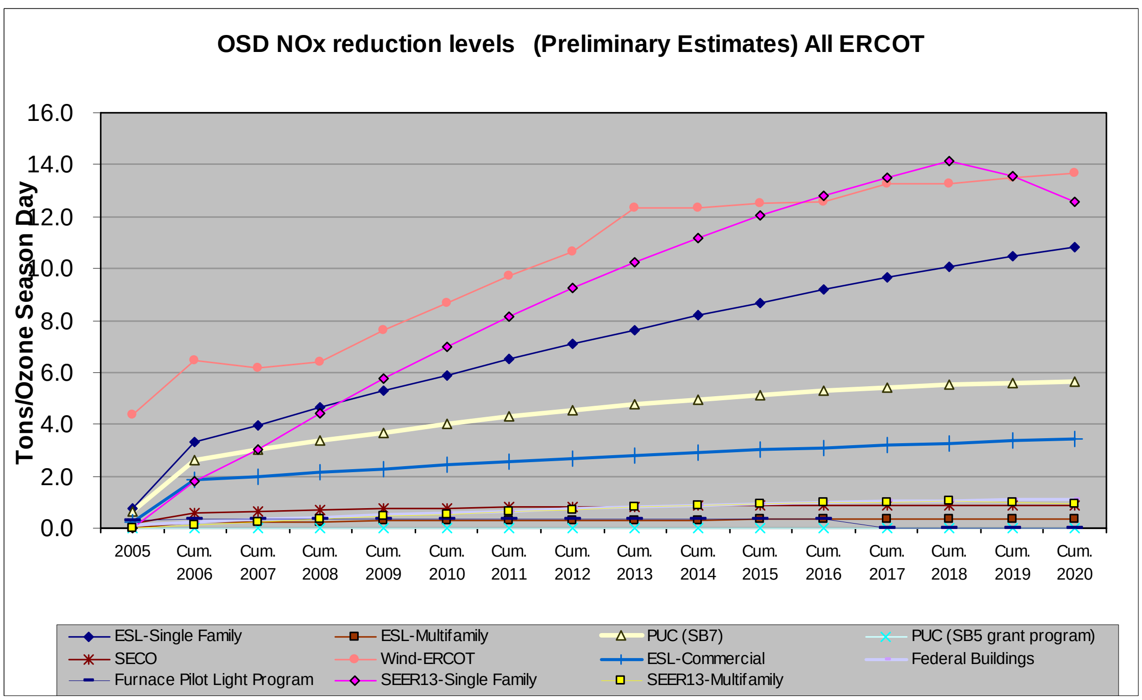


Figure 5-4: 2006 TCEQ Integrated NOx Emissions Savings: Cumulative OSD (Tons/day) savings from EE/RE programs in Texas (2006 – 2020).

6 PREDICTION OF ON-SITE WIND SPEED USING ARTIFICIAL NEURAL NETS

6.1 Introduction

Electricity produced by wind farms in Texas reduces the emission of air pollutants which would otherwise have been produced by burning fossil fuels to generate the same electricity. As more wind farms are commissioned (and some turbines decommissioned), proper accounting of pollution credits for wind energy requires normalization of the generation to a standard year, because year-to-year variations from the long term mean are significant.

In a Swedish study by Krieg reported in Giebel (2001) the variation was over 20% even for 5-year averages. In Texas, the year 1999 has been chosen by EPA as one of the standard reference years for air quality assessment purposes. In particular, the period from July 15 to September 15 has been designated as the ozone season period. We, therefore, need to determine what the performance of a wind turbine or a wind farm would have been in the reference year. Furthermore, an operating wind farm may not produce/transmit all the power it can generate due to transmission constraints or maintenance/repair shutdowns. Therefore, there is also concern about possible degradation in the performance of an operating wind farm. These questions can be addressed with a model of wind farm power that is reconciled with actual operational data.

In this section, we first discuss extrapolation to a reference year using an advanced Artificial Neural Network (ANN) model. Such a model is needed since we cannot expect to have wind data at the site of the turbine/farm for the reference year. In fact, even for an operating wind farm, contiguous wind data may not be available on a long-term basis. Furthermore, the available site wind data may not be representative of the height of the turbines nor of the location of any individual turbine in a farm and therefore cannot be used directly to determine the power output using turbine manufacturer's data. On the other hand, the National Weather Service, a part of the National Oceanic and Atmospheric Administration (NOAA), has a network of weather stations which 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, the main question addressed in this chapter is the following: is it possible to use available hourly NOAA data, hourly site wind data, and hourly power generation data for a period of a few months bracketing the ozone season for any given year to develop an hourly model relating power generation to site wind, and site wind to NOAA data. If so, we can extrapolate the hourly wind farm performance to the ozone season of the reference year. A secondary question addressed is: how to account for non-utilization of available wind power due to transmission constraints. Actually, two data sets are analyzed: one for a single-wind turbine in Randall County, and a second set for Indian Mesa I wind farm in Pecos County.

6.2 Single Turbine Analysis, Randall County.

In this section, we consider the problem of predicting the hourly site wind from NOAA data for a nearby weather station and then applying the predicted hourly site wind for estimating power generated by a single wind turbine. Specifically, we consider a turbine with a 44-ft rotor diameter installed in the Southern Great Plains at the USDA Conservation and Production Research Laboratory in 1982 in Randall County, Texas. The NOAA weather station is located at the Amarillo Rick Husband International Airport (AMA) located in an adjacent county.

To accomplish this analysis, hourly data for the period September 30, 2001 to September 29, 2002 were acquired from the wind turbine site as well as from the Amarillo NOAA weather site. After processing the data through proper filters, a total of 3981 rows of hourly data (out of a possible 8760 rows) were available for use. A plot of the power output from the turbine vs. site wind speed measured at a height of 10 meters is shown in Figure 6-1. A certain scatter is expected because the hourly average wind speed weights all readings during the hour equally. Strictly speaking, a large number of readings within an hour should be used with a weight proportional to the power output as determined by the manufacturer's data.

Furthermore, at low speeds, the turbine starts from rest when the wind speed exceeds the cut-in speed and shuts down when the wind speed falls below the cut-off speed, the cut-off speed being less than the cut-in speed. While it is possible to accommodate this feature approximately in the hourly data, for the purposes of this study, this feature is neglected.

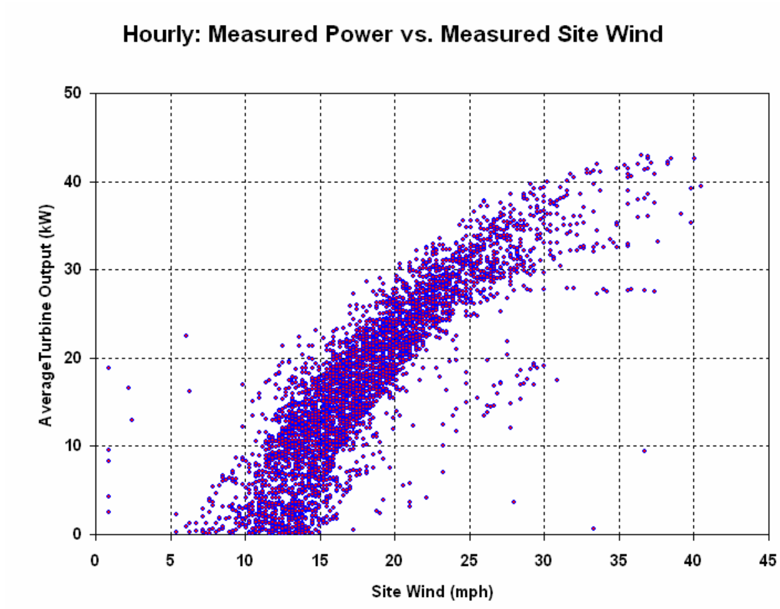


Figure 6-1: Hourly Output of the Turbine vs. Average Hourly Wind Speed Measured at the Site.

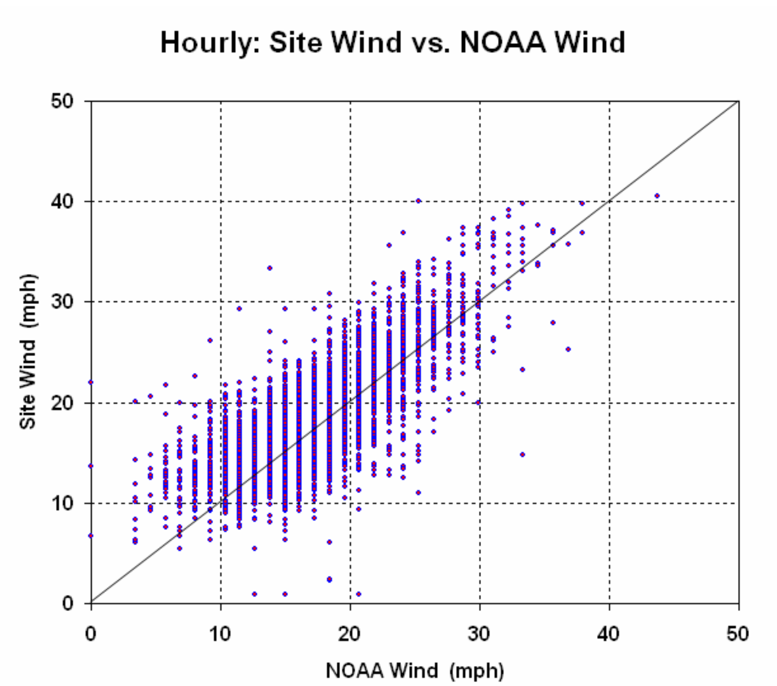


Figure 6-2: Site Wind Measured at the Site vs. the Wind Speed Measured at the Nearest NOAA Weather Station.

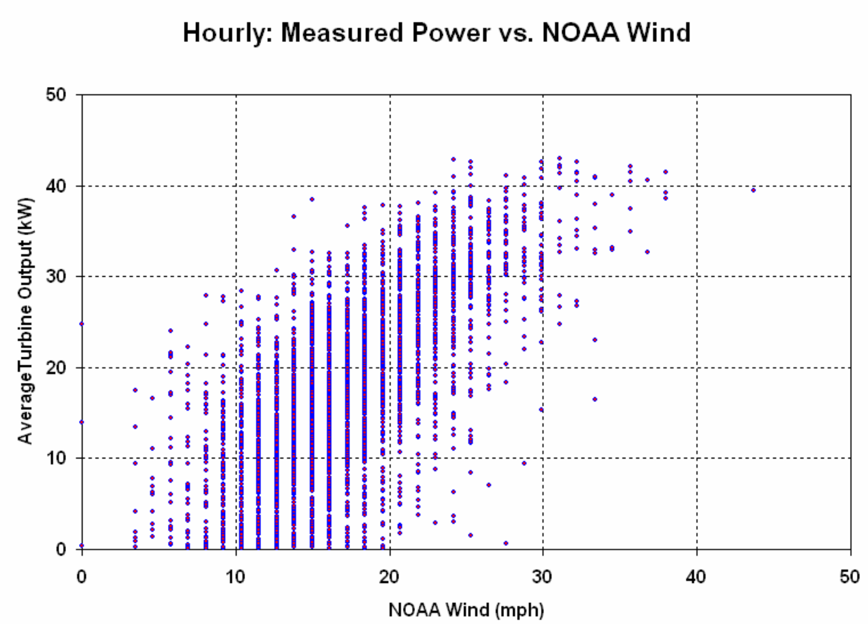


Figure 6-3: Measured Power vs. the Wind Speed Measured at the Nearest NOAA Weather Site.

Wind speeds measured at the site are compared against the NOAA weather station data in Figure 6-2. NOAA wind speeds are reported in integer values of knots, hence, the “rows” in the data. Unfortunately, for a given value of hourly NOAA wind speed, the hourly site wind speed varies significantly. Figure 6-3 shows the turbine output versus NOAA wind speed. Again, the variability is evident. It is clear that the site wind depends on other factors in addition to NOAA wind. In this analysis, a model that takes into account these other factors is desired.

There are a number of factors that are contributing to the scatter shown. The largest wind velocity gradients are near the ground over a region that is roughly 10% of the total atmospheric boundary layer. The thickness of this boundary layer varies considerably depending on the atmospheric conditions. At a wind speed of 8 m/s, typical night-time thickness in mid-latitudes is about 300 m. In addition, NOAA wind measurements are made at a height of 10 meters at a location possibly tens of miles away. Furthermore, typical wind turbines are driven by winds at a height considerably higher than the 10 meters at which NOAA wind speed is measured. Finally, wind farms sites are chosen to have high winds, often located on ridges. Although it is possible to construct a “first principles” model with terrain parameters driven by NOAA data from one or more nearby weather stations to determine the wind turbine site wind as a function of NOAA weather data. Such an effort would require considerable resources, and would result in a functional relationship that is complex.

Therefore, instead of such a “first principles” model, we propose the construction of a statistical empirical model. Artificial Neural Nets (ANN) are well suited for developing such a model. To develop an ANN model, one needs a period for which we have data on the dependent variable – site wind – and independent variables. Site wind speed is a function of other variables in addition to the NOAA wind speed and includes wind direction and past or future values of NOAA variables. For our purposes, we shall use, as independent variables, NOAA variables with the same time stamp: wind speed, wind direction, dry bulb and dew point temperatures. The wind direction is intended to account for terrain effects, and humidity is intended to account for clouds which affect wind. The temperatures are intended to take into account weather fronts.

An important consideration in using neural nets is the determination of its architecture. When multiple inputs are presented, it is possible that an input is largely irrelevant or redundant; if so, it can be dropped without significantly affecting the resulting fit. The number of nodes in the hidden layer is another parameter that needs to be determined. Automatic routines can perform this function through a search process resulting in the most effective ANN architecture.

An analysis of the data determined that using the NOAA wind speed and direction, dry and wet bulb temperatures, with a multilayer perceptron with a hidden layer of 6 nodes, as shown in Figure 6-4, was the most effective ANN for use. To analyze the accuracy of the model, the data set was divided into three random groups: one "training set" to train the network, one "verification set" to compare the goodness of fit between the training and verification sets, and one "test set" to determine the goodness of predictions. A fit that is good in training set and much worse in the verification set indicates over learning i.e., learning idiosyncrasies of the data rather than true features. The resulting neural net output of the site wind speed was then plotted against the measured site wind speed in Figure 6-5. The RMS error in all three sets was about 1.4 meters/sec.

A plot of the measured power versus ANN-predicted wind is shown in Figure 6-6. It is clear that the ANN approach results in a significant improvement over simply using the NOAA wind. Statistical measures of this improvement can be determined. These will be presented in the more interesting case of wind farms in the next section.

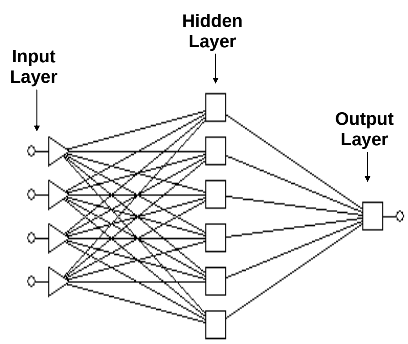


Figure 6-4: Multilayer Perceptron Neural Net Architecture for Relating Site Wind (Output) to (Input) Variables Measured at the NOAA Weather Site.

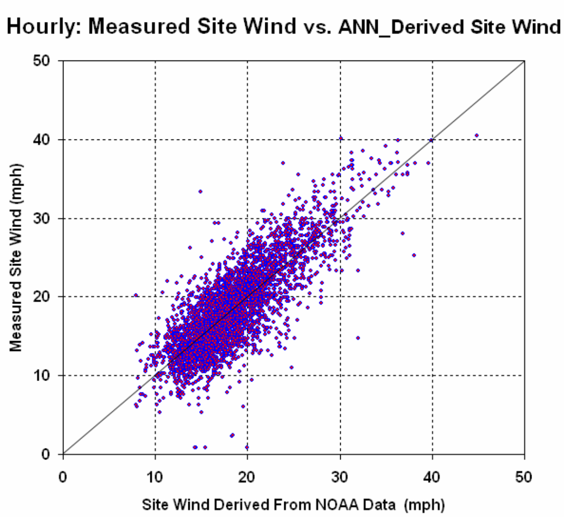


Figure 6-5: Measured Site Wind vs. ANN Derived Wind Speed from Data Measured at the Nearest NOAA Weather Site.

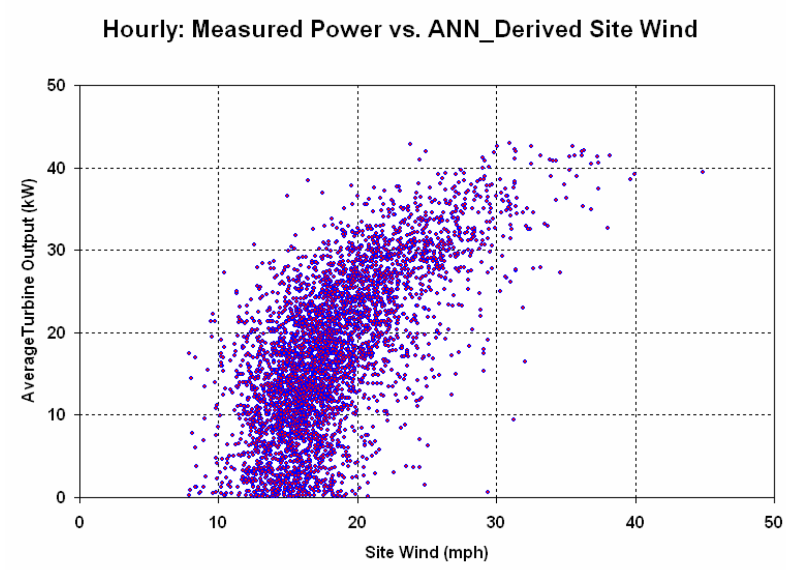


Figure 6-6: Measured Power vs. ANN-Derived Wind Speed.

6.3 Wind Farm Analysis, Pecos County.

Modelling the power output of an entire wind farm consisting of multiple turbines has all the complexity of a single turbine, and in addition, the wind may not be the same over the entire farm. In this section, we consider the problem of predicting the hourly wind at the wind farm from NOAA data for a nearby weather station and then applying the predicted hourly site wind for estimating power generated by the farm. Specifically, the wind farm is located at Indian Mesa in Pecos County, Texas, and the NOAA weather station is located at Fort Stockton. Hourly site wind speeds measured at a height of 75 ft., hourly power produced by the wind farm and hourly weather data from Fort Stockton NOAA site were used to develop this model. (Note that the NOAA wind speed is measured at a standard height of 10 meters or about 33 ft.).

Hourly data from July 1, 2002 to Jan 31, 2003 were available for this study. After processing the data through the appropriate filters[8], 4,543 rows of data (out of 6,450 rows) were usable. Figure 6-7 shows the measured output of the wind farm versus site-measured wind speed. Figure 6-8 shows wind speeds measured at the site and at the NOAA weather station. NOAA wind speeds are reported in integer values of knots; Figure 6-9 shows the wind farm power output versus NOAA wind speed. Again, we can see that the NOAA wind speed does not directly provide an adequate representation of site wind speed.

[8] The major correction that needed to be applied to the Indian Mesa dataset involved the removal of bad data that occurred when there was an electrical meter failure. This was identified with the help of the staff at ERCOT.

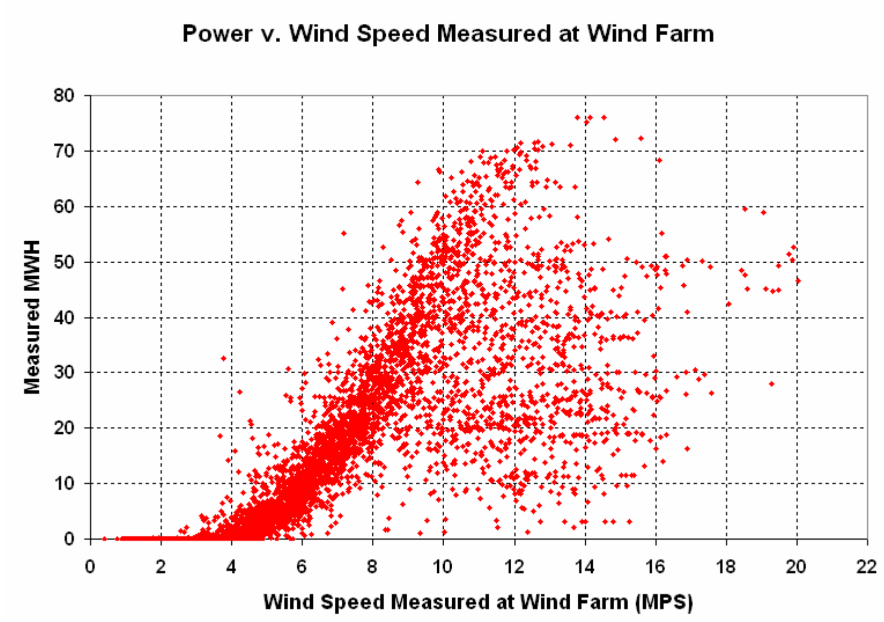


Figure 6-7: Measured Power vs. the Wind Speed Measured at the Wind Farm.

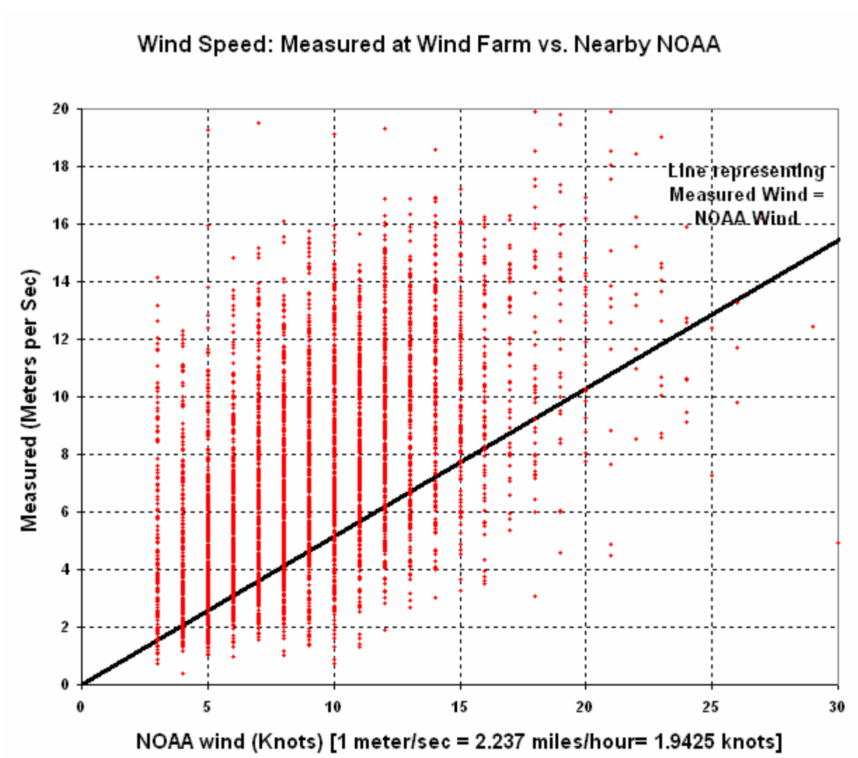


Figure 6-8: Measured Wind Speed at the Wind Farm vs. the Wind Speed Measured at the Nearest NOAA Weather Site.

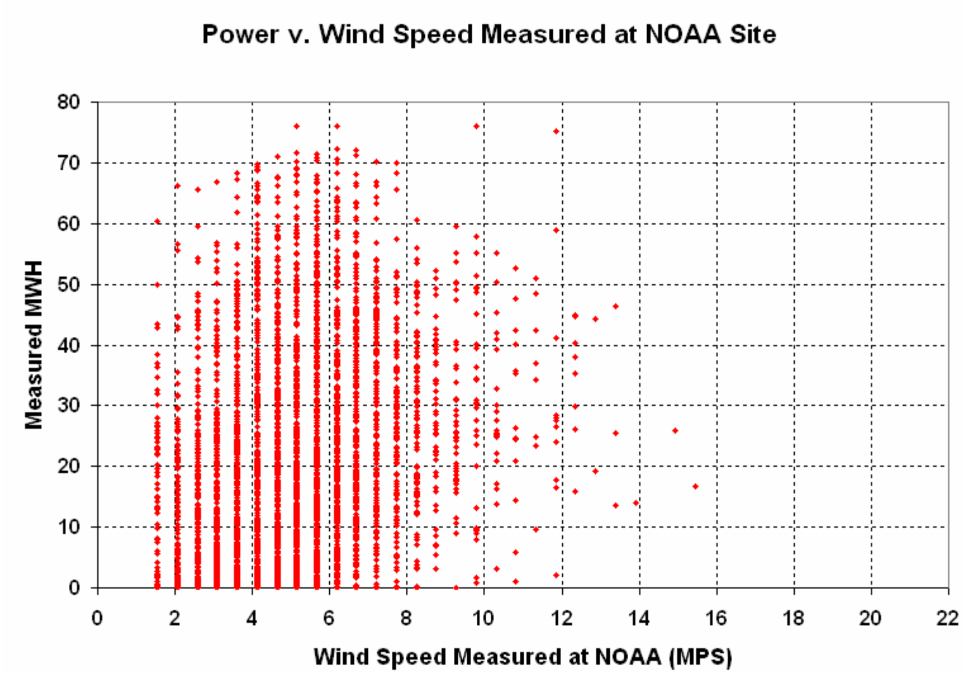


Figure 6-9: Measured Power vs. the Wind Speed Measured at the Nearest NOAA Weather Site.

As mentioned earlier, one of the objectives of this analysis was to determine the hourly site wind speed for periods (such as for the base year) for which hourly no site wind data are available, but only hourly NOAA data from the nearby weather station. As before, an artificial neural net approach was employed to accomplish the analysis. The most effective architecture was determined by a search process as shown in Figure 6-10. In this case, wind speed, wind direction, dry bulb temperature, and dew point temperature from the NOAA data were retained as the independent variables, and a hidden layer with six nodes was found to be optimal. As before, only a random sample of half the points was used to train the model and the remaining used to test the resulting model. Figure 6-11 shows measured hourly wind speeds versus neural net predicted hourly wind speeds. A visual inspection with Figure 6-8 shows the dramatic improvement in the ability to predict the on-site hourly wind speeds.

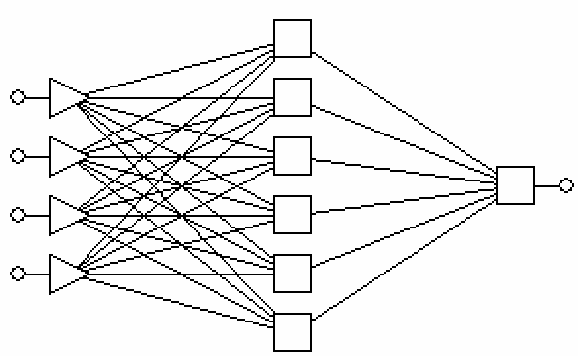


Figure 6-10: Multilayer Perceptron Artificial Neural Net Architecture for Relating Site Wind (Output) to (Input) Variables Measured at the NOAA Weather Site.

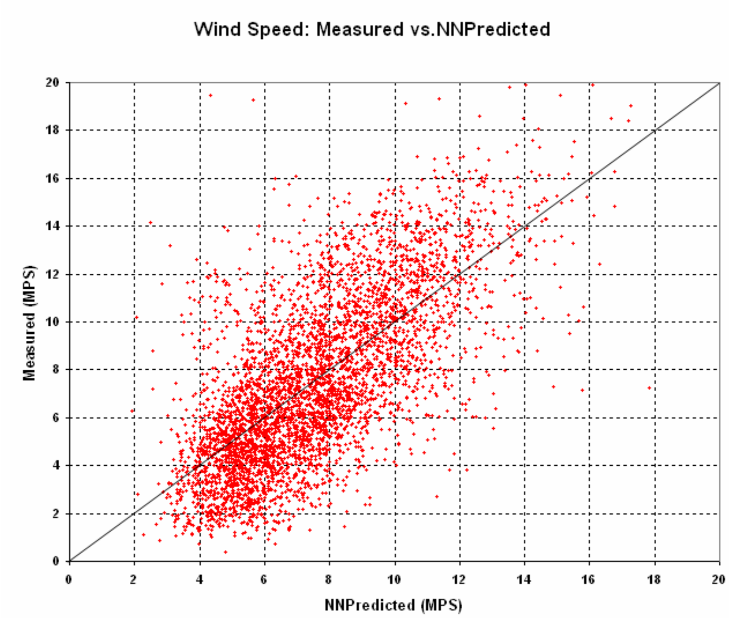


Figure 6-11: Wind Speed Measured at the Wind Farm vs. ANN-derived Wind Speed.

To further analyze the possible improvement due to the neural net approach, the neural net predicted wind speeds were grouped into bins of 1 meter/sec and the average values and the standard deviations of the corresponding measured wind speeds in each bin are plotted in Figure 6-12. As shown, the average wind speed is well predicted in the regions of most common wind speeds. Figure 6-13 shows the total wind energy produced by the farm during the data period in each 1 meter per second bin, using measured hourly wind speed, hourly NOAA wind speed and the neural net predicted hourly wind speed. Substantial improvements from the ANN approach can be seen in Figure 6-13. Figure 6-14 shows MWH "lost" to (full or partial) shutdowns – due to transmission constraints, maintenance, or repair – defined as reduction below average of power output as a function of wind speed. Reductions exceeding 1.5 standard deviations from the average output are attributed to curtailment. Although the neural net underestimates curtailment by about 50%, it provides a useful framework for addressing curtailment, using a strictly empirical method.

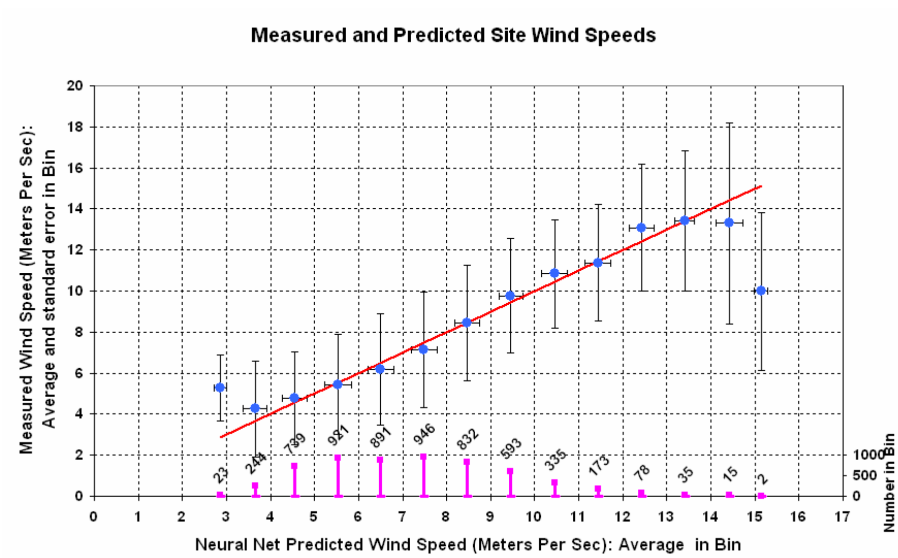


Figure 6-12: Measured and ANN-Predicted Wind Speeds.

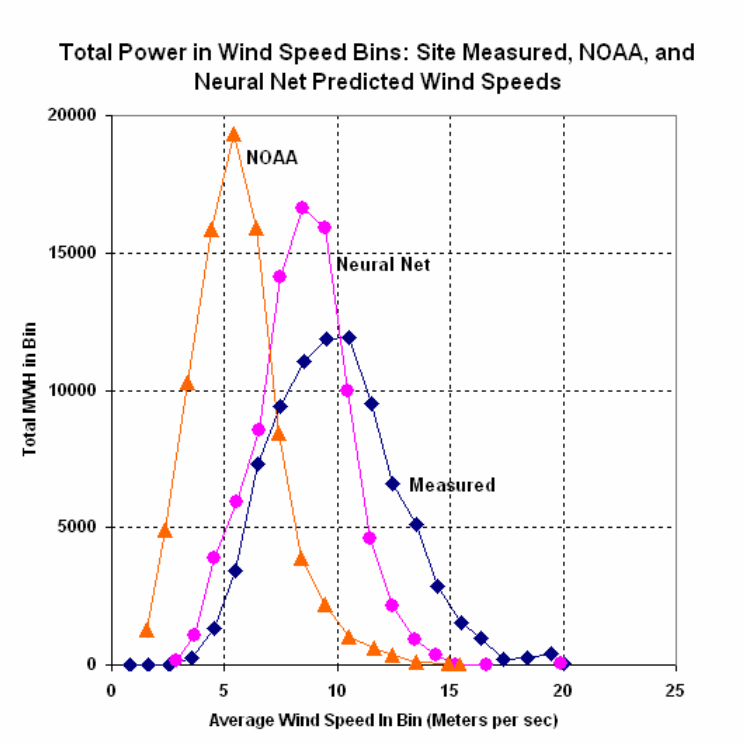


Figure 6-13: Measured Total Power in Wind Speed Bins.

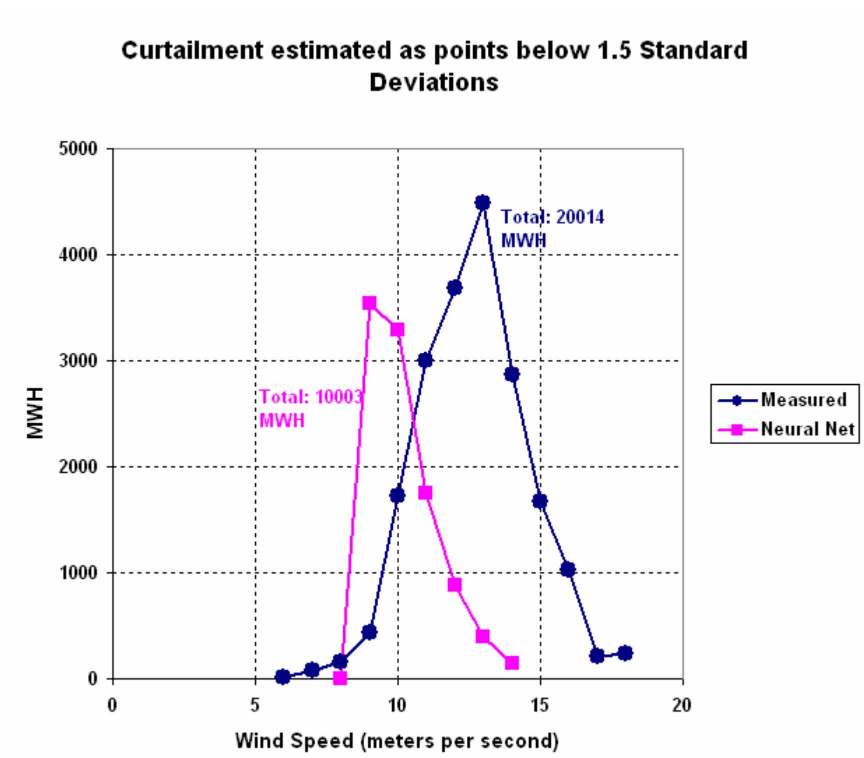


Figure 6-14: MWH “Lost” to (Full or Partial) Shutdowns.

6.4 Discussion

We have shown how to determine site wind using weather data from a nearby NOAA station. Explicit use of this approach to normalize emissions credit under standard reference conditions is planned for the near future. So far, to determine the site wind at time t, we have used NOAA weather data at time t. It is possible to use earlier or later values, also, depending on the wind direction. It is also desirable to use NOAA data from multiple nearby weather stations. In addition, we can group the data into quadrants depending on the wind direction, and use current, earlier or later NOAA wind speeds depending on the quadrant. It is also possible to use detailed meteorological models to determine hourly site wind from hourly NOAA weather data from multiple sites, and then calibrate the resulting site wind using short-term site wind measurements. These interesting approaches will be studied in the future.

6.5 Conclusions

To properly account for emissions credit for a wind farm, it is necessary to normalize power production to standard reference conditions, such as a base year. This requires accurately predicting the power produced during a base year for which site wind data are unavailable, and NOx emissions are measured for power plants. Using data from periods for which both site wind data and NOAA weather data from nearby weather stations are available, we developed an artificial neural net based model that relates site wind to NOAA weather data. This model substantially improves the use of daily NOAA wind as the wind data for regression for a site. The resulting ANN model can be used to normalize for power production to the base year. The use of the ANN model also provides a framework for addressing power lost due to transmission constraints, maintenance and repair, and can be used to more carefully study any degradation in the performance of the wind farm.

7 IMPROVEMENT OF DAILY MODEL USING ANN-DERIVED WIND SPEED

As presented in the previous section, the ANN model substantially improves on-site wind data predictions using NOAA data as a measure of the site wind. In this section the Indian Mesa wind farm was used again as an example to show that using ANN-derived, on-site wind speed in the daily regression model can provide more accurate prediction on monthly and Ozone Season Period (OSP) power generation. If this procedure could be used across all the wind farms in the ERCOT region, it is felt that substantial improvements could be made to reduce the uncertainty of the predictions of the power produced in the base year and, therefore, the reduce the NOx emissions from electricity derived from wind energy.

The procedure developed to compare the ANN daily model using ANN-derived on-site wind and the NOAA daily model using NOAA wind includes three steps illustrated in Figure 7-1.

<u>Step 1: Development and testing of ANN model for predicting on-site hourly wind speed.</u>

(1) Develop and test the ANN model using on-site and NOAA hourly wind speed, wind direction, dry bulb, and wet bulb temperature for a same period for a site.
(2) Convert the hourly ANN on-site wind and power output data to daily data and develop the ANN daily regression model and compare it against NOAA daily model for the same period.

<u>Step 2: Testing of the ANN derived on-site wind speed by comparing the performance of the 2005 ANN daily model against the 2005 NOAA daily model.</u>

(1) Apply the ANN model to the 2005 NOAA hourly wind speed for this site to derive the 2005 ANN hourly on-site wind speed.
(2) Convert the hourly ANN on-site wind and power output to daily data and develop the 2005 daily regression model using the measured 2005 daily power production and the ANN daily on-site wind.

<u>Step 3: Application of the ANN daily regression model for predicting the base year wind power output.</u>

(1) Apply the ANN model to the 1999 NOAA hourly wind speed for this site to derive the 1999 ANN hourly on-site wind speed.

(2) Convert the 1999 hourly ANN on-site wind to daily wind and apply the coefficients of the ANN daily regression model to the 1999 average daily wind speed to predict the power production in the 1999 and 1999 OSP periods.

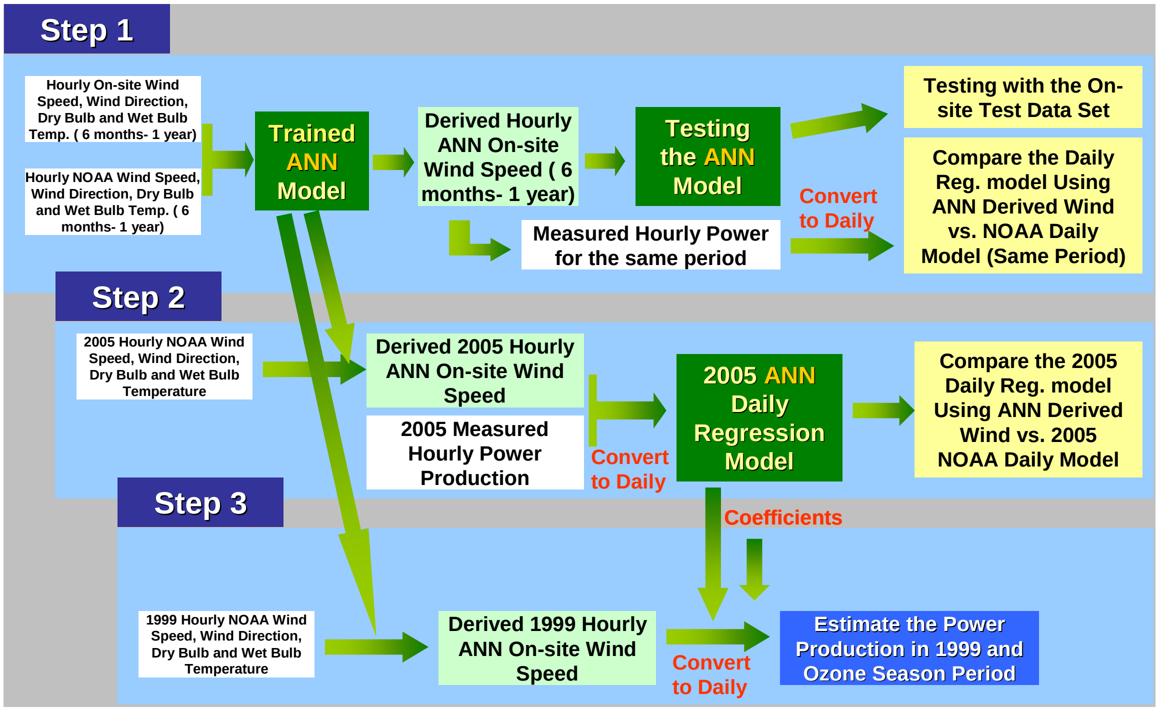


Figure 7-1: Flow Chart for the Comparison Procedure.

7.1 ANN-Derived Hourly On-site Wind Speed (2002-2003)

As shown in Figure 7-2 and Figure 7-3, the neural net predicted wind speeds during the period July 2002 to January 2003 provide an improved representation of the on-site wind speed when compared to the wind speed measured at the nearest NOAA weather station at Fort Stockton. Figure 7-4 shows the power production plotted against the NOAA wind speed (lower left plot), the measured on-site wind speed (upper plot), and the ANN-derived on-site wind speed (lower right plot). Also shown in Figure 7-4 is the manufacturer's power production curve and confidence bands (i.e., ± 5 MW).

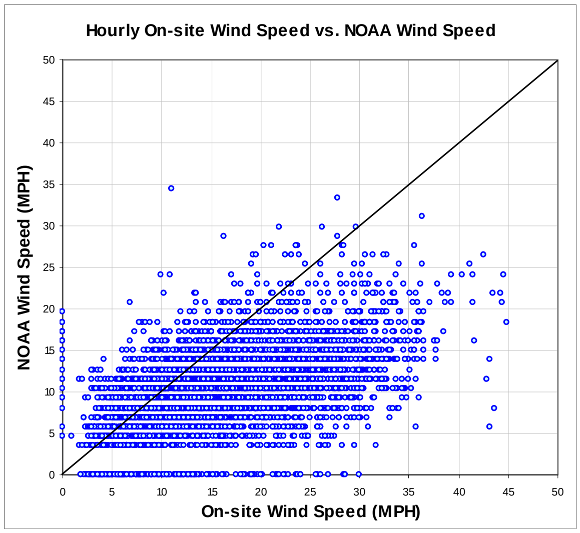


Figure 7-2: Measured Hourly On-site Wind Speed Compared Against Hourly NOAA Wind Speed (2002-2003).

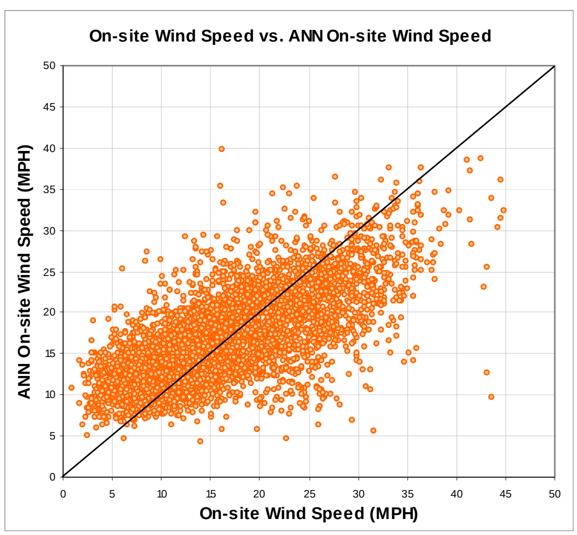
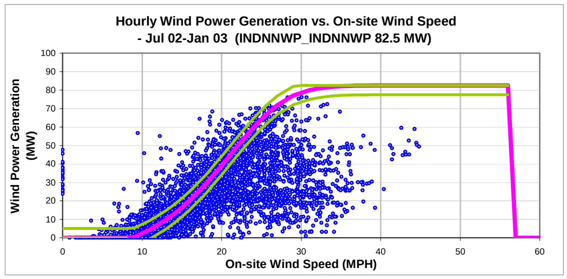
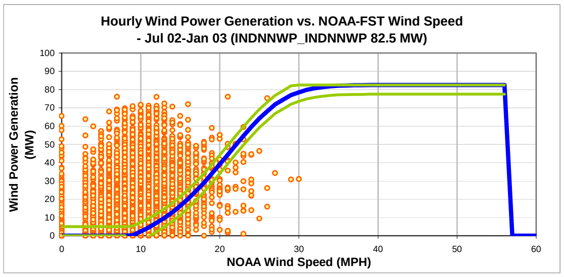


Figure 7-3: Measured Hourly On-site Wind Speed Compared Against ANN-Derived On-site Hourly Wind Speed (2002-2003).





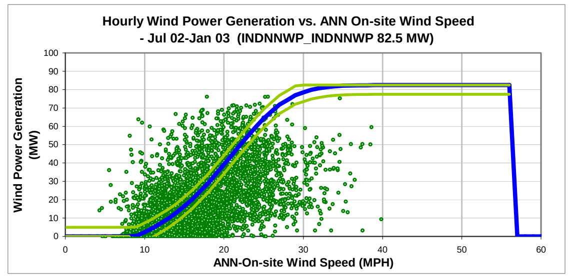


Figure 7-4: Measured Hourly Power Production Plotted with Hourly On-site, NOAA and ANN-Derived On-site Wind Speed (2002-2003).

In Figure 7-5, 3D colored, surface plots for NOAA wind speed (upper), on-site wind speed (second plot), ANN-derived on-site wind speed (third plot), and power production (lower plot) are shown for the period July 2002 to January 2003. These plots show the day-of-the-year on the x-axis and the hour of the day on the y-axis. Hourly wind speed and power for the period is shown as a difference in color. In these plots, the NOAA wind speed is significantly lower than the measured on-site wind. In addition, the on-site and ANN data show more wind in the summer period (July through September), and they show more wind during the evening period for this site. With the exception of the missing data, the plots show that the ANN-derived on-site data is more representative of the diurnal and seasonal characteristics than the NOAA data for the same period. The last plot in Figure 7-5 shows the measured power production during this period. It is expected that the power production map to be very similar to the on-site wind speed map because the measured hourly intensity for power is correlated to that of the wind speed based on the operating characteristics of the wind farm. What was actually observed is that the intensity of the power production map is lower than the measured on-site wind speed map for many of the peak hours. This most likely is indicating significant curtailment or maintenance at this site.

Figure 7-6 shows a 3D colored, surface plots that displays the difference between the measured power and the predicted power using a power curve and NOAA wind speed (upper plot), or on-site wind speed (lower plot), or ANN-derived on-site wind speed (lower plot). Red and dark brown colors on these plots indicate that the difference is within 5 MW. The green colors indicate a large overestimation (i.e., the curtailment or maintenance). Blue colors indicate a large underestimation of power production. These plots show large areas where the hourly NOAA data underestimate the power production. Whereas, on-site and ANN-derived wind speeds do a similar job of predicting the same power output as the measured power. In addition, as expected, the on-site wind speeds somewhat outperform the ANN-derived wind speeds.

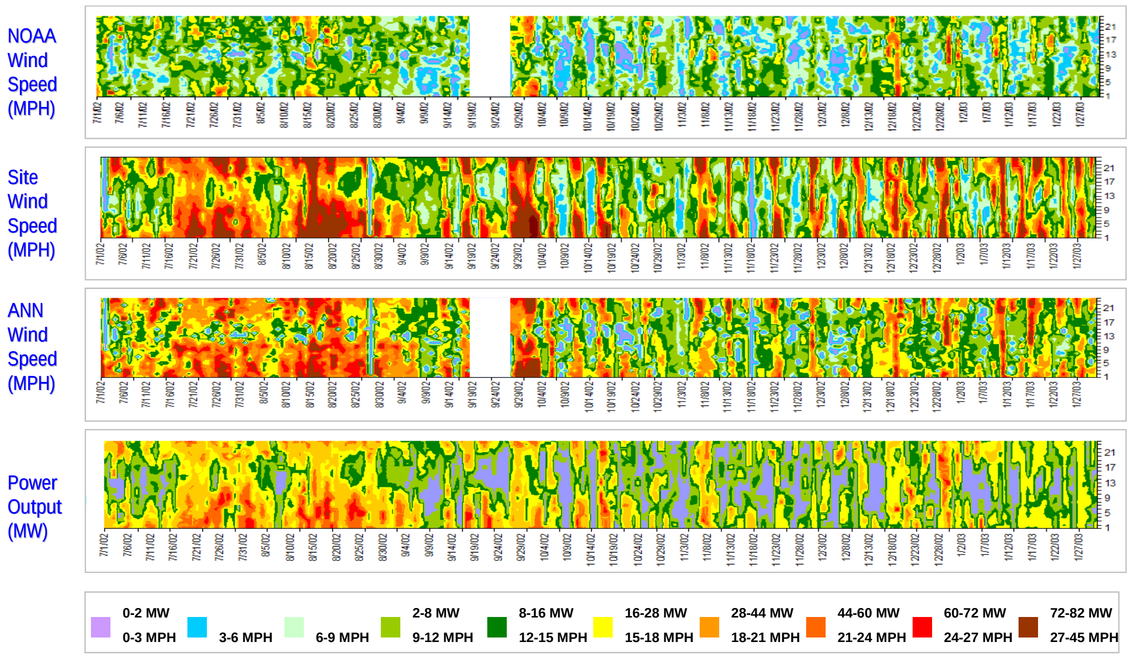


Figure 7-5: Surface Plots for Hourly NOAA (upper), On-site (middle), ANN-derived On-site Wind Speed, and Power Production (2002-2003).

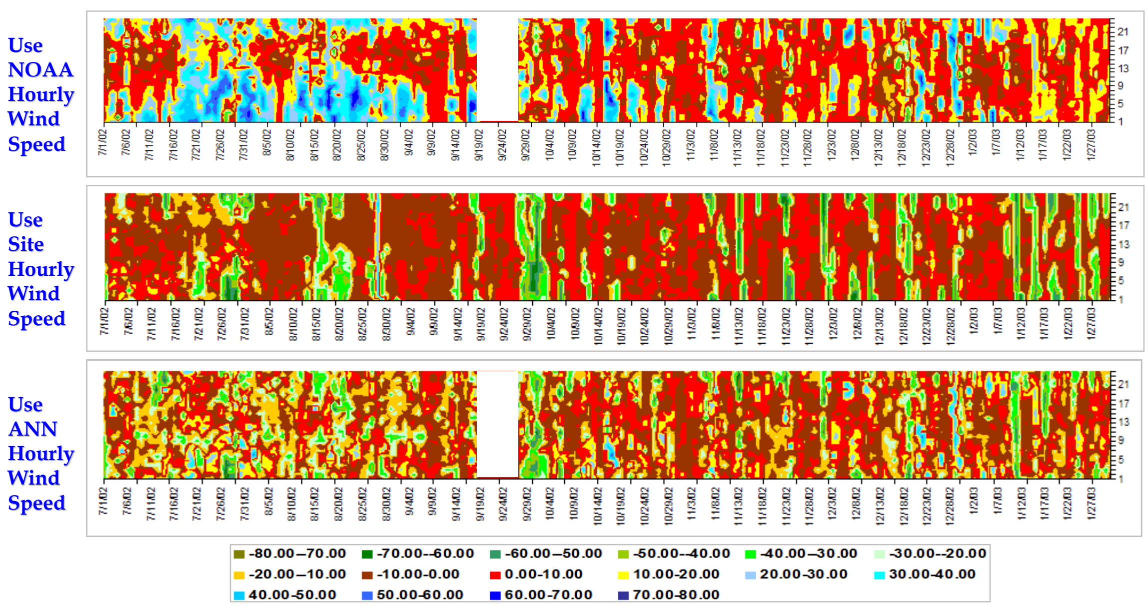


Figure 7-6: Surface Plots for Difference Between the Hourly Measured Power and the Predicted Power Using Power Curve and Hourly NOAA (upper), On-site (middle), ANN-derived On-site Wind Speed (lower) (2002-2003).

7.2 ANN Daily Regression Model (2002-2003)

To compare the daily models developed using daily average NOAA wind speed and ANN-derived, on-site wind speed for the period July 2002 to January 2003, first the hourly wind speed data were summed to daily and plotted against measured on-site wind speed as shown in Figure 7-7 and Figure 7-8. Next, change-point linear regression models using the ASHRAE Inverse Model Toolkit[9] (IMT) were developed using both NOAA wind speed and derived on-site wind speed as shown in Figure 7-9 and Figure 7-10. The summary of model coefficients is provided in Table 7-1. A closer inspection of Table 7-1 reveals that the slopes for the two models are very similar; however, the offsets vary significantly.

It is concluded that the ANN model improves the prediction during lower wind speeds for this site due to the shift of offset from 3.9 MPH to 9.2 MPH. As a result, the monthly errors and errors during the Ozone Season Period from the ANN daily model decreased significantly compared to the NOAA daily model (Figure 7-11). The comparison between the predicted monthly capacity factors and measured monthly capacity factors also show that the ANN daily model provides a better prediction on monthly capacity factors (Figure 7-12).

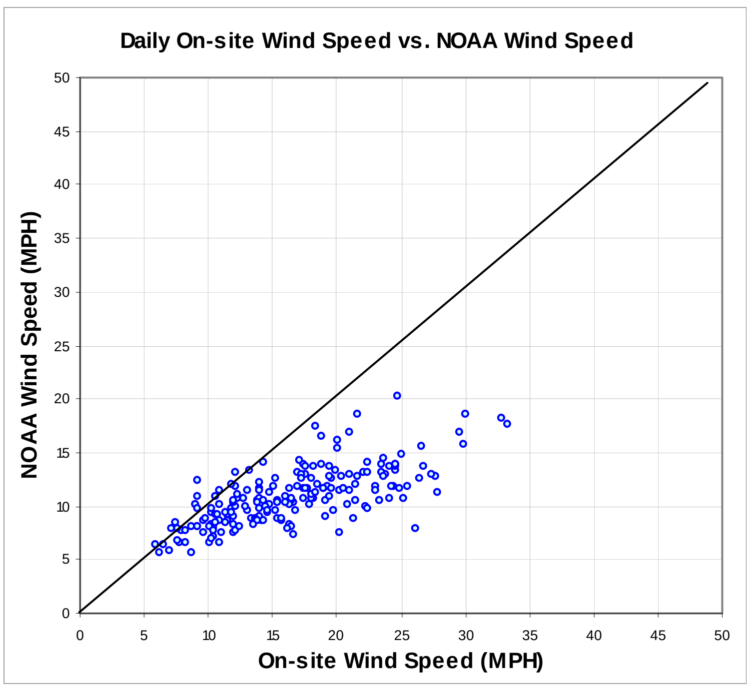


Figure 7-7: Comparison of Measured Daily On-site and NOAA Wind Speed.

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[9] For more information on the ASHRAE IMT toolkit, see: 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, Pt. 2, pp. 425-434; and Haberl, J., Claridge, D., Kissock, K. 2003. "Inverse Model Toolkit (1050RP): Application and Testing, *ASHRAE Transactions-Research,* Vol. 109, Pt. 2, pp. 435-448.

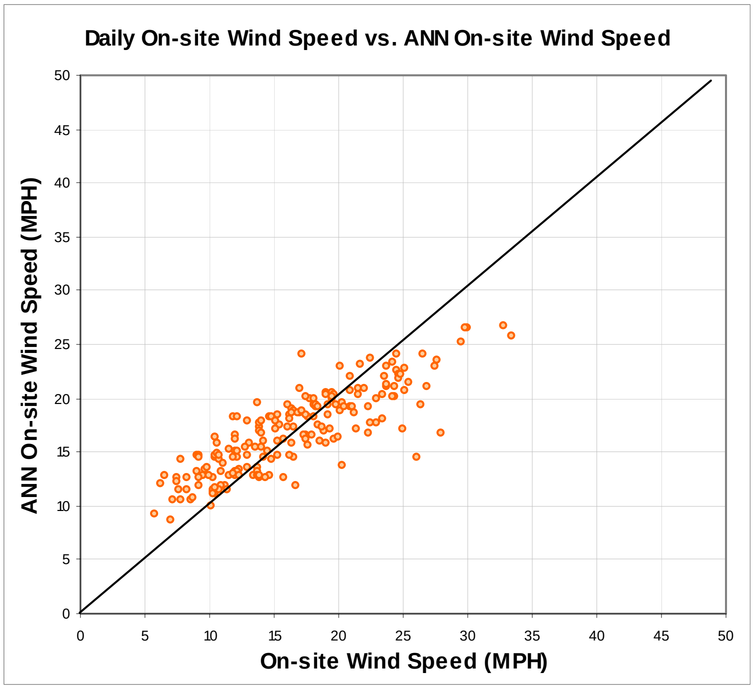


Figure 7-8: Comparison of Measured Daily On-site and ANN-derived On-site Wind Speed.

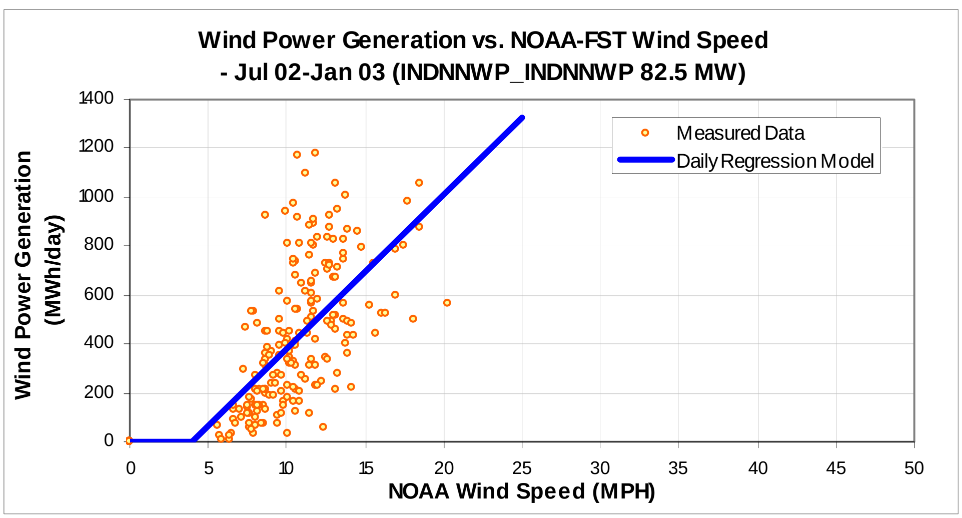


Figure 7-9: Average Daily Wind Power Production Plotted Against NOAA Average Daily Wind Speed (2002-2003).

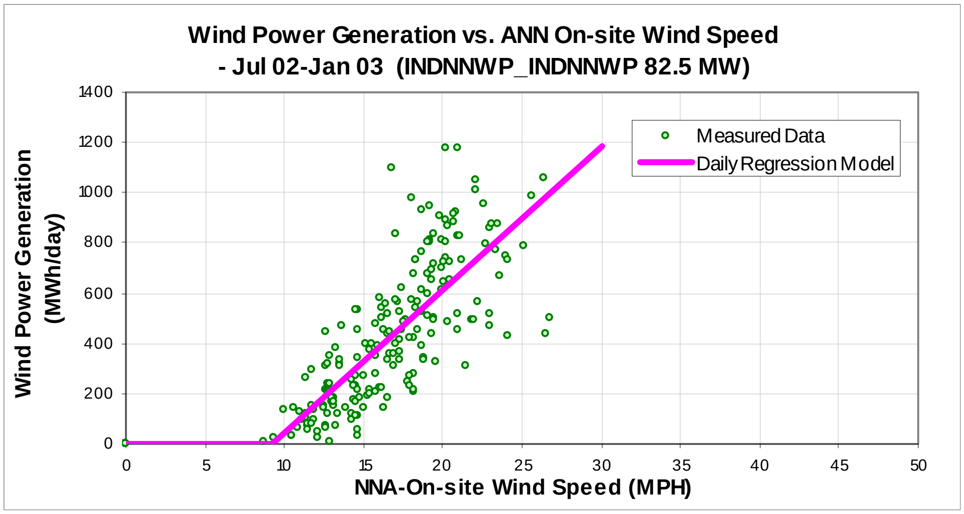


Figure 7-10: Average Daily Wind Power Production Plotted Against ANN-derived On-site Average Daily Wind Speed (2002-2003).

Table 7-1: Model Coefficients (2002-2003)

IMT Coefficients	NOAA Daily Model	ANN Daily Model
Ycp (MWh/day)	-245.7633	-533.5283
Left Slope (MWh/mph-day)	62.9789	56.8717
RMSE (MWh/day)	227.2800	181.5342
R2	0.3598	0.5916
CV-RMSE	52.1%	41.6%

Table 7-2: Comparison of Predicted and Measured Power Production (2002-2003).

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh/Mo) NOAA	Predicted Power Generation Using Daily Model (MWh/mo) NOAA	Diff. NOAA	Average Daily Wind Speed (MPH) ANN-On-site	Measured Power Generation (MWh/Mo) ANN-On-site	Predicted Power Generation Using Daily Model (MWh/mo) ANN-On-site	Diff. ANN-On-site
Jul-02	30	11.47	17,821	14,302	19.75%	19.03	17,821	16,799	7.14%
Aug-02	30	12.25	20,996	15,766	24.91%	20.53	20,996	19,348	10.46%
Sep-02	21	10.11	8,793	8,212	6.61%	17.14	8,793	9,494	-8.53%
Oct-02	29	10.43	11,152	11,924	-6.92%	16.17	11,152	11,516	-3.05%
Nov-02	27	9.73	6,815	9,912	-45.45%	14.34	6,815	7,916	-11.11%
Dec-02	30	11.12	10,862	13,639	-25.56%	15.25	10,862	10,370	3.61%
Jan-03	30	10.33	9,468	12,152	-28.36%	15.34	9,468	10,495	-8.45%
Feb-03									
Mar-03									
Apr-03									
May-03									
Jun-03									
Total	197	10.83	85,907	85,907	0.00%	16.86	85,907	85,937	-0.03%
Total in OSP (07/15-09/15)	62	11.36	38,678	29,137	24.67%	19.20	38,678	35,296	11.61%

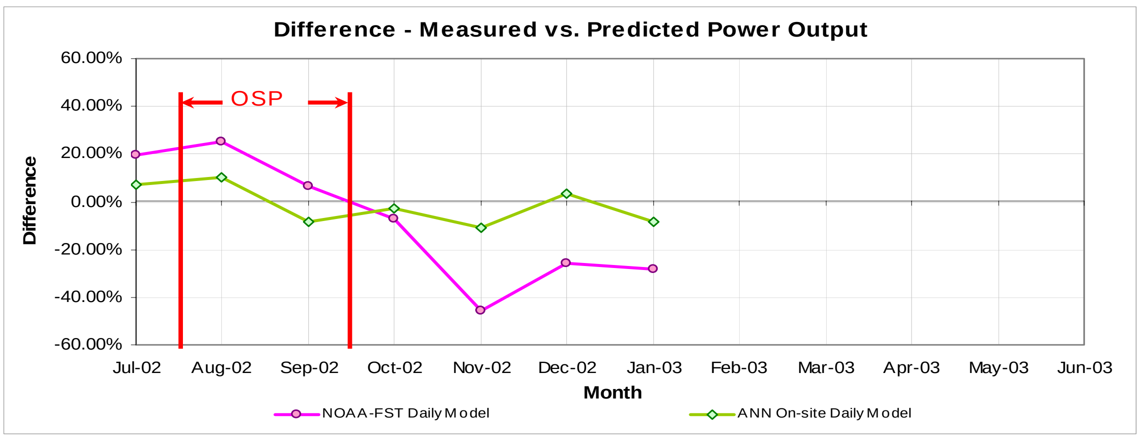


Figure 7-11: Comparison of Difference between Measured and Predicted Power Production Using NOAA Wind and ANN-derived Wind.

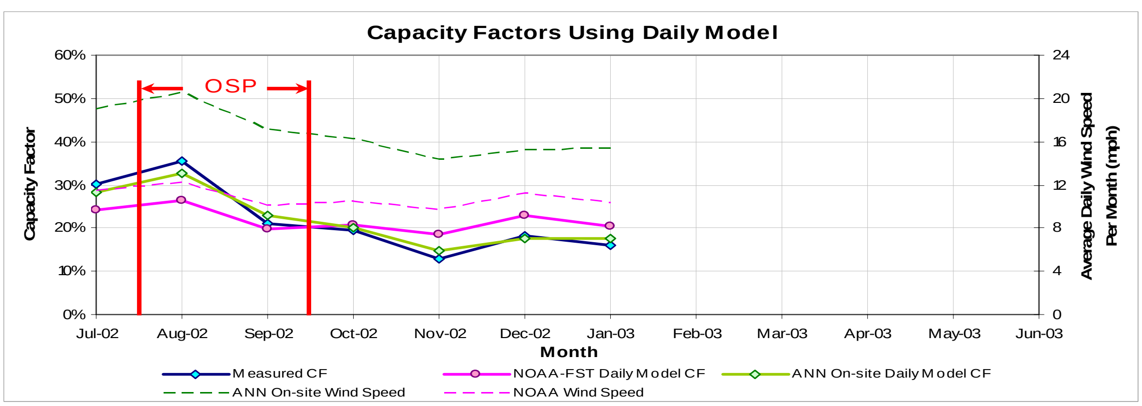


Figure 7-12: Measured Capacity Factors vs. Predicted Capacity Factors Using NOAA Wind and ANN-derived Wind.

7.3 ANN Daily Regression Model (2005)

To test the performance of the ANN model for predicting on-site hourly wind speed for other years, such as a base year, the developed ANN model was applied to the 2005 NOAA hourly weather data to predict the 2005 hourly on-site wind speed. Next, daily regression models were developed using both ANN-derived on-site wind and NOAA wind to compare the accuracy of the models.

The 2005 measured hourly power production at the Indian Mesa wind farm was first plotted against NOAA wind speed and ANN-derived wind speed as shown in Figure 7-13 and Figure 7-14, respectively. In Figure 7-15 and Figure 7-16, the hourly wind power production were summed to daily power production and then plotted against average daily NOAA wind speed and ANN-derived on-site wind speed, respectively. In Figure 7-15 and Figure 7-16, the corresponding change-point, linear regression models were shown super-imposed on the daily data for 2005 and the Ozone Season Period. The coefficients from the daily models are listed in Table 7-3.

A comparison of the data presented in these two figures indicates that the predicted daily power data are more evenly distributed around the predictions from the ANN daily regression model. Especially, the prediction for the lower wind speed range is significantly improved using the ANN daily regression model due to the shift in the offset from 4.1 MPH (NOAA) to 10.0 MPH (ANN). As a result, the calculated monthly difference between the measured and the predicted decreased substantially for the ANN daily regression model, as shown in Table 7-4 and Figure 7-17. The same conclusion was observed for the 2005 Ozone Season Period. Figure 7-18 shows the comparison of the measured monthly capacity factors and the predicted monthly capacity factors using NOAA daily regression model and ANN daily regression model. An inspection of this figure reveals that the ANN daily model provides more accurate prediction.

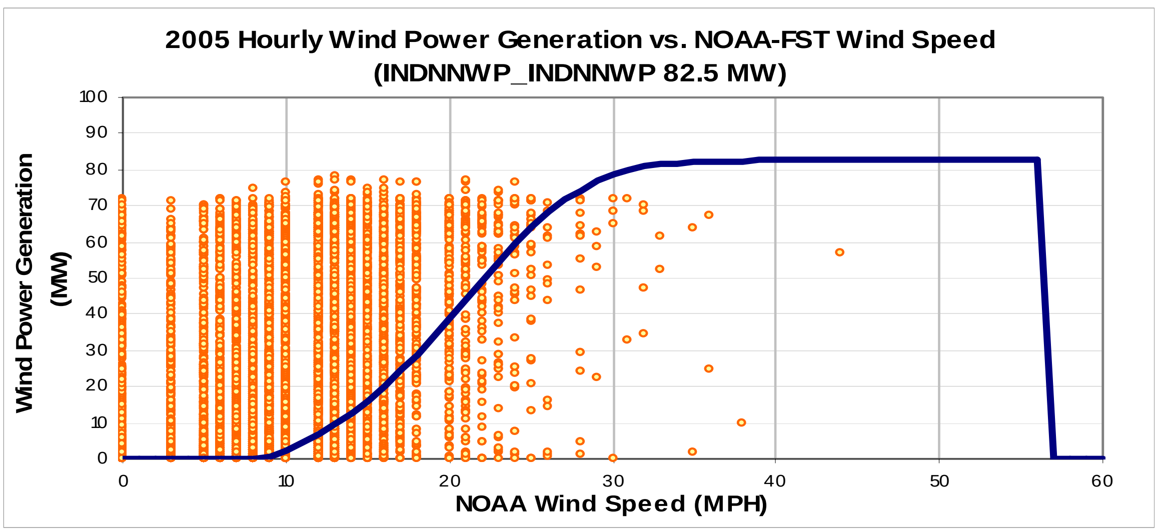


Figure 7-13: Measured Hourly Power Production Plotted with Hourly NOAA Wind Speed (2005).

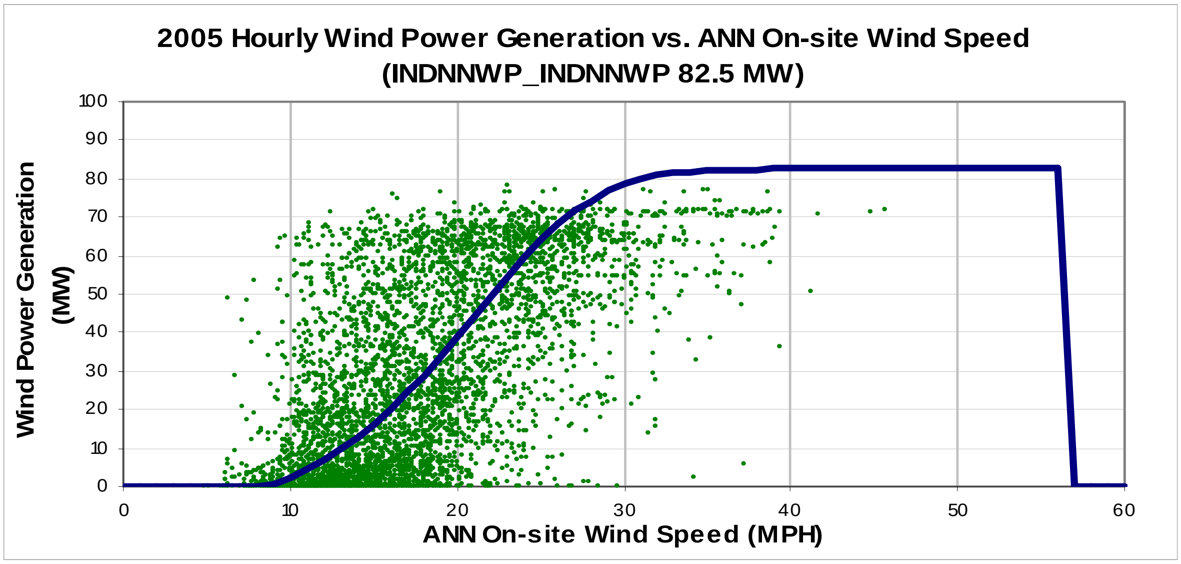


Figure 7-14: Measured Hourly Power Production Plotted with Hourly ANN-derived Wind Speed (2005).

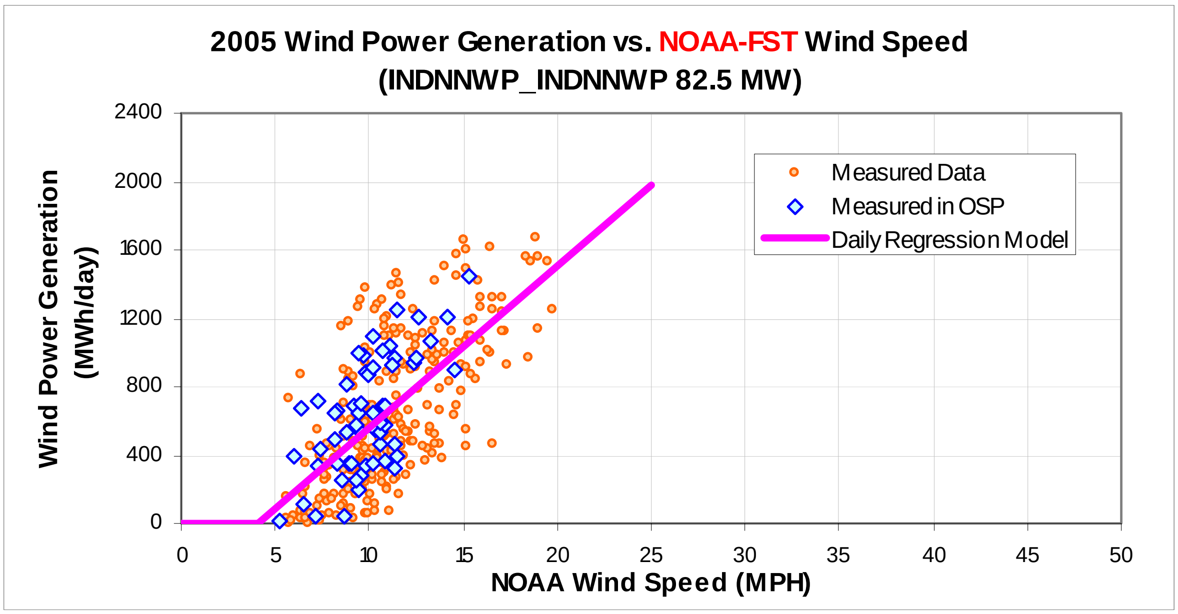


Figure 7-15: Average Daily Wind Power Production Plotted Against NOAA Average Daily Wind Speed (2005).

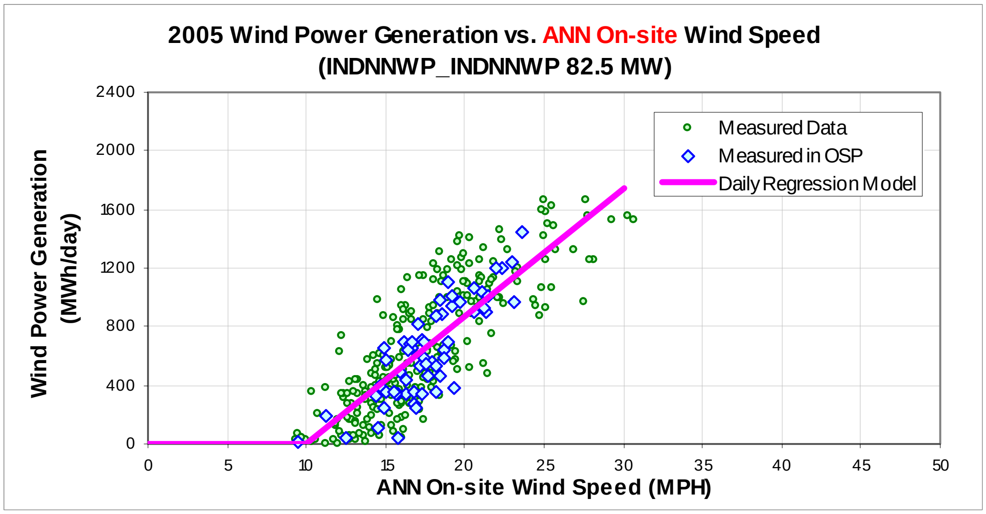


Figure 7-16: Average Daily Wind Power Production Plotted Against ANN-derived Average Daily Wind Speed (2005).

Table 7-3: Model Coefficients (2005).

IMT Coefficients	NOAA Daily Model	ANN Daily Model
Ycp (MWh/day)	-387.5741	-864.8626
Left Slope (MWh/mph-day)	94.8694	86.9193
RMSE (MWh/day)	307.6465	235.8795
R2	0.4487	0.6759
CV-RMSE	47.1%	36.1%

Table 7-4: Comparison of Predicted and Measured Power Production (2005).

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh/Mo) NOAA	Predicted Power Generation Using Daily Model (MWh/mo) NOAA	Diff. NOAA	Average Daily Wind Speed (MPH) ANN-On-site	Measured Power Generation (MWh/Mo) ANN-On-site	Predicted Power Generation Using Daily Model (MWh/mo) ANN-On-site	Diff. ANN-On-site
Jan-05	30	10.59	20,259	18,508	8.64%	16.89	20,259	18,085	11.74%
Feb-05	26	9.80	9,887	14,099	-42.60%	14.82	9,887	11,064	-8.35%
Mar-05	30	11.44	14,950	20,942	-40.08%	15.64	14,950	14,834	0.55%
Apr-05	29	12.85	22,835	24,107	-5.57%	18.51	22,835	21,574	5.23%
May-05	29	11.98	22,439	21,721	3.20%	19.04	22,439	22,961	-2.41%
Jun-05	29	12.87	26,162	24,160	7.65%	20.82	26,162	27,412	-5.17%
Jul-05	29	11.33	19,456	19,942	-2.50%	18.54	19,456	21,641	-10.96%
Aug-05	30	8.96	16,970	13,867	18.29%	16.73	16,970	17,726	-5.45%
Sep-05	28	9.73	17,361	14,986	13.68%	17.78	17,361	19,054	-11.30%
Oct-05	29	10.18	19,412	16,768	13.62%	17.38	19,412	18,742	4.00%
Nov-05	24	10.99	15,607	15,726	-0.76%	16.46	15,607	13,572	12.95%
Dec-05	19	10.70	11,402	11,915	-4.50%	16.15	11,402	10,238	9.77%
Total	332	10.97	216,740	216,740	0.00%	17.46	216,740	216,904	-0.08%
Total in OSP (07/15-09/15)	59	9.87	37,078	32,353	12.74%	17.64	37,078	39,468	-7.39%

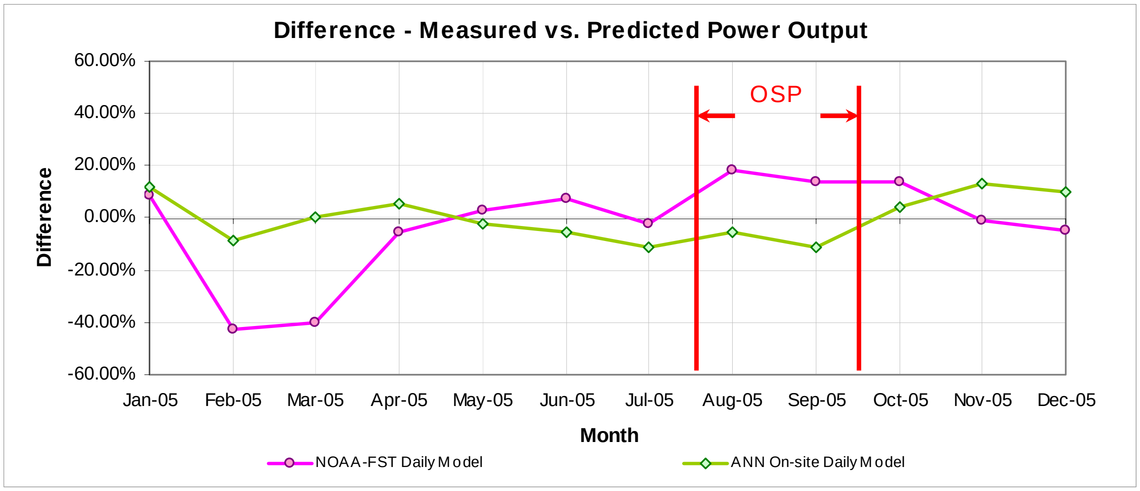


Figure 7-17: Comparison of Difference between Measured and. Predicted Power Production Using NOAA Wind and ANN-derived Wind.

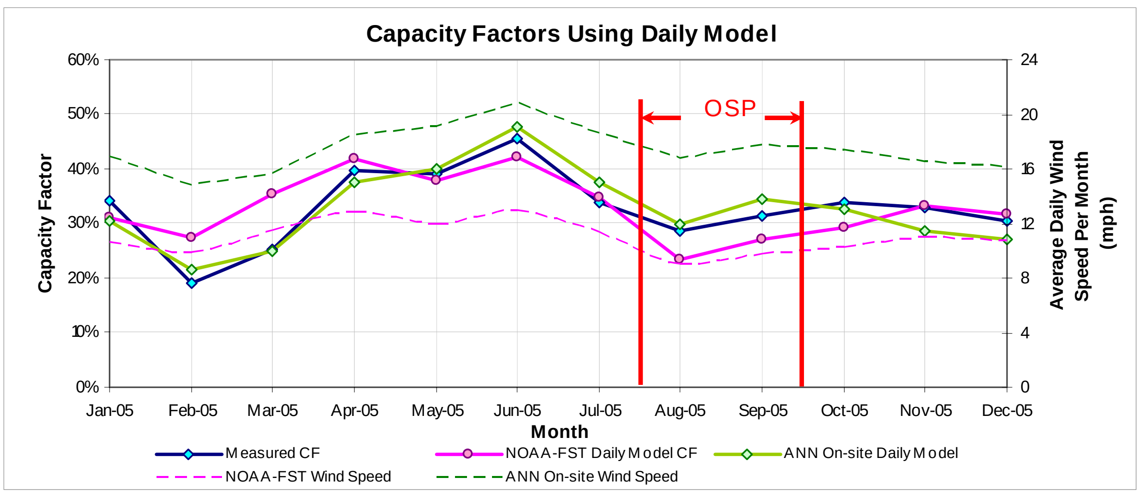


Figure 7-18: Measured Capacity Factors vs. Predicted Capacity Factors Using NOAA Wind and ANN-derived Wind.

7.4 Prediction of Wind Power in 1999

Finally the ANN model was applied in the 1999 NOAA weather data to derive the on-site wind speed in 1999. In addition, the coefficients from the 2005 ANN daily regression model and 2005 NOAA regression model were used to predict the wind power production in 1999 and the values compared. Table 7-5 presents the predicted power production in the 1999 base year using the NOAA daily model and the ANN daily model. This table shows that both the NOAA and ANN daily models perform well for predicting annual power production. However, the ANN daily model provides a more accurate annual prediction and a more accurate prediction during the Ozone Season Period. Finally, a closer inspection of the predictions reveals that there is a potential for under-estimating OSP power production by 10% if only the average daily NOAA wind speeds are used for the wind speeds in the 1999 base year.

Table 7-5: Summary of Predicted Power Production in 1999 and 2005.

Annual - ANN On-site Wind Data

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr	2005 Predicted MWh/yr (2005 Daily Model)
245,921	238,283	238,283

OSP - ANN On-site Wind Data

1999 OSD Estimated MWh/day (2005 Daily Model)	2005 OSD Measured MWh/day	2005 OSD Predicted MWh/day (2005 Daily Model)
702	628	669

Annual - NOAA-FST Wind Data

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr	2005 Predicted MWh/yr (2005 Daily Model)
245,966	238,283	238,283

OSP - NOAA-FST Wind Data

1999 OSD Estimated MWh/day (2005 Daily Model)	2005 OSD Measured MWh/day	2005 OSD Predicted MWh/day (2005 Daily Model)
557	628	548

8 DEGRADATION ANALYSIS

The analysis contained in this section is in response to a request by TCEQ to determine what amounts of degradation could be observed in the measured power from Texas wind farms. Currently, the TCEQ uses a very conservative 5% degradation per year for the power output from a wind farm when making future projections from existing wind farms. Accordingly, the TCEQ asked the Laboratory to evaluate any observed degradation from the measured data for Texas wind farms. To accomplish this, nine wind farms in Texas (14 sites) from 2002 to 2005 were evaluated. These wind farms were built before Jan 2002 with a total capacity of 1,010 MW.

In this analysis, a sliding statistical index was established for each site that uses 10th, 25th, 50th, 75th, 90th, 99th percentiles of the hourly power generation over a 12-month sliding period[10], as well as mean, minimum and maximum hourly power generation of the same 12-month period. These indices are then displayed using one data symbol for each 12-month slide, beginning from the first 12-month period (i.e., January 2002 to December 2002) until the last 12-month period (January 2005 to December 2005) for each of the wind farms, as shown from Figure 8-1 to Figure 8-14. The 90th percentile values were chosen to represent the degradation for each wind farm[11]. In addition, our analysis revealed that the maximum hourly power generation over a 12-month period was also a useful index to watch, since this facilitated a way to observe if there was a major operation change, i.e., shut down of wind turbines, during the studied 4-year period.

For example, for the site at Indian Mesa Wind Farm (Figure 8-1), the 90th percentile varies from 26 MW for a 12-month period ending October 2003 to 39.4 MW for a 12-month period ending December 2005, with an average of 31 MW over the entire 4-year period. However, the 90th percentile hourly wind power for the first 12-months was 29.5 MW, which shows that no degradation was observed over the four-year period for this farm. It is also shown that the maximum hourly power changed from 50.2 MW for the first 12-month period to 48.2 MW for the last 12-month period ending December 2005, dropping significantly in the middle period from 2003 to 2004.

According to the published information, there are 76 Vestas V-47 (660 kW) wind turbines in this site. This drop from 50.2 to 48.2 MW could indicate that three of the wind turbines were not operating by the end of 2005. Nevertheless, although there was a decrease in the maximum power output indicating the potential available wind turbines, this index does not have a significant impact on the total power output of the wind farm, as indicated by the 90th percentile. The 99th percentile was 4 to 16 MW lower than the maximum power output during this period and had a profile that was somewhere between the maximum and 90th percentile profiles.

[10] To calculate this hourly data for the 12 month period is converted into quartiles, and those quartiles are recorded in a table. Then, the oldest month is dropped from the dataset and a new month is added, and the quartiles recalculated and recorded, etc.

[11] The choice of the 90th percentile is consistent with the recommendation by Abushakra, B., Haberl, J., Claridge, D. 2004. "Overview of Literature on Diversity Factors and Schedules for Energy and Cooling Load Calculations (1093-RP)," *ASHRAE Transactions-Research,* Vol. 110, Pt. 1 (February), pp. 164-176; and in Claridge, D., Abushakra, B., Haberl, J. 2003. "Electricity Diversity Profiles for Energy Simulation of Office Buildings (1093-RP)," *ASHRAE Transactions-Research,* Vol. 110, Pt. 1 (February), pp. 365-377.

Table 8-1 presents the summary of the degradation analysis for the nine wind farms. Of the 14 sites analyzed, 8 sites showed an increase when compared to the 90th percentile from January 2002 to December 2005 to the 90th percentile of the first 12-month period, ranging from 2.4% to 13.4%. The remaining 6 sites showed a decrease from -0.8% to -13.1%. The weighted average of this increase across all wind farms studied is 3.2% (positive), which indicates that no degradation was observed from the aggregate energy production from these wind farms over a 4-year operation period.

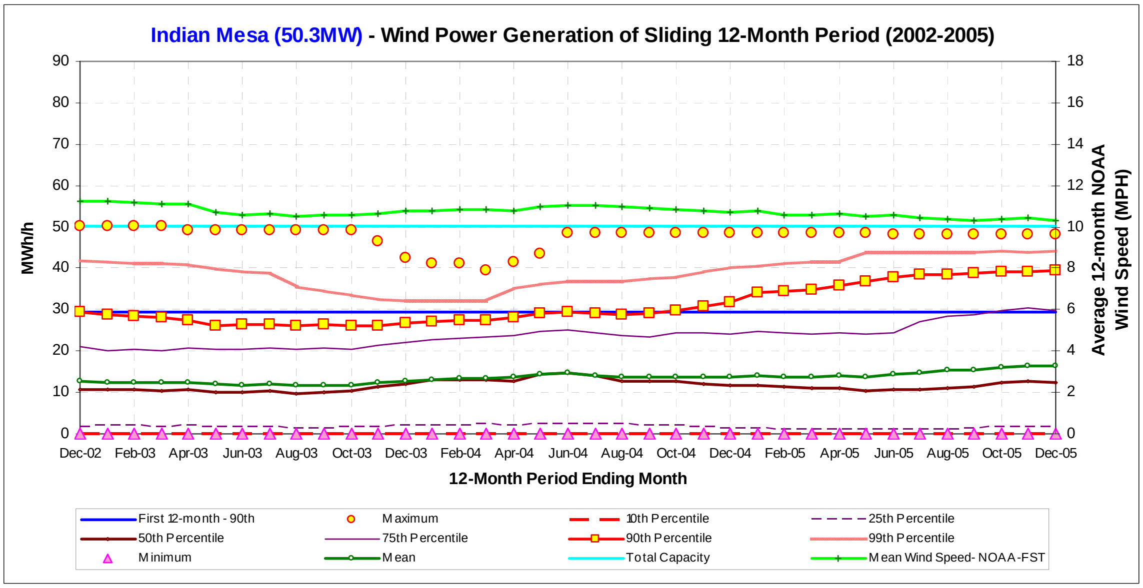


Figure 8-1: Sliding 12-month Hourly Wind Power Generation for Indian Mesa -1.

Table 8-2 and Figure 8-15 show the design capacity, the maximum and minimum of the observed maximum hourly wind power over the sliding 12-month period, and the observed maximum hourly wind power for the last 12-month period for the studied wind farms. It is interesting to note that the observed maximum hourly wind power generation is slightly lower than the design/announced capacity for majority of the sites. In total, the maximum hourly wind power output during the four year period (2002-2005) is 951 MW for nine wind farms, 59 MW (5.8%) lower than the design capacity. It also shows that, for some sites, the maximum hourly wind power over the last 12-month period is lower than the maximum hourly wind power measured during the 4-year period. The total decrease from all wind farms is 27 MW, which is about 2.7% of total design capacity. Additional operation information will be needed from the owners of the wind farms or ERCOT to explain this observation, such as maintenance records, curtailment, etc.

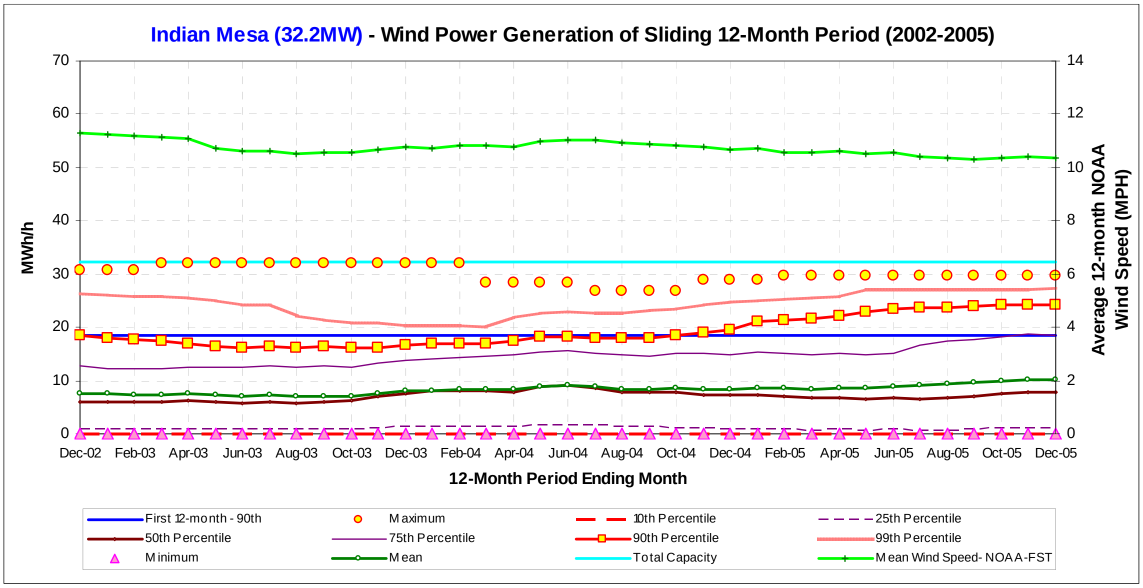


Figure 8-2: Sliding 12-month Hourly Wind Power Generation for Indian Mesa -2.

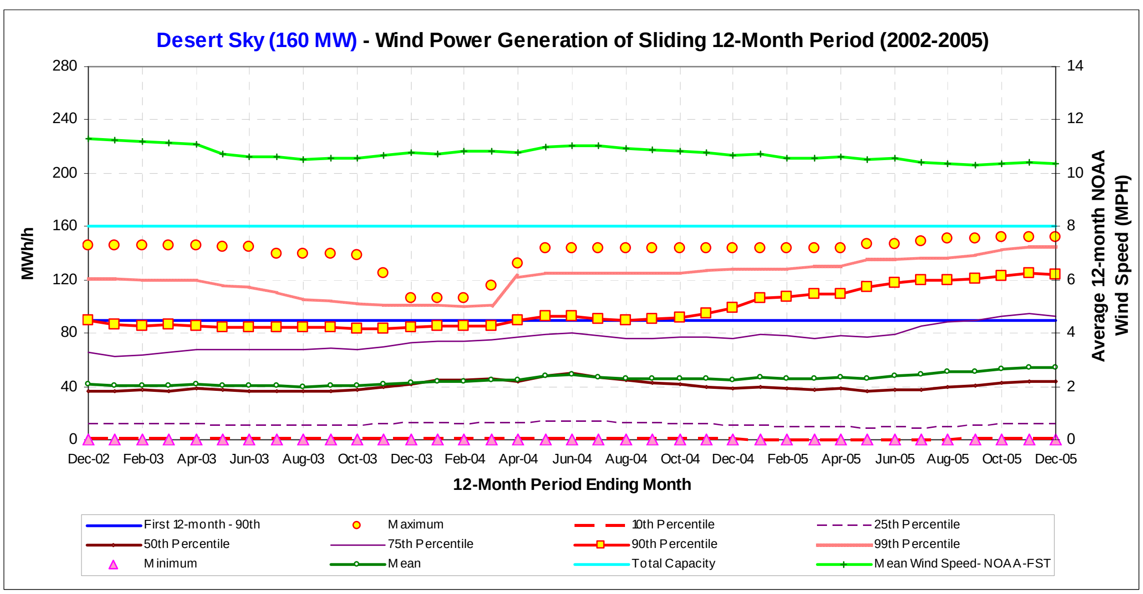


Figure 8-3: Sliding 12-month Hourly Wind Power Generation for Desert Sky.

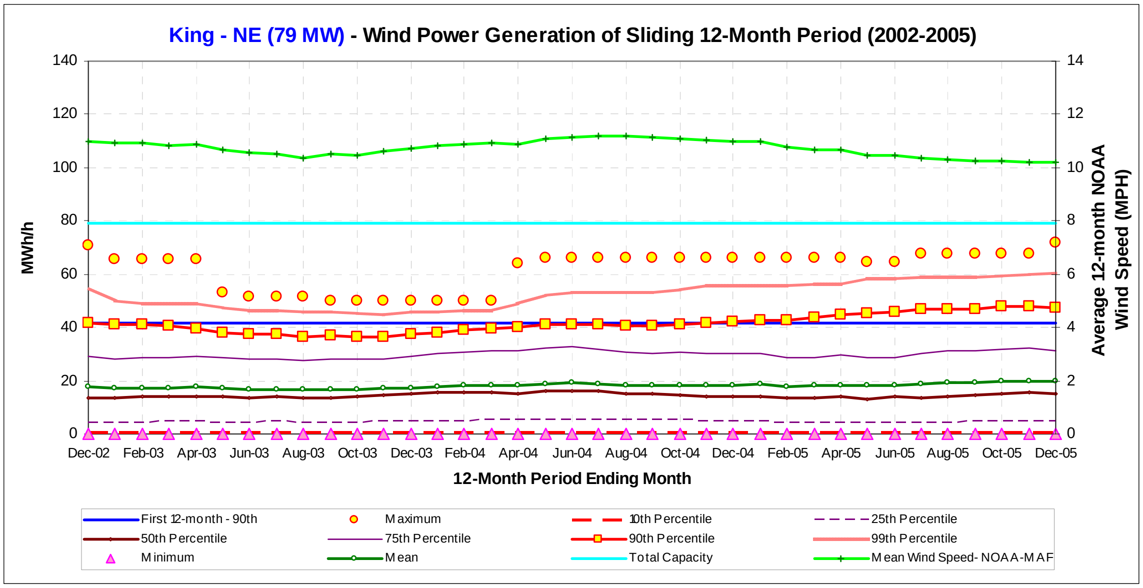


Figure 8-4: Sliding 12-month Hourly Wind Power Generation for King Mountain –NE.

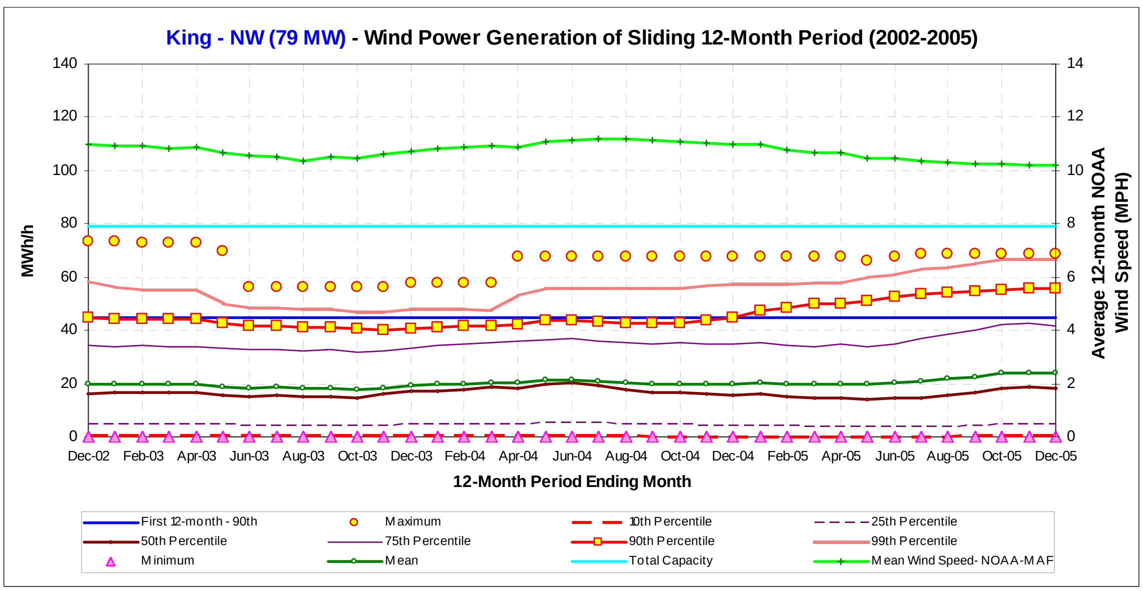


Figure 8-5: Sliding 12-month Hourly Wind Power Generation for King Mountain –NW.

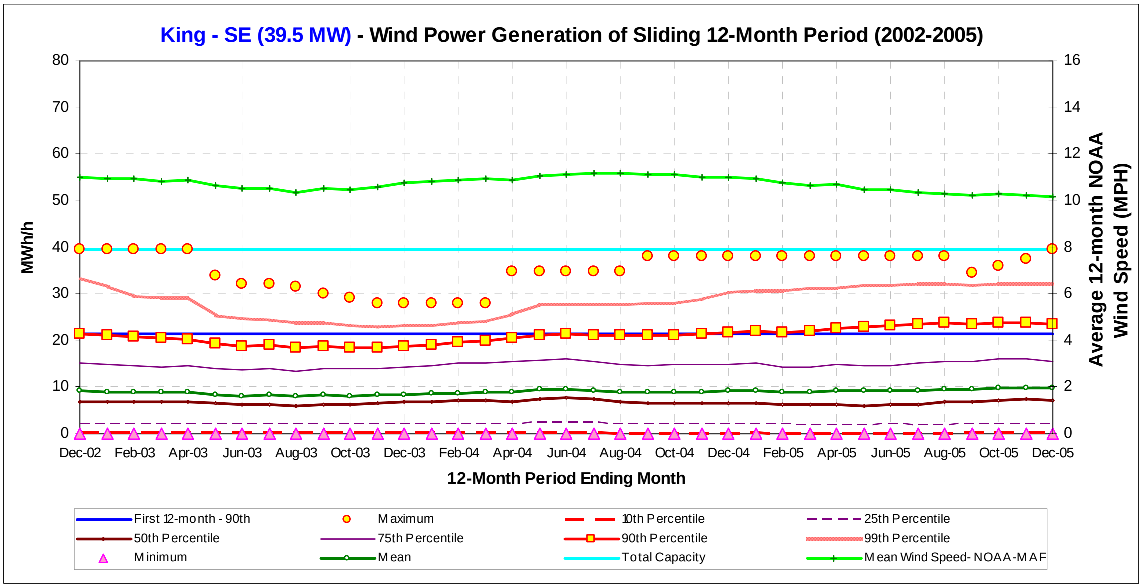


Figure 8-6: Sliding 12-month Hourly Wind Power Generation for King Mountain –SE.

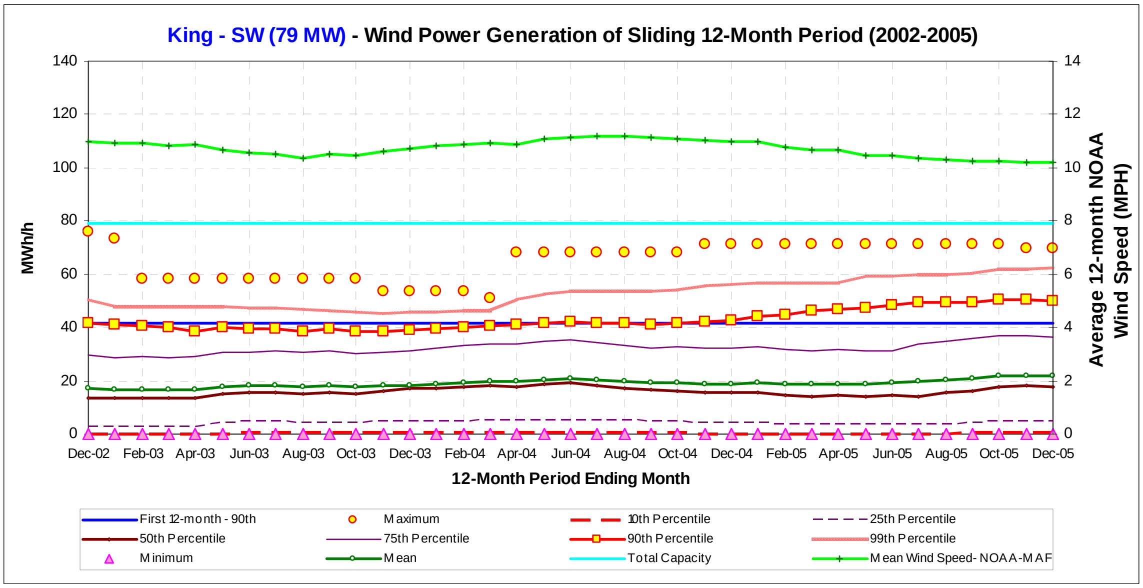


Figure 8-7: Sliding 12-month Hourly Wind Power Generation for King Mountain –SW.

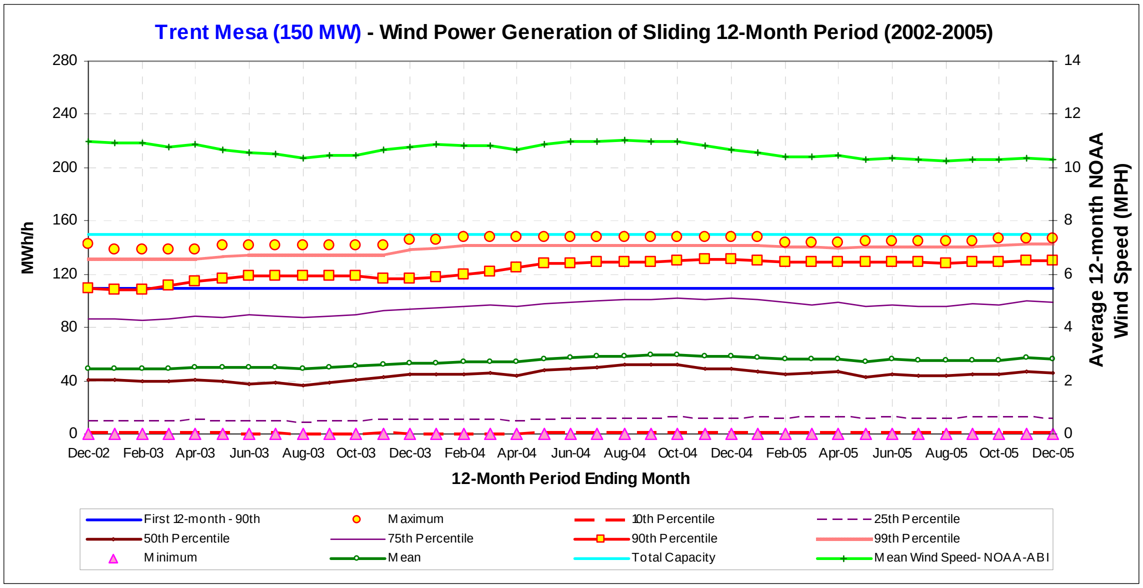


Figure 8-8: Sliding 12-month Hourly Wind Power Generation for Trent Mesa.

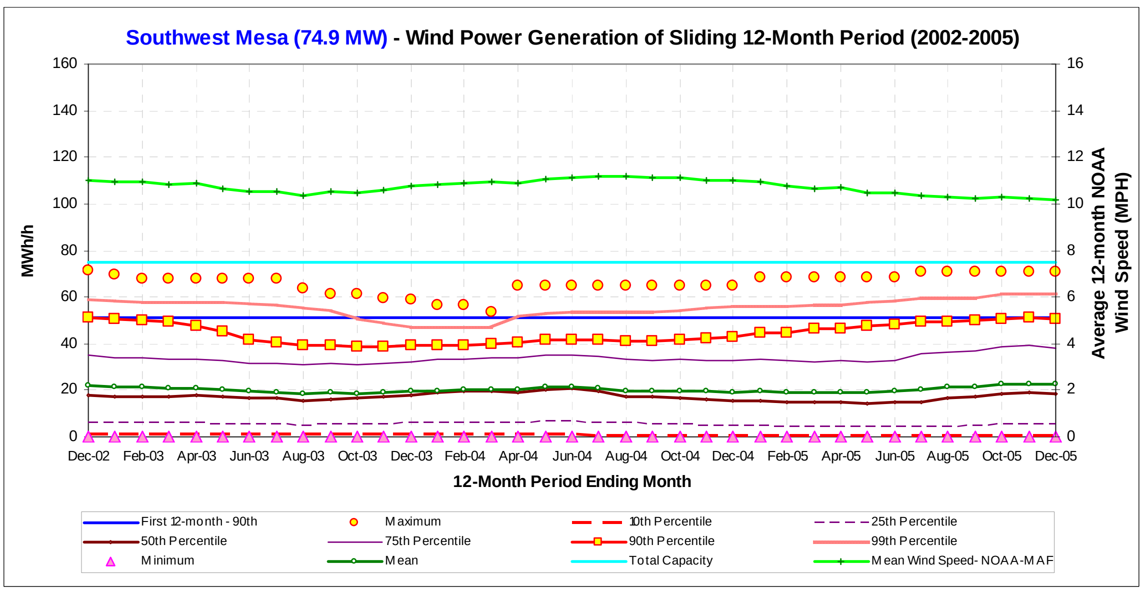


Figure 8-9: Sliding 12-month Hourly Wind Power Generation for Southwest Mesa.

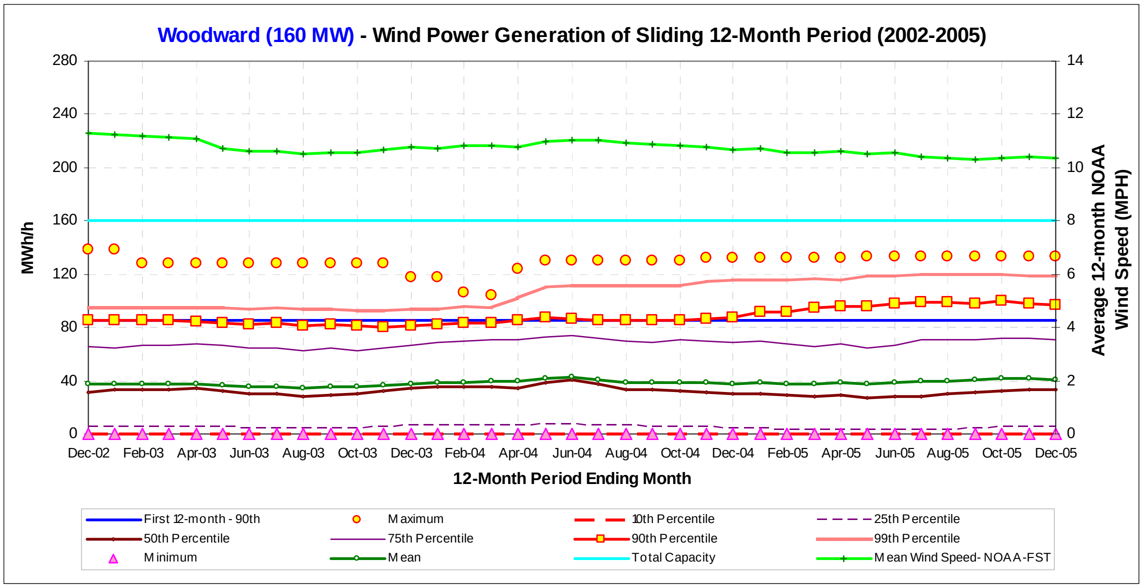


Figure 8-10: Sliding 12-month Hourly Wind Power Generation for Woodward Mountain.

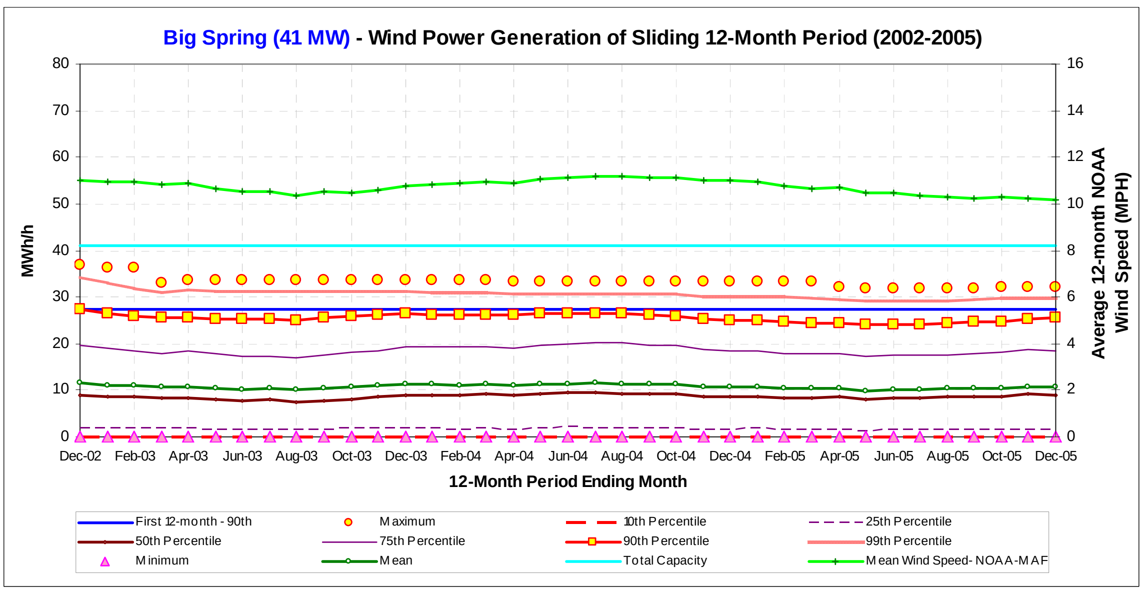


Figure 8-11: Sliding 12-month Hourly Wind Power Generation for Big Spring.

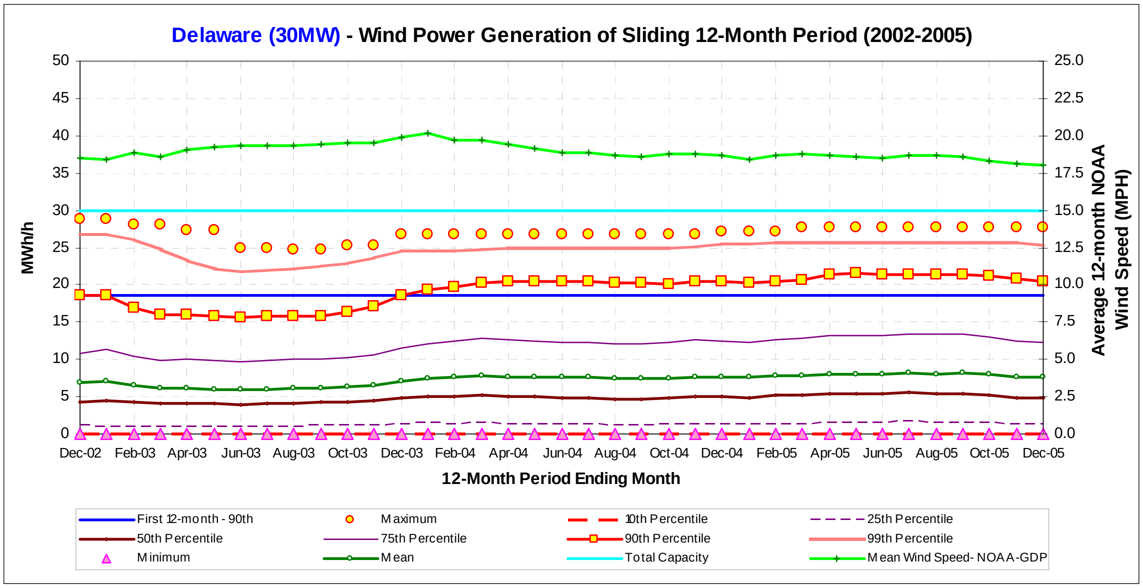


Figure 8-12: Sliding 12-month Hourly Wind Power Generation for Delaware Mountain.

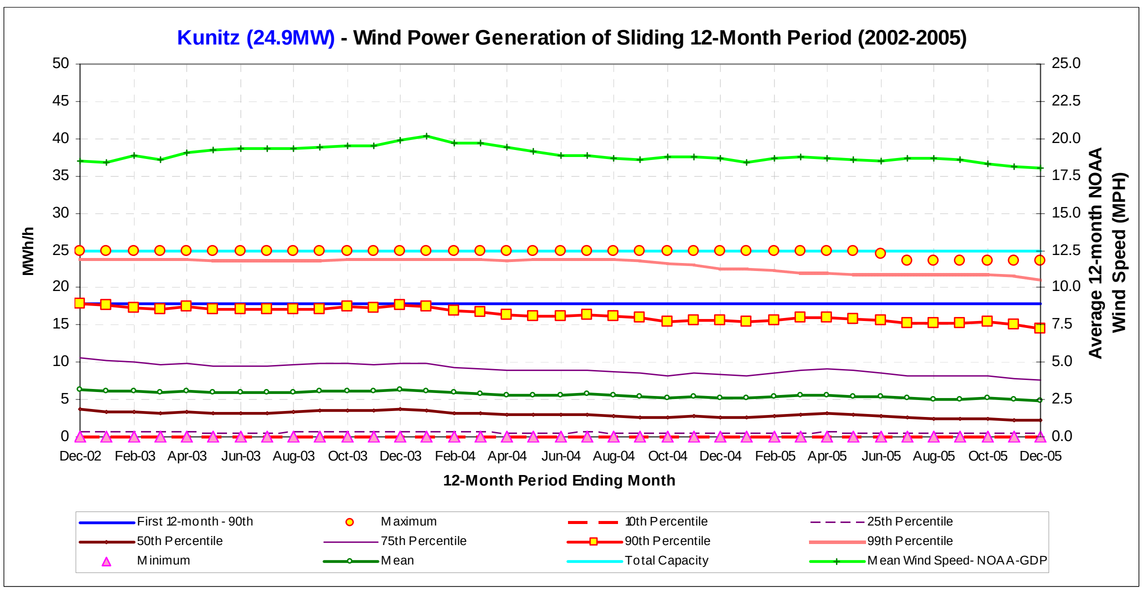


Figure 8-13: Sliding 12-month Hourly Wind Power Generation for Kunitz-1.

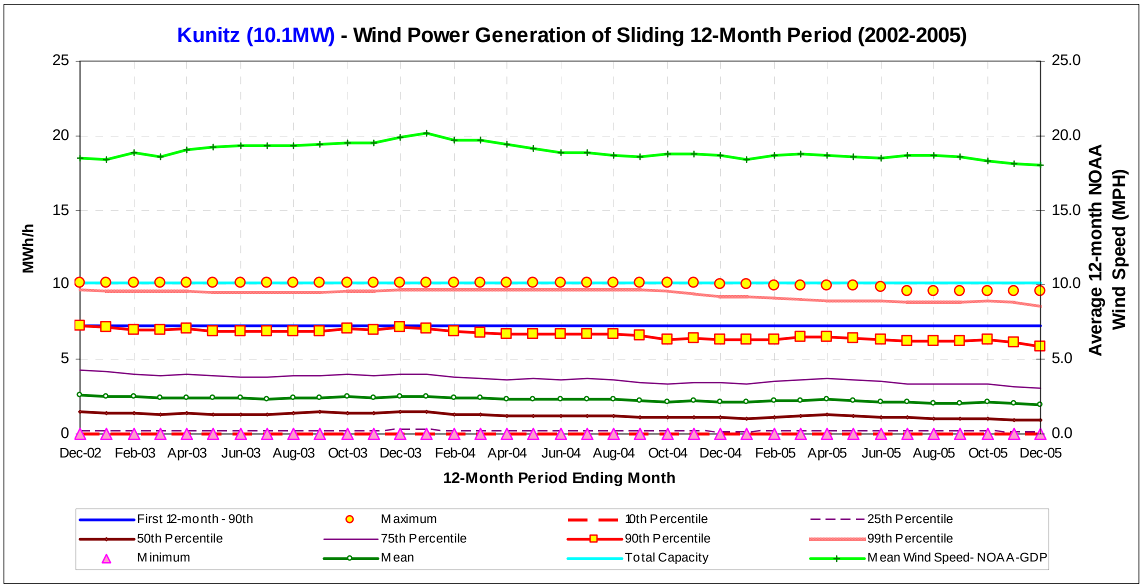


Figure 8-14: Sliding 12-month Hourly Wind Power Generation for Kunitz-2.

Table 8-1: Summary of 90th Percentile Hourly Wind Power Analysis for Nine Wind Farms in Texas

Wind Farm	First 12-mo 90th Percentile Hourly Wind Power		Average of the Sliding 12-mo 90th Precentile Hourly Wind Power		Minimum of the Sliding 12-mo 90th Precentile Hourly Wind Power		Maximum of the Sliding 12-mo 90th Precentile Hourly Wind Power		No. of Month of Data	Capacity (MW)
	First 12-mo Ending Mo.	MW	MW	% Diff. vs. First 12-mo	MW	% Diff. vs. First 12-mo	MW	% Diff. vs. First 12-mo		
Indian Mesa -1	Dec-02	29.5	31.0	5.1%	26.0	-11.8%	39.4	33.5%	48	50.3
Indian Mesa -2	Dec-02	18.5	19.2	3.5%	16.1	-13.4%	24.3	31.1%	48	32.2
Delaware	Dec-02	18.6	19.2	3.6%	15.6	-15.8%	21.5	15.7%	48	30
Desert Sky	Dec-02	89.0	97.0	8.9%	83.1	-6.7%	124.4	39.7%	48	160
King Mountain-NE	Dec-02	41.8	41.5	-0.8%	36.3	-13.2%	48.1	14.9%	48	79
King Mountain-NW	Dec-02	44.7	45.8	2.4%	40.2	-10.1%	55.6	24.4%	48	79
King Mountain-SE	Dec-02	21.6	21.1	-2.3%	18.4	-14.8%	23.9	10.7%	48	39.5
King Mountain-SW	Dec-02	41.6	42.9	3.2%	38.4	-7.6%	50.6	21.7%	48	79
Trent	Dec-02	108.8	123.5	13.4%	108.2	-0.6%	131.1	20.4%	48	150
Woodward	Dec-02	85.3	88.1	3.4%	80.4	-5.7%	99.5	16.7%	48	160
Kunitz -1	Dec-02	17.9	16.4	-8.6%	14.5	-19.3%	17.9	0.0%	48	24.9
Kunitz -2	Dec-02	7.2	6.7	-7.9%	5.9	-18.3%	7.2	0.0%	48	10.1
Big Spring	Dec-02	27.2	25.5	-6.4%	23.9	-12.0%	27.2	0.0%	48	41
Southwest Mesa	Dec-02	51.1	44.4	-13.1%	38.5	-24.6%	51.1	0.0%	48	74.9
Weighted Average:				**3.2%**		**-9.5%**		**20.3%**	**Total:**	**1009.9**

Table 8-2: Summary of Maximum Hourly Wind Power Analysis for Nine Wind Farms in Texas.

Wind Farm	Design Capacity (A)	Maximum of the Sliding 12-mo Maximum MW-Measured (B)	Minimum of the Sliding 12-mo Maximum MW - Measured (C)	Maximum MW in Last 12-mo - Measured (D)	Difference (A-B)	Difference (B-D)
Indian Mesa-1	50.3	50.2	39.5	48.2	0.1	2.0
Indian Mesa-2	32.2	29.9	26.9	29.8	2.3	0.2
Delaware	30	28.9	24.8	27.6	1.1	1.3
Desert Sky	160	152.2	105.8	152.2	7.8	0.0
King Mountain-NE	79	72.0	49.8	72.0	7.0	0.0
King Mountain-NW	79	73.2	56.2	68.6	5.8	4.6
King Mountain-SE	39.5	39.5	27.8	39.5	0.0	0.0
King Mountain-SW	79	75.9	51.2	69.9	3.1	6.0
Trent	150	147.6	138.8	147.3	2.4	0.3
Woodward	160	138.7	104.1	132.9	21.3	5.8
Kunitz-1	24.9	24.9	23.5	23.5	0.0	1.4
Kunitz-2	10.1	10.1	9.6	9.6	0.0	0.5
Big Spring	41	37.0	31.7	32.2	4.0	4.8
South Mesa	74.9	71.2	53.8	70.7	3.7	0.5
Total:	**1009.9**	**951.2**	**743.5**	**923.9**	**58.7**	**27.3**

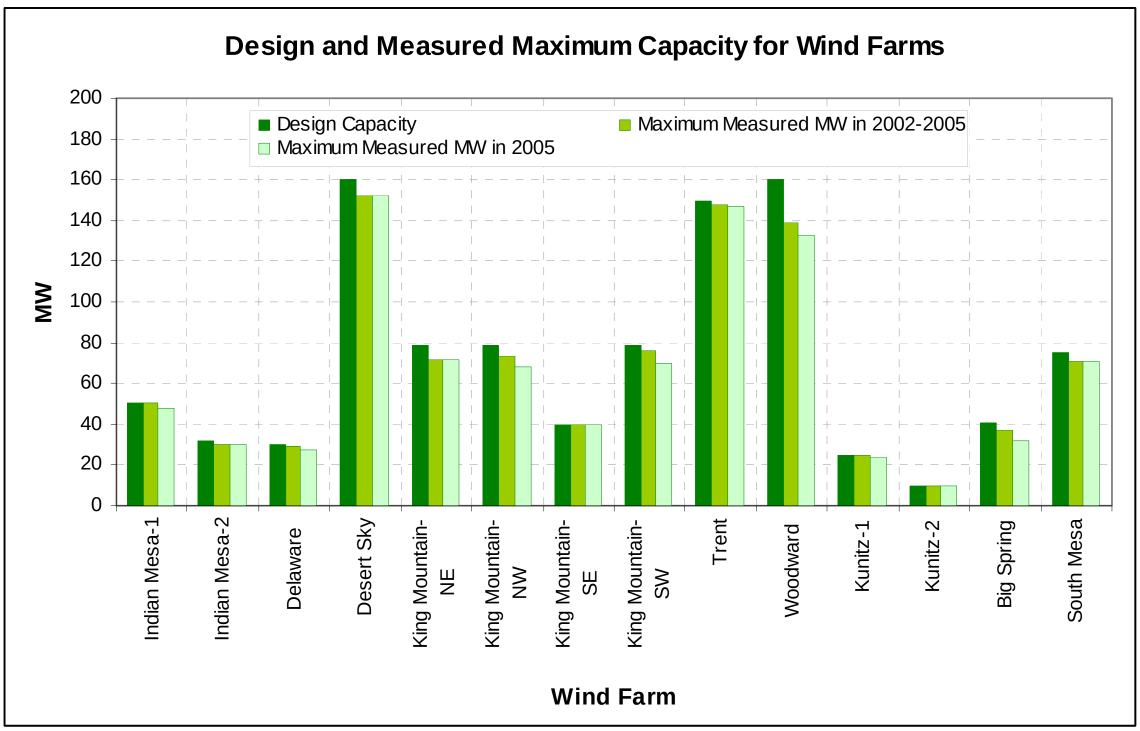


Figure 8-15: Design and Measured Maximum Capacity for Texas Wind Farms.

9 CURTAILMENT ANALYSIS FOR INDIAN MESA WIND FARM

During the analysis of the measured power production from the Indian Mesa wind farm, and the subsequent discussions with the wind stakeholders, group, including representatives from ERCOT, it became clear that the dataset contained substantial amounts of data that represented periods when the wind farm owners were instructed to curtail their power production because of constraints on the electric transmission lines. Unfortunately, it was determined that there was no electronic record of the amount of curtailment for this site[12]. As the analysis progressed, it became clear that an hourly analysis that used a manufacturer's wind power curve, multiplied times the prevailing on-site wind speed, and scaled for the number of turbines at the site, presented the possibility of empirically determining the curtailment for the site. Therefore, the TCEQ requested that the Laboratory perform a proof-of-concept analysis to empirically determine the curtailment at the Indian Mesa site.

In this section, the measured power production for the period July 2002 to January 2003 from the Indian Mesa wind farm (Figure 9-1) was analyzed using the on-site wind speed and manufacturer's power curves. Significant curtailment was observed during this period due to the power constraints in the McCamey power transmission area. Figure 9-2 shows the proposed plan from ERCOT concerning the development of new transmission lines in this area, which may alleviate the transmission constraint problem in the future and, as a result, will allow more electricity from the wind power projects in this area to be transmitted to other parts of Texas through the ERCOT grid.

Figure 9-3 and Figure 9-4 show the hourly measured power production for the seven-month period from July 2002 to January 2003, and during the Ozone Season Period, respectively, which are plotted against the measured hourly on-site wind speed, as well as the predicted power production using the manufacturer's power curve, scaled to the total number of wind turbines at the wind farm. Both figures show that during the higher wind speeds (>20 MPH), the measured power frequently falls below the power curve, which is attributed to either curtailment, maintenance or both.

Figure 9-5 shows a time series plot of the power-curve predicted and measured electricity production for the 7-month period from July 2002 to January 2003. Periods of curtailment can be seen where significant amounts of the estimated power-curve (red) appear above the measured electricity production (blue). In this figure, the sliding 24-hour average dry bulb temperature from the NOAA weather station is also plotted on a secondary Y axis. An inspection of the plot reveals that the temperature does not appear to have a direct influence on the curtailment.

In Figure 9-6, the cumulative difference between the power-curve predicted power and measured power is plotted with several of the most significant curtailments marked. Figure 9-7 shows a time-series difference plot between the measured power and predicted power using the manufacturer's power curve for the Ozone Season Period.

Table 9-1 and Figure 9-8 summarize the calculated annual curtailment factor (33.6%), curtailment factor in the Ozone Season Period (26.4%), as well as the monthly curtailment factors for this wind farm. In Figure 9-8, it can be seen that the monthly curtailment is higher in the winter months than during summer months. However, the amount of the curtailment (MWH) is relatively similar from month to month. This is due to the fact that summer is windier in this site for the studied 7-month period.

[12] This would appear to be true for other sites in ERCOT.

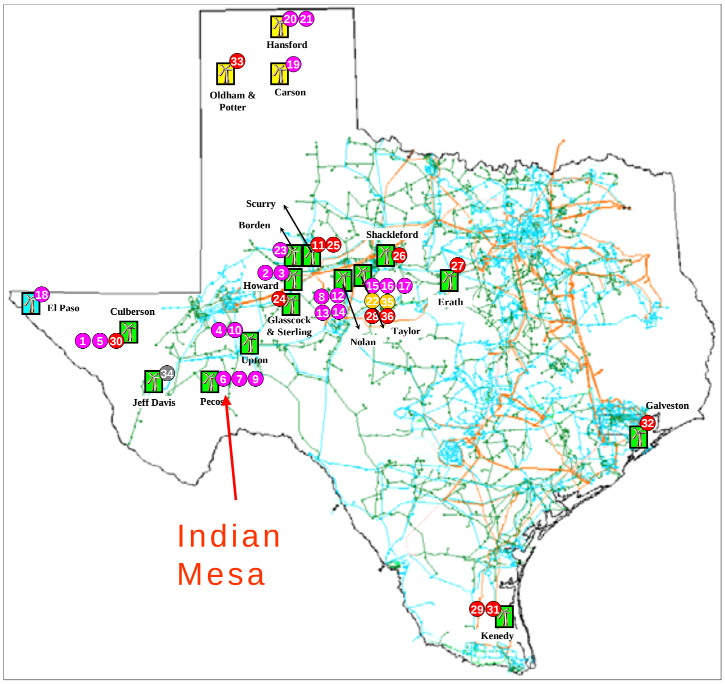


Figure 9-1: Location of Indian Mesa Wind Farm.

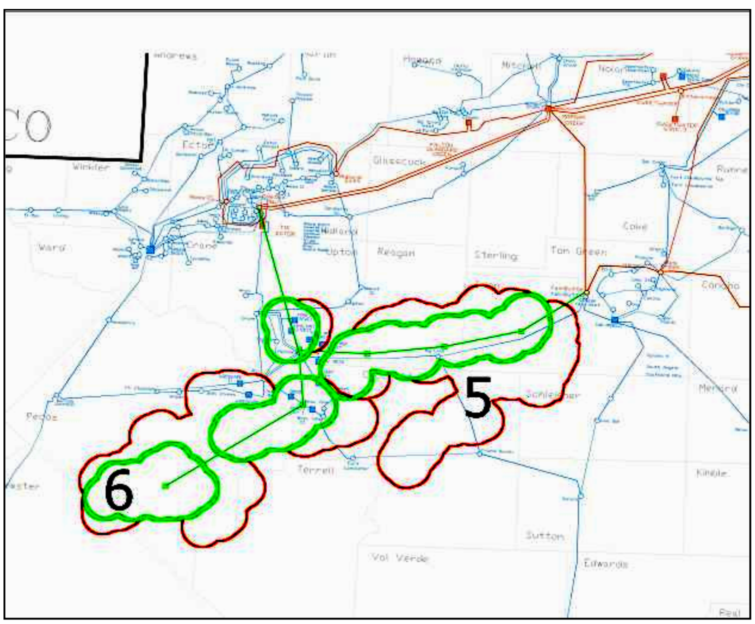


Figure 9-2: Power Constraints in McCamey Area.

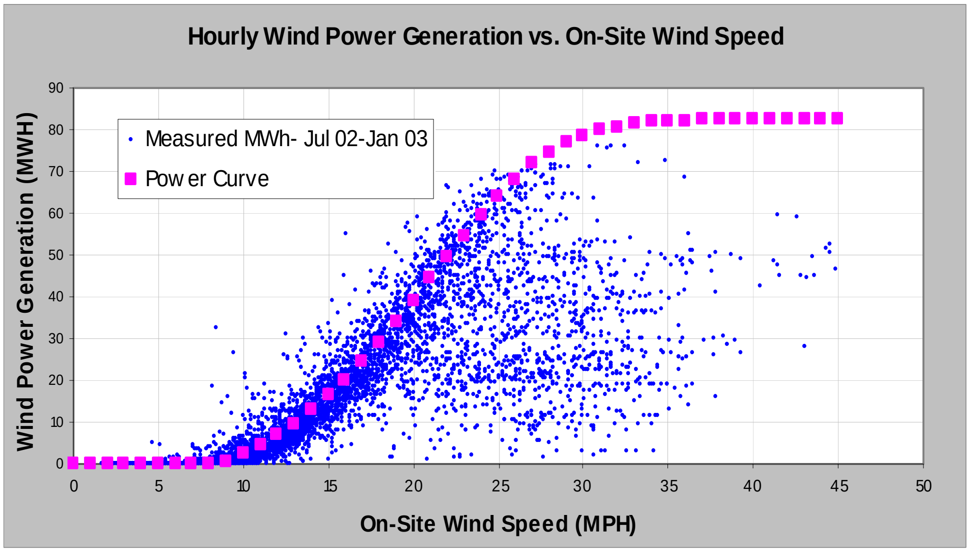


Figure 9-3: Hourly Power Production vs. On-site Wind Speed for the Period Jul 02 to Jan 03.

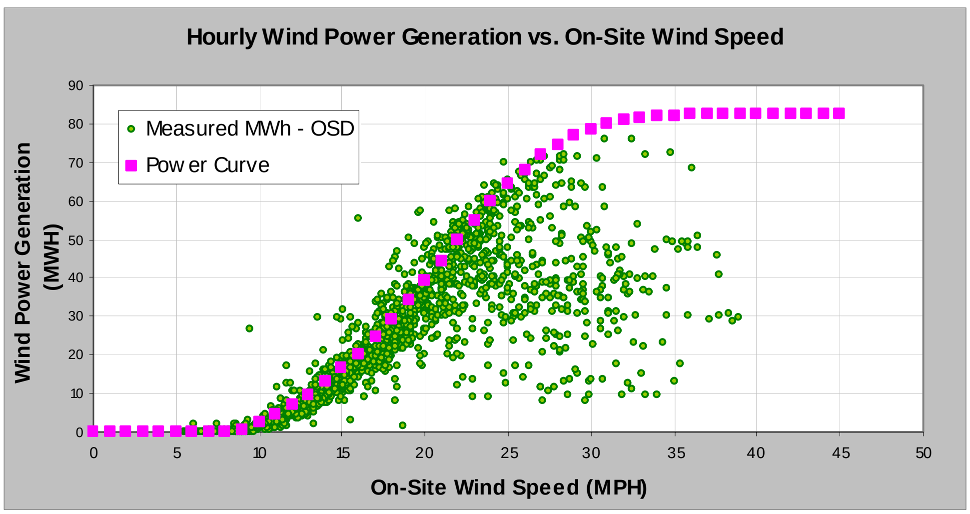


Figure 9-4: Hourly Power Production vs. On-site Wind Speed for the OSP.

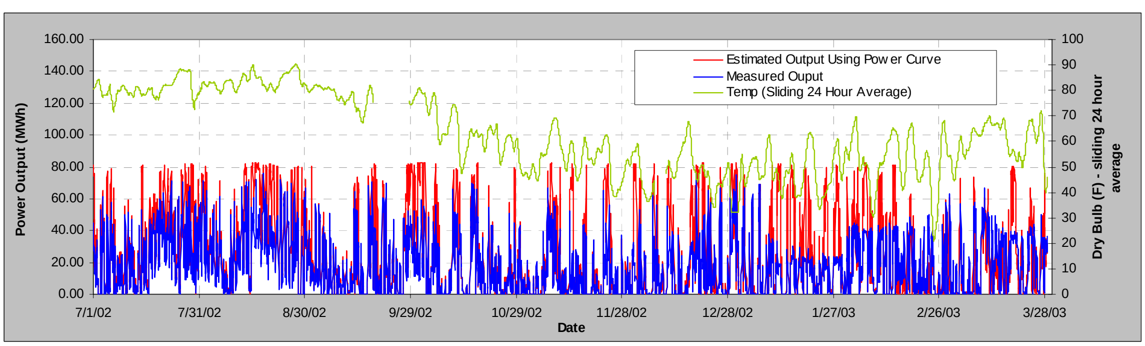


Figure 9-5: Measured Power Output vs. Predicted Power Using Power Curve.

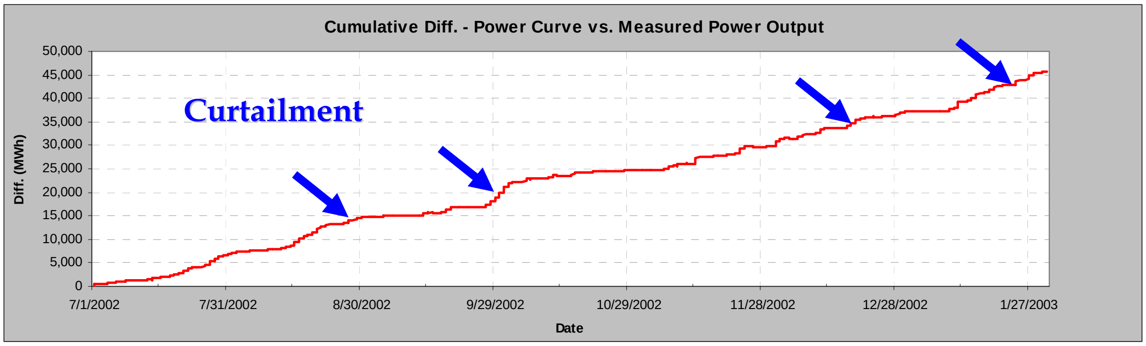
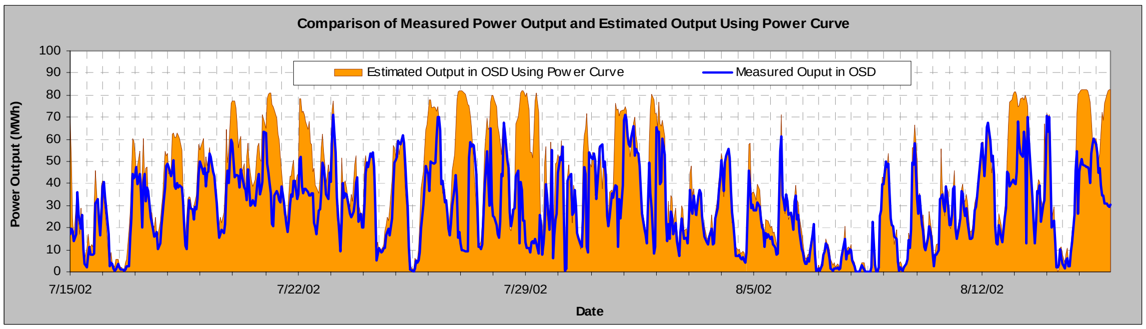


Figure 9-6: Cumulative Difference between the Predicted Power Curve and Measured Power.



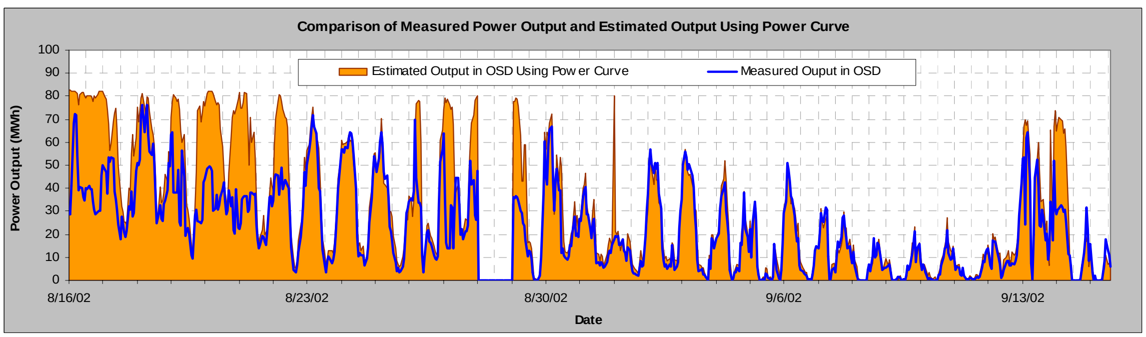


Figure 9-7: Measured Power Output vs. Predicted Power Using Power Curve in OSP.

Table 9-1: Curtailment and Maintenance Factor for the Period July 2002 to January 2003.

Predicted MWH in 2002 OSD Using Power Curve and On-site Wind	2002-2003 Measured in OSD	Curtailment and Maintenance Factor for OSD Period
52,565	38,678	26.4%

Predicted MWH Using Power Curve and On-site Wind (Jul 02 - Jan 03)	2002-2003 Measured (Jul 02 - Jan 03)	Curtailment and Maintenance Factor for Jul 02 - Jan 03
135,251	89,747	33.6%

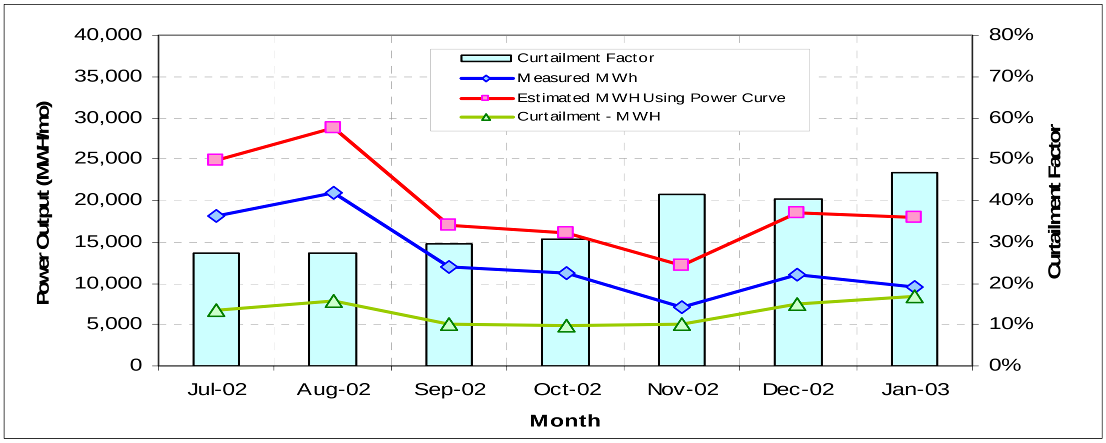


Figure 9-8: Monthly Curtailment and Maintenance Factor for the Period July 2002 to January 2003.

10 OTHER RENEWABLES

Renewable energy projects throughout the state of Texas were located to determine the NOx emissions reduction. Searches were conducted on four specific categories: solar photovoltaic, geothermal, hydroelectric, and Landfill Gas-fired Power Plants. The criteria for each project included in the data collection were: 1) the installation date was after the year 2000, and 2) the project was installed within the state of Texas. In order to provide a complete record, however, projects reported prior to 2000 were also included. Table 10-1 provides a cross listing of county names and assigned number used in this section.

10.1 Implementation

An initial search on the internet was conducted to find solar photovoltaic, hydroelectric, geothermal, and landfill gas projects. Following these preliminary searches a more thorough investigation was conducted on specific websites that were deemed credible. Unfortunately, most of the project descriptions did not include system specifications data. To find this information, the corresponding companies, organizations, or government entities that were mentioned in the article were contacted via email or phone. Unfortunately, these efforts were productive in only a small number of cases. In addition to these efforts to find individual projects, manufacturers and contractors of the various systems were contacted about project installations following the determined criteria.

After the necessary information was obtained, the annual power production was calculated by entering the project specifics into the Laboratory's eCALC program to calculate the energy savings and emissions reduction for each of the projects. Since eCALC relies on county designations, it was necessary to find the nearest geographical county, since not all of the counties in Texas are available in eCalc. Table 10-1 provides a cross listing of county names and assigned number used in this section.

10.2 Other Renewables Sources

10.2.1 Solar Photovoltaic

One of the primary sources of information proved to be the website maintained by the Soltrex Company. Soltrex provides data servers, websites, and data loggers to track the performance of PV systems. Within the Soltrex website, several hundred schools across the nation provided the energy output of their PV system, the installation date, and the system specifications.

Another noteworthy source of information was the website for Meridian Energy Systems, Inc., located in Austin, Texas. Their website provided a portfolio that included information about multiple projects completed within the last five to ten years. However, specific information was not provided. Therefore, further information regarding all these projects will be provided in a future report.

The Electric Reliability Council of Texas (ERCOT) and State Energy Conservation Office (SECO) also provided information for several projects. Their websites described the use of solar panels at school crossings throughout the state. There were some instances where only partial information was listed. So, efforts were made to locate more specific information on some of these, such as the Sheldon Lake and Environmental Learning Center. At this site, the superintendent, Mr. Robert Comstock, was contacted for specific information about their PV system. Hensley Field was another project where the project manager, Mr. Michael Kawecki, was contacted and replied with a presentation containing more specific information.

After the above sources were assembled, additional manufacturers and contractors were contacted to find additional installations. A major contributor for projects was found on one distributor's website, the Southwest Photovoltaic Systems, Inc. (SWPV), an international distributor of BP Solar Panels. Their website provides a snapshot of installed projects throughout the United States, so the company was contacted to gain further information about their Texas projects. When asked about the slope of their products used in the qualifying projects, the company could not respond in detail to each one due to time constraints. However, they did inform us that the average solar panel used was 12.5 square feet (5 feet by 2.5 feet). This figure was then used for calculations, and an appropriate assumption was made about the azimuth and slope.

For both of these sources, the corresponding websites cited the type of solar panel installed as well as the number of modules. Unfortunately, the square footage of each module was not always available. Since eCalc requires the area of the solar panels for each project, it was necessary to find this data for each site. Therefore, an additional search was performed by contacting the individual manufacturers of these products or were found on the web.

eCalc includes the photovoltaic option for high- or low-end systems. A high-end PV system was assumed for all of the projects based on the average efficiency of the photovoltaic cells in the last decade, which is 11% or higher.

A summary of the different projects and their outputs from eCalc can be found in Table 10-2 to Table 10-7, respectively. Figure 10-1 shows the location of the projects in Texas. The annual electric savings per county for the projects are presented in Figure 10-6, and the Ozone Season Day savings in Figure 10-7. The respective annual and ozone season day emissions reductions are shown in Figure 10-8 and Figure 10-9, respectively. Table 10-16 and Table 10-17 contain tabulated values shown in Figure 10-8 and Figure 10-9.

For the projects identified, a total potential of 386,487 kWh/year were calculated, which translates to 567 lbs-NOx/year, 380 lbs-SOx/year, and 483,511 lbs-CO2/year using the 2007 eGRID values. During the Ozone Season Period, the total savings were 1,206 kWh/day, which translates to 1.75 lbs-NOx/OSD, 0.66 lbs-SOx/OSD, and 1,413 lbs-CO2/OSD using the 2007 eGRID.

10.2.2 Solar Thermal

Information regarding the solar thermal projects was obtained from a joint survey issued by the Laboratory and the Texas Renewable Energy Industries Association (TREIA) sent to various companies. Figure 10-2 shows the location of the projects in Texas. In addition, information was obtained from several manufacturers' websites. This survey revealed that Techsun Solar, Inc., is responsible for eight out of the nine projects documented in this report. The ninth project is presented as a special project since there is no methodology currently available to obtain these values. This special project is a Roof-Mounted Parabolic Trough collector located at Fort Sam Houston in the San Antonio, Texas, area.

A summary of the different projects and their electricity and emissions reductions using eCalc can be found in Table 10-8 and Table 10-9, and in Figure 10-10 through Figure 10-13, respectively. Table 10-10 presents the information from an especially large project reported at Fort Sam Houston in San Antonio. Table 10-18 Table 10-19 present the tabulated values shown in Figure 10-10 through Figure 10-13.

For the projects identified, a total potential of 40,518 kWh/year were calculated, which translates to 65 lbs-NOx/year, 56 lbs-SOx/year, and 19,365 lbs-CO2/year using the 2007 eGRID values. During the Ozone Season Period, the total savings were 138 kWh/day, which translates to translates to 0.22 lbs-NOx/OSD, 0.11 lbs-SOx/OSD, and 207 lbs-CO2/OSD using the 2007 eGRID.

10.2.3 Hydroelectric

The main source of information for hydroelectric systems came from the Idaho National Laboratory website that has an interactive map regarding hydroelectric sites. The user chooses a specific dam; when the dam is chosen, the name, operator, and the capacity of the dam appears. Locations of twenty-eight dams were found through this process. However, the date of the installation was not available. Further investigation for this information was conducted by contacting the Corps of Engineers and various authorities in charge of each plant including the Guadalupe Blanco River Authority and the Lower Colorado River Authority. Owners of several additional private dams were contacted with limited success. All hydroelectric project information is presented in Table 10-11. Figure 10-3 contains a Texas map that shows the location of the different projects per county is presented in Table 10-11.

Since none of the hydroelectric sites were constructed after 2001, no electricity savings were calculated.

10.2.4 Geothermal

Geothermal projects were also found through various websites. Since this did not result in locating many projects, contractors and manufacturers of geothermal systems were contacted directly to find their projects installed after the year 2001. The Geothermal Heat Pump Consortium's website was used to find contractors of geothermal heat pumps. Six major projects were identified in this website; however, more information is needed in order to conduct a more exhaustive analysis that allows for the emissions reductions to be calculated due to the use of ground-coupled heat pumps. Companies such as Trane, WaterFurnace, and Mammoth, Inc., also provided a few case studies. Once again, the information was limited, and many of the sites listed were constructed prior to 2001.

The Geothermal Lab and the Geo-Heat Center from the Oregon Institute of Technology provided additional information about geothermal sites, but none of the information obtained contained any specific projects in the Texas area. The resulting information can be found in Table 10-12, with a corresponding map contained in Figure 10-4 that shows the resulting projects in different counties.

10.2.5 Landfill Gas-fired Power Plants

House Bill 3415 went into effect in 2001 and encouraged the development and use of landfill gas for state energy and environmental purposes. This allowed TCEQ to give priority to processing applications for registrations.

The City of Denton's landfill has been given various awards for its innovation to produce biodiesel fuel. This is used to power a three million-gallon biodiesel production facility. This is the first facility of its kind in the world where landfill gas is used to produce biodiesel, according to the Environmental Protection Agency. This landfill gas supplies all of the energy needs to the production facility including all process heat and power. This biodiesel is then used in part to power the city's truck fleet with B20 which is a blend of 80% diesel and 20% biodiesel.

The EPA has a project database for the Landfill Methane Outreach Program (LMOP). The implemented, candidate, and potential projects in Texas are listed in Table 10-13 through Table 10-15, respectively. Figure 10-5 shows the location of these operational projects implemented throughout Texas.

Table 10-1. Counties for Documented Projects.

Assigned Number	County	Assigned Number	County	Assigned Number	County	Assigned Number	County
1	Archer	18	Denton	35	Kimble	52	Tarrant
2	Bastrop	19	DeWitt	36	Kinney	53	Taylor
3	Bexar	20	El Paso	37	Lampasas	54	Tom Green
4	Bosque	21	Fayette	38	Lee	55	Travis
5	Brazoria	22	Fort Bend	39	Llano	56	Uvalde
6	Brazos	23	Galveston	40	Maverick	57	Valverde
7	Brown	24	Gillespie	41	McLennan	58	Victoria
8	Burnet	25	Gonzales	42	Montgomery	59	Ward
9	Caldwell	26	Grayson	43	Newton	60	Washington
10	Calhoun	27	Gregg	44	Nueces	61	Webb
11	Cameron	28	Guadalupe	45	Palo Pinto	62	Wharton
12	Chambers	29	Harris	46	Potter	63	Wichita
13	Childress	30	Harrison	47	Presidio	64	Williamson
14	Collin	31	Hidalgo	48	Randall	65	Wood
15	Colorado	32	Jasper	49	Scurry	66	Zapata
16	Comal	33	Jones	50	Smith	67	Hays
17	Dallas	34	Kendall	51	Sutton		

Table 10-2. Solar Photovoltaic Cell Projects: Data and Information.

Solar Project	City/Town	County	County for ECALC	Date	PV Modules	Capacity(kW)	Total Area (sqft)	Slope	Azimuth (South=180)
Giddings Middle School	Giddings, TX	Lee	Bastrop	Jun-05	GE Energy GEPV-050-M	1	121.4	30	180
La Grange Intermediate School	La Grange, TX	Fayette	Bastrop	May-05	GE Energy GEPV-050-M	1	121.4	30	180
Schulenburg Elementary School	Schulenburg, TX	Fayette	Bastrop	Jun-05	GE Energy GEPV-050-M	1	121.4	30	180
Smithville Junior High School	Smithville, TX	Bastrop	Bastrop	Jun-05	GE Energy GEPV-050-M	1	121.4	30	180
Bastrop Intermediate School	Bastrop, TX	Bastrop	Bastrop	May-07	Sharp Electronics NE-170-U1	1.02	84	35	180
Eagle Pass High School - CC Winn Campus	Eagle Pass, TX	Maverick	Bexar	Feb-02	Siemens SP 75	0.9	81.84	25	180
East Central ISD	San Antonio, TX	Bexar	Bexar	Nov-03	Shell SP-140-PC	1.12	113.92	60	180
James Madison High School	San Antonio, TX	Bexar	Bexar	Feb-02	Siemens SP 75	0.9	81.84	25	180
John Jay High School	San Antonio, TX	Bexar	Bexar	Dec-01	Siemens SP 75	0.9	81.84	60	180
Roosevelt High School	San Antonio, TX	Bexar	Bexar	Mar-04	Shell SP140PC	1.12	113.92	30	180
Utopia ISD	Utopia, TX	Uvalde	Bexar	Jun-05	GE Energy GEPV-050-M	1	121.4	30	180
City Public Services of San Antonio, Northside	San Antonio, TX	Bexar	Bexar	Jul-02	MSX-120	17.28	1699.2	30*	180*
Del Rio High School	Del Rio, TX	Kinney	Bexar	Jul-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Kendall Elementary School	Boerne, TX	Kendall	Bexar	Apr-07	Sharp Electronics NE-170-U2	1.02	84	35	180
Uvalde Junior High School	Uvalde, TX	Uvalde	Bexar	Jul-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
City Public Services Primary Control Center	San Antonio, TX	Bexar	Bexar	Jun-04	BP MSX-120	17.28	1699.2	30*	N/A
Institute of Texan Cultures	San Antonio, TX	Bexar	Bexar	N/A	N/A	15	N/A	N/A	N/A
Ft. Sam Houston Bldg. 1350	San Antonio, TX	Bexar	Bexar	Apr-06	N/A	181	N/A	N/A	N/A
Bexar County Jail Annex	San Antonio, TX	Bexar	Bexar	N/A	N/A	N/A	N/A	N/A	N/A
Alvin High School	Alvin, TX	Brazoria	Brazoria	Nov-03	Shell SP-140-PC	1.12	113.92	30	180
El Campo Middle School	El Campo, TX	Wharton	Brazoria	Jul-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Bluebonnet Elementary School	Lockhart, TX	Caldwell	Caldwell	Jul-05	GE Energy GEPV-050-M	1	121.4	30	180
Flatonia Elementary School	Flatonia, TX	Gonzales	Caldwell	May-07	Sharp Electronics NE-170-U1	1.02	84	35	180
Leonard Shanklin Elementary School	Luling, TX	Caldwell	Caldwell	Apr-07	Sharp Electronics NE-170-U4	1.02	84	35	180
Waelder ISD	Waelder, TX	Gonzales	Caldwell	May-07	Sharp Electronics NE-170-U5	1.02	64.08	35	180
Blue Ridge ISD	Blue Ridge, TX	Collin	Collin	Oct-03	Siemens SP 75	0.9	81.84	25	180
McKinney Green Building	McKinney, TX	Collin	Collin	Mar-06	ASE-300-DG-FT	45	3749.76	30*	N/A
Canyon High School	New Braunfels, TX	Comal	Comal	Feb-04	Shell SP140PC	1.12	113.92	20	230
Dallas ISD Environmental Education Center	Seagoville, TX	Dallas	Dallas	Feb-04	Shell Solar SP140PC	1.12	113.92	30	180
The Winston School	Dallas, TX	Dallas	Dallas	N/A	BP XXXXXXX	71	N/A	0	N/A
Childress High School	Childress, TX	Childress	Denton	Jul-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Cordova Middle School	El Paso, TX	El Paso	El Paso	Jan-03	Shell SP140PC	1.12	113.92	25	180
Gene Roddenberry Planetarium	El Paso, TX	El Paso	El Paso	Jun-02	4-kW ASE SunSine AC	3.42	313.44	25	180
Monahans High School	Monahans, TX	Ward	El Paso	Dec-01	Siemens SP 75	0.9	81.84	60	180
Presidio High School	Presidio, TX	Presidio	El Paso	Dec-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Weimar High School	Weimar, TX	Colorado	Fort Bend	May-05	GE Energy GEPV-050-M	1	121.4	30	180
Univeresity of Texas Medical Branch at Galveston	Galveston, TX	Galveston	Galveston	Mar-02	Solarex SX-80U	19.2	1892.88	30*	180*

Table 10-3 (cont'd.). Solar Photovoltaic Cell Projects: Data and Information.

Solar Project	City/Town	County	County for ECALC	Date	PV Modules	Capacity(kW)	Total Area (sqft)	Slope	Azimuth (South=180)
Pine Tree Junior High School	Longview, TX	Gregg	Gregg	Mar-00	ASE Americas ASE-300-DG/50	4.56	417.92	25	180
Marion Middle School	Marion, TX	Guadalupe	Guadalupe	May-05	GE Energy GEPV-050-M	1	121.4	30	180
Seabrook Intermediate School	Seabrook, TX	Harris	Harris	Nov-03	Shell SP-140-PC	1.12	113.92	60	180
NASA Johnson Space Center	Houston, TX	Harris	Harris	Oct-04	MSX-121	9.72	955.8	30*	180*
UT Health Science Center	Houston, TX	Harris	Harris	Feb-00	Solarex SJ-7500	1.5	271	30*	180*
Aircraft Obstruction Light	Houston, TX	Harris	Harris	N/A	SX65U	N/A	162.6	30*	180*
Learning Center at Sheldon Lake State Park	Houston, TX	Harris	Harris	N/A	BP Solar	170	108.4	40	180*
Learning Center at Sheldon Lake State Park	Houston, TX	Harris	Harris	N/A	N/A	N/A	81.3	25	180*
Hempstead Middle School	Hempstead, TX	Washington	Harris	Apr-07	Sharp Electronics NE-170-U1	1.02	84	35	180
Houston Ship Channel	Houston, TX	Harris	Harris	Sep-00	BP SX65U	0.78	72	30*	N/A
House in Brenham	Brenham, TX	Washington	Harris	Dec-99	Solarex SJ-7500	1.2	N/A	N/A	N/A
Upper Kirby District Center	Houston, TX	Harris	Harris	N/A	BP XXXXXXX	53	N/A	N/A	N/A
Brenham Jr. High School	Brenham, TX	Washington	Harris	Feb-07	Sharp NE-170-U1	1.02	64.08	35	180
Jefferson Middle School	Jefferson, TX	Harrison	Harrison	Sep-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Brooksmith ISD	Brooksmith, TX	Brown	Hood	Nov-01	Siemens SP 75	0.9	81.84	90	180
Abilene School District Planetarium	Abilene, TX	Taylor	Hood	Aug-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Brenham Middle School	Brenham, TX	Washington	Montgomery	Jun-05	GE Energy GEPV-050-M	1	121.4	30	180
Solar Powered Water Pumping	Bryan, TX	Brazos	Montgomery	N/A	Solarex MST-43/mv	N/A	271	30*	180*
Mission High School	Mission, TX	Hidalgo	Nueces	Feb-00	ASE Americas ASE-300-DG/50	4.56	417.92	25	180
Rio Hondo High School	Rio Hondo, TX	Cameron	Nueces	Apr-00	ASE Americas ASE-300-DG/50	4.56	417.92	25	180
Solar Powered Reverse Osmosis in Colorado Acres	Laredo, TX	Webb	Nueces	N/A	BP3150U	7.2	620.64	30*	180*
Calallen High School	Corpus Cristi, TX	Nueces	Nueces	Nov-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Martin High School	Laredo, TX	Webb	Nueces	Oct-99	ASE Americas ASE-300-DG/50	4.56	418.08	0.01	180
Hamlin ISD	Hamlin, TX	Jones	Parker	Nov-01	Siemens SP 75	0.9	81.84	25	180
Holliday ISD	Holliday, TX	Archer	Parker	Dec-01	Siemens SP 75	0.9	81.84	60	180
Ira ISD	Ira, TX	Scurry	Parker	Nov-01	Siemens SP 75	0.9	81.84	60	180
River Road ISD	Amarillo, TX	Potter	Parker	Dec-01	Siemens SP 75	0.9	81.84	60	180
Spring Hill Junior High School	Longview, TX	Smith	Smith	Nov-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Bryker Woods Elementary School	Austin, TX	Travis	Travis	Oct-03	Shell SP-150-PC	1.2	113.92	60	195
Junction High School	Junction, TX	Kimble	Travis	Feb-04	Shell SP-140-PC	1.12	113.92	60	180
Kealing Middle School	Austin, TX	Travis	Travis	Jan-04	Shell SP140PC	1.2	113.92	60	180
Maplewood Elementary School	Austin, TX	Travis	Travis	Oct-01	Siemens SP 75	1.8	163.68	25	180
City Hall, Austin, Texas	Austin, TX	Travis	Travis	xxx-04	PROSOL (type-austin)***	9.74	894.3	30*	180*
Bedichek Middle Shool	Austin, TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
Blanton Elementary School	Austin, TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
Cunningham elementary School	Austin, TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
Garza High School	Austin, TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
Harper School	Harper, TX	Gillespie	Travis	Mar-07	Sharp Electronics NE-170-U1	1.02	84	35	180
Llano Junior High School	Llano, TX	Llano	Travis	Apr-07	Sharp Electronics NE-170-U5	1.02	84	35	180

Table 10-4 (cont'd.). Solar Photovoltaic Cell Projects: Data and Information.

Solar Project	City/Town	County	County for ECALC	Date	PV Modules	Capacity(kW)	Total Area (sqft)	Slope	Azimuth (South=180)
Martin Middle School	Austin, TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
Murchison Middle School	Austin, TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
O'Henry Middle School	Austin, TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
Pond Springs Elementary School	Austin, TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
San Marcos Electric Utility	San Marcos, TX	Travis	Travis	Apr-07	Sharp Electronics NE-170-U5	1.02	64.08	35	180
Sonora High School	Sonora, TX	Sutton	Travis	Dec-99	ASE Americas ASE-300-DG/50	4.56	418.08	15	220
Vliet Residence	Austin, TX	Travis	Travis	Jan-99	Siemens SP 75	1.8	163.92	20	260
Westwood High School	Austin, TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	225
Zilker Elementary School	Austin TX	Travis	Travis	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
Courtyard Tennis Club	Austin, TX	Travis	Travis	N/A	N/A	23	N/A	N/A	N/A
Escarpment Village	Austin, TX	Travis	Travis	N/A	N/A	7	N/A	N/A	N/A
IBM	Austin, TX	Travis	Travis	N/A	N/A	22	N/A	N/A	N/A
Hines Pool and Spa	Austin, TX	Travis	Travis	N/A	N/A	21	N/A	N/A	N/A
Centex Beverage Inc.	Austin, TX	Travis	Travis	N/A	N/A	22	N/A	N/A	N/A
Lake Austin Marina	Austin , TX	Travis	Travis	N/A	N/A	21	N/A	N/A	N/A
Habitat Suites	Austin, TX	Travis	Travis	N/A	N/A	17	N/A	N/A	N/A
Palmer events Center	Austin, TX	Travis	Travis	N/A	N/A	36	N/A	N/A	N/A
LCRA Environmental Laboratory	Austin, TX	Travis	Travis	N/A	N/A	22	N/A	N/A	N/A
Austin Bergstrom International Airport	Austin, TX	Travis	Travis	N/A	N/A	32	N/A	N/A	N/A
Sand Hill power Plant, Control Building	Austin, TX	Travis	Travis	N/A	N/A	15	N/A	N/A	N/A
Spring Terrace	Austin, TX	Travis	Travis	N/A	N/A	18	N/A	N/A	N/A
American YouthWorks	Austin, TX	Travis	Travis	N/A	N/A	21	N/A	N/A	N/A
Town Lake Trail Foundation	Austin, TX	Travis	Travis	N/A	N/A	0.5	N/A	N/A	N/A
Garden Terrace	Austin, TX	Travis	Travis	N/A	N/A	21	N/A	N/A	N/A
Vintage Creek learning Center	Austin, TX	Travis	Travis	N/A	N/A	11	N/A	N/A	N/A
Ebeneezer Baptist Church	Austin, TX	Travis	Travis	N/A	N/A	8.4	N/A	N/A	N/A
Sierra Ridge	Austin, TX	Travis	Travis	N/A	N/A	17	N/A	N/A	N/A
Westcave Preserve	Round Mountain, TX	Llano	Travis	N/A	N/A	1.7	N/A	N/A	N/A
St. Andrews Episcopal School	Austin, TX	Travis	Travis	N/A	N/A	22	N/A	N/A	N/A
St. Gabriel Catholic Church	Austin, TX	Travis	Travis	N/A	N/A	21	N/A	N/A	N/A
Hornsby Bend Birding Shelter	Austin, TX	Travis	Travis	N/A	N/A	0.3	N/A	N/A	N/A
Casa Verde	Austin, TX	Travis	Travis	N/A	N/A	1.5	N/A	N/A	N/A
Mineola High School	Mineola, TX	Wood	Upshur	Oct-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Cuero Junior High School	Cuero, TX	DeWitt	Victoria	Jun-05	GE Energy GEPV-050-M	1	121.4	30	180
Solar Powered Water Purification	Matagorda Island, TX	Calhoun	Victoria	N/A	BP585U	N/A	111.23	30*	180*
Central High School	San Angelo, TX	Tom Green	Williamson	Jul-99	ASE Americas ASE-300-DG/50	4.56	418.08	25	180
Davis Elementary School	Round Rock, TX	Williamson	Williamson	Oct-06	Sharp ND-L3EJEA	4.059	352.44	30	180
Lampasas Middle School	Lampasas, TX	Lampasas	Williamson	Apr-07	Sharp Electronics NE-170-U3	1.02	84	35	180

Note: (*) = Assumed

Table 10-5. Solar Photovoltaic Cell Projects: Energy and NOx Reductions.

		Annual Energy Savings (for base year conditions)							Average per Ozone Season Day (for base year conditions)						
		Annual Energy	1999			2007			Annual Energy	1999			2007		
Project	County for ECALC	Consumption (KWh/yr)	No_x	So_x	CO_2	No_x	So_x	CO_2	Consumption (KWh/yr)	No_x	So_x	CO_2	No_x	So_x	CO_2
Giddings Middle School	Bastrop	1774.00	6.90	3.92	2548.00	2.90	1.62	2286.00	5.00	0.02	0.01	8.00	0.01	0.00	7.00
La Grange Intermediate School	Bastrop	1774.00	6.90	3.92	2548.00	2.90	1.62	2286.00	5.00	0.02	0.01	8.00	0.01	0.00	7.00
Schulenburg Elementary School	Bastrop	1774.00	6.90	3.92	2548.00	2.90	1.62	2286.00	5.00	0.02	0.01	8.00	0.01	0.00	7.00
Smithville Junior High School	Bastrop	1774.00	6.90	3.92	2548.00	2.90	1.62	2286.00	5.00	0.02	0.01	8.00	0.01	0.00	7.00
Bastrop Intermediate School	Bastrop	1212	4.71	2.67	1741	1.98	1.11	1562	4	0.01	0.01	5	0.01	0	4
Eagle Pass High School - CC Winn Campus	Bexar	1207.00	3.18	1.15	1792.00	1.99	1.98	1960.00	4.00	0.01	0.00	6.00	0.01	0.00	6.00
East Central ISD	Bexar	1411.00	3.72	1.34	2096.00	2.33	2.31	2292.00	4.00	0.01	0.00	6.00	0.01	0.00	6.00
James Madison High School	Bexar	1207.00	3.18	1.15	1792.00	1.99	1.98	1960.00	4.00	0.01	0.00	6.00	0.01	0.00	6.00
John Jay High School	Bexar	1013.00	2.67	0.96	1505.00	1.67	1.66	1646.00	3.00	0.01	0.00	4.00	0.00	0.00	4.00
Roosevelt High School	Bexar	1669.00	4.40	1.58	2478.00	2.75	2.73	2711.00	5.00	0.01	0.00	7.00	0.01	0.01	8.00
Utopia ISD	Bexar	1779.00	4.69	1.69	2641.00	2.94	2.91	2889.00	5.00	0.01	0.01	8.00	0.01	0.01	9.00
City Public Services of San Antonio, Northside	Bexar	24895.00	65.67	23.63	36970.00	41.08	40.79	40436.00	75.00	0.20	0.07	112.00	0.12	0.08	120.00
Del Rio High School	Bexar	6165	16.26	5.85	9155	10.17	10.1	10013	19	0.05	0.02	28	0.03	0.02	30
Kendall Elementary School	Bexar	1215	3.21	1.15	1805	2.01	1.99	1974	4	0.01	0	5	0.01	0	6
Uvalde Junior High School	Bexar	6165	16.26	5.85	9155	10.17	10.1	10013	19	0.05	0.02	28	0.03	0.02	30
City Public Services Primary Control Center	Bexar	24895	65.67	23.63	36970	41.08	40.79	40436	75	0.2	0.07	112	0.12	0.08	120
Institute of Texan Cultures	Bexar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ft. Sam Houston Bldg. 1350	Bexar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bexar County Jail Annex	Bexar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Alvin High School	Brazoria	1490.00	3.60	3.08	2344.00	2.58	2.00	2106.00	4.00	0.01	0.01	7.00	0.01	0.00	6.00
El Campo Middle School	Brazoria	5513	13.31	11.41	8670	9.54	7.4	7790	17	0.04	0.03	26	0.03	0.02	23
Bluebonnet Elementary School	Caldwell	1774.00	4.93	1.02	2469.00	2.13	0.71	2087.00	5.00	0.01	0.00	7.00	0.01	0.00	6.00
Flatonia Elementary School	Caldwell	1212	3.36	0.7	1687	1.46	0.49	1426	4	0.01	0	5	0	0	4
Leonard Shanklin Elementary School	Caldwell	1212	3.36	0.7	1687	1.46	0.49	1426	4	0.01	0	5	0	0	4
Waelder ISD	Caldwell	925	2.57	0.53	1287	1.11	0.37	1088	3	0.01	0	4	0	0	3
Blue Ridge ISD	Collin	1230.00	4.72	2.73	1777.00	2.00	1.12	1586.00	4.00	0.01	0.01	6.00	0.01	0.00	5.00
McKinney Green Building	Collin	56096	215.35	124.75	81061	91.21	50.98	72330	171	0.66	0.38	248	0.28	0.07	213
Canyon High School	Comal	1681.00	4.43	1.60	2496.00	2.77	2.75	2730.00	5.00	0.01	0.01	8.00	0.01	0.01	8.00
Dallas ISD Environmental Education Center	Dallas	1704.00	6.62	3.76	2448.00	2.79	1.56	2196.00	5.00	0.02	0.01	7.00	0.01	0.00	6.00
The Winston School	Dallas	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Childress High School	Denton	6284	24.12	13.98	9081	10.22	5.71	8103	20	0.08	0.04	28	0.03	0.01	24
Cordova Middle School	El Paso	2008.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00
Gene Roddenberry Planetarium	El Paso	5525.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00
Monahans High School	El Paso	1240.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
Presidio High School	El Paso	7370	0	0	0	0	0	0	21	0	0	0	0	0	0

Table 10-6 (cont'd.). Solar Photovoltaic Cell Projects: Energy and NOx Reductions.

		Annual Energy Savings (for base year conditions)							Average per Ozone Season Day (for base year conditions)						
		Annual Energy	1999			2007			Annual Energy	1999			2007		
Project	County for ECALC	Consumption (KWh/yr)	No_x	So_x	CO_2	No_x	So_x	CO_2	Consumption (KWh/yr)	No_x	So_x	CO_2	No_x	So_x	CO_2
Weimar High School	Fort Bend	1588.00	3.84	3.25	2490.00	2.77	2.16	2249.00	5.00	0.01	0.01	7.00	0.01	0.01	7.00
Univeresity of Texas Medical Branch at Galveston	Galveston	24763.00	59.80	51.24	38942.00	42.85	33.23	34990.00	74.00	0.18	0.15	116.00	0.12	0.08	101.00
Pine Tree Junior High School	Gregg	5747.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00
Marion Middle School	Guadalupe	1779.00	4.69	1.69	2641.00	2.94	2.91	2889.00	5.00	0.01	0.01	8.00	0.01	0.01	9.00
Seabrook Intermediate School	Harris	1255.00	2.10	1.77	1358.00	1.51	1.18	1226.00	3.00	0.01	0.00	4.00	0.00	0.00	3.00
NASA Johnson Space Center	Harris	12504.00	20.87	17.66	13.53	15.04	11.75	12216.00	37.00	0.06	0.05	40.00	0.04	0.03	35.00
UT Health Science Center	Harris	3545.00	5.92	5.01	3835.00	4.26	3.33	3464.00	11.00	0.02	0.01	11.00	0.01	0.01	10.00
Aircraft Obstruction Light	Harris	2127.00	3.65	3.00	2301.00	2.56	2.00	2078.00	6.00	0.01	0.01	7.00	0.01	0.00	6.00
Learning Center at Sheldon Lake State Park	Harris	1372.00	2.29	1.94	1484.00	1.65	1.29	1340.00	4.00	0.01	0.01	4.00	0.00	0.00	4.00
Learning Center at Sheldon Lake State Park	Harris	1072.00	1.79	1.51	1160.00	1.29	1.01	1048.00	3.00	0.01	0.00	4.00	0.00	0.00	3.00
Hempstead Middle School	Harris	1083	1.81	1.53	1171	1.3	1.02	1058	3	0.01	0	3	0	0	3
Houston Ship Channel	Harris	942	1.57	1.33	1019	1.13	0.89	920	3	0	0	3	0	0	3
House in Brenham	Harris	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Upper Kirby District Center	Harris	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Brenham Jr. High School	Harris	826	1.38	1.17	893	0.99	0.78	807	2	0	0	3	0	0	2
Jefferson Middle School	Harrison	5749	0	0	0	0	0	0	18	0	0	0	0	0	0
Brooksmith ISD	Hood	670.00	2.57	1.49	969.00	1.09	0.61	864.00	1.00	0.01	0.00	2.00	0.00	0.00	2.00
Abilene School District Planetarium	Hood	6284	24.12	19.98	9081	10.22	5.71	8103	20	0.08	0.04	28	0.03	0.01	24
Brenham Middle School	Montgomery	1588.00	2.65	2.24	1718.00	1.91	1.49	1552.00	5.00	0.01	0.01	5.00	0.01	0.00	4.00
Solar Powered Water Pumping	Montgomery	3545.00	5.92	5.01	3835.00	4.26	3.33	3464.00	11.00	0.02	0.01	11.00	0.01	0.01	10.00
Mission High School	Nueces	5565.00	15.45	3.20	7746.00	6.68	2.23	6546.00	17.00	0.05	0.01	24.00	0.02	0.00	20.00
Rio Hondo High School	Nueces	5565.00	15.45	3.20	7746.00	6.68	2.23	6546.00	17.00	0.05	0.01	24.00	0.02	0.00	20.00
Solar Powered Reverse Osmosis in Colorado Acres	Nueces	8187.00	22.73	4.70	11395.00	9.83	3.28	9630.00	25.00	0.07	0.01	35.00	0.03	0.01	28.00
Calallen High School	Nueces	5567	15.45	3.2	7748	6.68	2.23	6549	17	0.05	0.01	24	0.02	0	20
Martin High School	Nueces	5373	14.91	3.09	7478	6.45	2.15	6320	18	0.05	0.01	25	0.02	0	20
Hamlin ISD	Parker	1230.00	4.78	2.71	1766.00	2.01	1.13	1585.00	4.00	0.01	0.01	6.00	0.01	0.00	5.00
Holliday ISD	Parker	1047.00	4.07	2.31	1504.00	1.71	0.96	1349.00	3.00	0.01	0.01	4.00	0.00	0.00	3.00
Ira ISD	Parker	1047.00	4.07	2.31	1504.00	1.71	0.96	1349.00	3.00	0.01	0.01	4.00	0.00	0.00	3.00
River Road ISD	Parker	1047.00	4.07	2.31	1504.00	1.71	0.96	1349.00	3.00	0.01	0.01	4.00	0.00	0.00	3.00
Spring Hill Junior High School	Smith	5749	22.35	12.69	8258	9.4	5.26	7408	18	0.07	0.04	26	0.03	0.01	22
Bryker Woods Elementary School	Travis	1404.00	5.39	3.03	2014.00	2.28	1.26	1807.00	4.00	0.01	0.01	5.00	0.01	0.00	5.00
Junction High School	Travis	1404.00	5.39	3.03	2014.00	2.28	1.26	1807.00	4.00	0.01	0.01	5.00	0.01	0.00	5.00
Kealing Middle School	Travis	1404.00	5.39	3.03	2014.00	2.28	1.26	1807.00	4.00	0.01	0.01	5.00	0.01	0.00	5.00
Maplewood Elementary School	Travis	2408.00	9.25	5.20	3455.00	3.91	2.17	3100.00	7.00	0.03	0.02	11.00	0.01	0.00	9.00
City Hall, Austin, Texas	Travis	13069.00	50.19	28.24	18747.00	21.23	11.75	16821.00	39.00	0.15	0.09	57.00	0.06	0.02	49.00
Bedichek Middle Shool	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
Blanton Elementary School	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
Cunningham elementary School	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
Garza High School	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19

Table 10-7 (cont'd.). Solar Photovoltaic Cell Projects: Energy and NOx Reductions.

		Annual Energy Savings (for base year conditions)							Average per Ozone Season Day (for base year conditions)						
		Annual Energy	1999			2007			Annual Energy	1999			2007		
Project	County for ECALC	Consumption (KWh/yr)	No_x	So_x	CO_2	No_x	So_x	CO_2	Consumption (KWh/yr)	No_x	So_x	CO_2	No_x	So_x	CO_2
Harper School	Travis	1212	4.65	2.62	1739	1.97	1.09	1560	4	0.01	0.01	5	0.01	0	4
Llano Junior High School	Travis	1212	4.65	2.62	1739	1.97	1.09	1560	4	0.01	0.01	5	0.01	0	4
Martin Middle School	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
Murchison Middle School	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
O'Henry Middle School	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
Pond Springs Elementary School	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
San Marcos Electric Utility	Travis	925	3.55	2	1326	1.5	0.83	1190	3	0.01	0.01	4	0	0	3
Sonora High School	Travis	6131	23.54	13.25	8795	9.96	5.51	7891	20	0.07	0.04	28	0.03	0.01	24
Vliet Residence	Travis	2415	9.27	5.22	3465	3.92	2.17	3109	8	0.03	0.02	11	0.01	0	9
Westwood High School	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
Zilker Elementary School	Travis	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
Courtyard Tennis Club	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Escarpment Village	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
IBM	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hines Pool and Spa	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Centex Beverage Inc.	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lake Austin Marina	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Habitat Suites	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Palmer events Center	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LCRA Environmental Laboratory	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Austin Bergstrom International Airport	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sand Hill power Plant, Control Building	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Spring Terrace	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
American YouthWorks	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Town Lake Trail Foundation	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Garden Terrace	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vintage Creek learning Center	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ebeneezer Baptist Church	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sierra Ridge	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Westcave Preserve	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
St. Andrews Episcopal School	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
St. Gabriel Catholic Church	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hornsby Bend Birding Shelter	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Casa Verde	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mineola High School	Upshur	5749	0	0	0	0	0	0	18	0	0	0	0	0	0
Cuero Junior High School	Victoria	1624.00	4.51	0.93	2260.00	1.95	0.65	1910.00	5.00	0.01	0.00	7.00	0.01	0.00	6.00
Solar Powered Water Purification	Victoria	1488.00	4.13	0.86	2071.00	1.79	0.60	1750.00	4.00	0.01	0.00	6.00	0.01	0.00	5.00
Central High School	Williamson	6151	23.62	13.29	8824	9.99	5.53	7917	19	0.07	0.04	27	0.03	0.01	23
Davis Elementary School	Williamson	5150	19.78	11.13	7389	8.37	4.63	6629	16	0.06	0.03	22	0.03	0.01	19
Lampasas Middle School	Williamson	1212	4.65	2.62	1739	1.97	1.09	1560	4	0.01	0.01	5	0.01	0	4
TOTAL		396467.00	1151.65	618.50	504339.53	566.73	379.78	483511.00	1206.00	3.46	1.78	1565.00	1.75	0.66	1413.00

Note: Nox, Sox, and CO_2 emissions reductions are zero for not ERCOT counties (El Paso, Harrison,Gregg, and Upshur).

Table 10-8. Solar Thermal Projects.

City	County	County for eCalc	Project Purpose	Model	Total Area (sqft)	Slope (degree)	Azimuth (i.e. South=0, West (-) and East (+))	Fluid
Austin	Travis	Travis	Domestic Hot Water (DHW)	N/A	N/A	N/A	0	Antifreeze
Austin	Travis	Travis	Domestic Hot Water (DHW)	SS HX Drainback	78.75	20	0	Water
Round Rock	Willamson	Willamson	Domestic Hot Water (DHW)	SS HX Drainback	52.5	20	-90	Water
Dripping Springs	Hays	Hays	Domestic Hot Water (DHW)	SS HX Drainback	52.5	20	20	Water
San Antonio	Bexar	Bexar	Domestic Hot Water (DHW)	SS HX Drainback	52.5	20	0	Water
San Antonio	Bexar	Bexar	Pool Heating System	FS collector	256	20	-45	Water
N/A	N/A	N/A	Domestic Hot Water (DHW)	SS HX Drainback	78.75	20	-45	Water
N/A	N/A	N/A	Domestic Hot Water (DHW)	SS HX Drainback	52.5	20	-45	Water

Table 10-9. Solar Thermal Projects Emissions Reduction.

		Annual Energy Savings (for base year conditions)							Average per Ozone Season Day (for base year conditions)						
		Annual Energy	1999			2007			Annual Energy Consumption	1999			2007		
Project	County for ECALC	Consumption (KWh/yr)	No_x	So_x	CO_2	No_x	So_x	CO_2	(KWh/yr)	No_x	So_x	CO_2	No_x	So_x	CO_2
1	Travis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Travis	4134	15.87	8.93	5930	6.71	3.72	5320	14	0.05	0.03	20	0.02	0.01	17
3	Willamson	3211	12.33	6.94	4606	5.22	2.89	4133	13	0.05	0.03	18	0.02	0	16
4	Hays	3469	9.16	2.44	4791	4.41	1.14	4234	12	0.03	0.01	17	0.02	0	15
5	Bexar	3469	9.15	3.29	5152	5.73	5.68	5635	12	0.03	0.01	18	0.02	0.01	19
6	Bexar	26235	69.2	24.9	38960	43.3	42.98	42.612	87	0.23	0.08	130	0.14	0.09	140
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL		40518	115.71	46.5	59439	65.37	56.41	19364.6	138	0.39	0.16	203	0.22	0.11	207

Table 10-10. Solar Thermal Special Project.

Special Case	
Location	Fort Sam Houston, San Antonio TX
Date	Jun-03
Collector	Roof Mounted Parabolic Trough
Number of collectors	129
Total Aperture area (sqft)	4515
Maximum operation temperature (°F)	400
Annual Energy Consumption (KWh/yr)	270583
Annual Energy Consumption OSD (KWh/yr)	741.3

Table 10-11. Hydroelectric Plant Information.

Hydropower Plant	County	Operator	District per IDL*	Date Built	Capacity (MW)
Abbott TP-3	Victoria	Guadalupe Blanco River Authority	12	1920/30's	2.8
Amistad	Valverde	Intl Bndry and water commission	13	1969	66
Austin (Miller)	Lampasas	Lower Colorado River Authority	12	1938	13.4
Buchanan 3	Burnet	Lower Colorado River Authority	12	1931	22.5
Buchanan	Burnet	Lower Colorado River Authority	12	1931	11.25
Canyon	Randall	Guadalupe Blanco River Authority	12	1989	6.07
Cuero	Dewitt	Cuero Hydroelectric	12	Historical Register 1977	1.125
Denison	Grayson	Corps of Engineergs	11	1940's	70
Dunlap TP 1	Guadalupe	Guadalupe Blanco River Auth	12	1920/30's	3.6
Eagle Pass	Maverick	Central Power and LT Co	13	1930's	9.6
Falcon	Zapata	Intl Bndry and water commission	13	1953	31.5
Gonzales	Gonzales	Gonzales	12	1925	1.14
H-4 (Lake Gonzales)	Guadalupe	Guadalupe Blanco River Auth	12	1920/30's	2.4
H-5 (Lake Wood)	Guadalupe	Guadalupe Blanco River Auth	12	1920/30's	2.4
Inks	Burnet	Lower Colorado River Authority	12	1936	12.5
LB Johnson (Wirtz)	Burnet	Lower Colorado River Authority	12	1949	45
Lewisville	Denton	Denton	12	N/A	2
Mansfield	Burnet	Lower Colorado River Authority	12	1937	83.7
Max Starcke	Burnet	Lower Colorado River Authority	12	1949	30
Morris Sheppard	Palo Pinto	Brazos River Authority	12	N/A	22.5
Nolte (TP- 5/Meadow Lake)	Williamson	Guadalupe Blanco River Auth	12	1920/30's	2.4
Ray Roberts	Grayson	Denton	12	N/A	1.2
Sam Rayburn	Jasper	Corps of Engineergs	12	1956	52
Seguin	Guadalupe	Seguin	12	N/A	0.25
Toledo Bend	Newton	Sabine R Authority LA & Tex	12	N/A	80.75
Town Bluff	Jasper	Corps of Engineergs	12	1989	8
TP 4	Guadalupe	Guadalupe Blanco River Auth	12	1920/30's	2.4
Whitney	Bosque	Corps of Engineergs	12	1955	30
Total capacity					**616.485**

*Note: IDL is the Idaho National Laboratory which supports the U.S. Department of Energy's energy research.

Table 10-12. Geothermal Heat Pump Energy Projects.

Project	County	Implementation Date	Capacity (ton)	Area (sqft)
Birdville High School Campus	Denton	2001	N/A	N/A
Texas Motor Speedway	Denton	1998	N/A	N/A
George W. Bush's ranch	McLennan	2001	14	N/A
Esperanza del Sol, Dallas (Hope of the Sun)	Dallas	1994	18	15276
Hillside Oaks, East Dallas	Dallas	1997	366	276120
Pease Elementary School, Austin	Travis	1997	90	39162
Brooke Elementary School	Travis	1997	150	51605
Govalle Elementary School	Travis	1997	230	89319
Bailey Middle School, Austin	Travis	1997	512	200000
Home in Iowa Park	Wichita	1997	1	1668
The Home of the Future	Dallas	1997	13	4573

Table 10-13. Landfill Gas-fired Power Plants: Operational.

Landfill Name	City	County	Waste In Place (tons)	Landfill Owner Organization	Project Status	Project Start Date	MW Capacity	LFG Flow to Project (SCFD)	Emission Reductions (MTCO2)
Arlington LF	Arlington	Tarrant	13,981,144	City of Arlington	Operational	6/1/2001	5.0	1.584	0.217
BFI - Tessman Road Landfill	San Antonio	Bexar	11,300,000	Allied Waste Services	Operational	10/10/2002	5.4	2.900	0.234
BFI - Tessman Road Landfill	San Antonio	Bexar	11,300,000	Allied Waste Services	Operational	5/1/2003	2.7	1.450	0.117
Blue Bonnet LF	Houston	Harris	2,526,000	Waste Management, Inc.	Operational	3/1/2003	1.9	0.928	0.084
Castle Road Landfill	Garland	Dallas	4,012,500	City of Garland	Operational	5/1/2000	N/A	N/A	0.089
City of Austin LF	Austin	Travis	4,858,500	City of Austin, TX	Operational	2/1/2004	0.2	N/A	0.009
City of Brownwood Landfill	Brownwood	Brown	1,300,100	City of Brownwood	Operational	1/1/1998	N/A	N/A	0.035
City of Conroe LF	Conroe	Montgomery	3,146,000	City of Conroe	Operational	3/1/2003	2.9	N/A	0.126
City of Waco LF	Woodway	McLennan	2,225,000	City of Waco	Operational	3/1/2004	1.5	1.000	0.065
Coastal Plains LF	Alvin	Galveston	6,546,410	Waste Management, Inc.	Operational	1/10/2003	6.7	N/A	0.289
Covel Gardens LF	San Antonio	Bexar	12,007,000	Waste Management, Inc.	Operational	12/1/2005	9.6	N/A	0.416
Dallas-Fort Worth LF	Dallas	Denton	18,388,100	Waste Management, Inc.	Operational	1/1/1992	6.6	N/A	0.286
Denton Sanitary Landfill	Denton	Denton	2,266,664	City of Denton, TX	Operational	2/1/2005	N/A	0.432	0.035
McCarty Road LF	Houston	Harris	28,918,718	Allied Waste Services	Operational	1/1/1986	N/A	N/A	0.797
McCommas Bluff LF/City of Dallas	Dallas	Dallas	26,470,000	City of Dallas, TX	Operational	1/1/2000	N/A	N/A	0.772
Rosenberg Landfill	Rosenberg	Fort Bend	2,649,100	Fort Bend County, TX	Operational	1/1/2000	N/A	1.000	0.082
Sanifill Of Texas-Baytown LF	Baytown	Chambers	6,290,000	Waste Management, Inc.	Operational	1/24/2003	3.9	1.730	0.169
Security Recycling and Disposal LF	Cleveland	Montgomery	4,014,800	Waste Management, Inc.	Operational	5/1/2003	5.0	N/A	0.217
Sunset Farms	Austin	Travis	9,600,000	Allied Waste Services	Operational	12/1/1996	3.0	1.500	0.130
WMI/Atascocita LF	Humble	Harris	9,628,700	Waste Management, Inc.	Operational	6/1/2003	8.5	3.090	0.368
WMI/Atascocita LF	Humble	Harris	9,628,700	Waste Management, Inc.	Operational	1/1/2004	1.7	0.620	0.074
Denton Sanitary Landfill	Denton	Denton	2,266,664	City of Denton, TX	Construction	9/1/2006	1.5	0.860	0.065
Fort Worth Regional LF	Haltom City	Tarrant	N/A	Allied Waste Services	Construction	3/15/2006	1.6	0.720	0.069
McCommas Bluff LF/City of Dallas	Dallas	Dallas	26,470,000	City of Dallas, TX	Construction	7/1/2006	22.0	N/A	0.953
Austin Community LF	Austin	Travis	10,380,188	Waste Management, Inc.	Shutdown	1/1/1998	N/A	N/A	N/A

SCFD = Million of standard cubic feet
MTCO2 = Million Tons of CO2

Table 10-14. Landfill Gas-Fired Power Plants: Candidates.

Landfill Name	City	County	Waste In Place (tons)	Year Landfill Opened	Landfill Closure Year	Landfill Owner Organization
Services LLC	Altair	Colorado	9,195,000	1988	2004	Clean Harbors
Amarillo LF	Amarillo	Potter	7,031,400	1976	2050	City of Amarillo
LF	Austin	Travis	10,380,188	1977	2001	Waste Management, Inc.
Landfill	Abilene	Jones	7,921,300	1982	2067	Ray Knowles
Blue Ridge LF	Fresno	Fort Bend	4,113,900	1993	2025	Allied Waste Services
Disposal LF	Angleton	Brazoria	6,279,700	1993	2050	Republic Services, Inc.
SWMA Landfill	Brian & College Station	Brazos	3,009,600	1981	2007	Brazos Valley SWMA
C&T Landfill	Linn	Hidalgo	3,844,000	1976	2004	Duncan Disposal, Inc.
Camelot Landfill	Lewisville	Denton	6,044,700	1981	2019	City of Farmers Branch
Landfill	Odessa	Ector	1,300,000	N/A	N/A	Republic Services, Inc.
LF	Beaumont	Jefferson	2,868,800	1983	2021	City of Beaumont
Prairie LF	Grand Prairie	Dallas	2,835,800	1977	2021	City of Grand Prairie
Landfill	Irving	Dallas	2,063,900	1981	2065	City of Irving, TX
City of Laredo LF	Laredo	Webb	3,180,000	1986	2015	City of Laredo
City of Lubbock LF	Lubbock	Lubbock	2,177,800	1975	2008	City of Lubbock
LF	Mckinney	Collin	3,957,000	1980	2004	City of McKinney
City Of Midland LF	Midland	Midland	3,053,200	1990	2170	City of Midland
Nacogdoches	Nacogdoches	Nacogdoches	1,296,200	1977	2033	City of Nacogdoches
City of Pampa LF	Pampa	Gray	1,176,200	1975	2007	City of Pampa
Landfill	Perryton	Ochiltree	1,631,100	1979	2006	City of Perryton
Landfill	Port Arthur	Jefferson	1,802,100	1986	2044	City of Port Arthur
LF	Sweetwater	Nolan	1,283,800	1976	2040	City of Sweetwater
Landfill	Temple	Bell	3,600,000	N/A	N/A	City of Temple
Landfill	Bloomington	Victoria	2,556,000	1982	2040	City of Victoria
Weatherford LF	Weatherford	Parker	1,079,000	1976	2060	IESI, Inc.
Falls LF	Wichita Falls	Wichita	4,073,200	1982	2021	City of Wichita Falls
Clint LF	Clint	El Paso	4,904,400	1983	2006	City of El Paso
Landfill	Colorado City	Mitchell	1,545,200	1975	2020	City of Colorado City
Comal County LF	New Braunfels	Comal	3,817,620	1975	2010	Waste Management, Inc.
Landfill	Avalon	Ellis	4,254,250	1985	2100	Republic Services, Inc.
Eastside Landfill	Fort Worth	Tarrant	N/A	N/A	N/A	Waste Management, Inc.
Southeast Landfill	Kennedale	Tarrant	5,299,400	1976	2036	City of Fort Worth, TX
LF	Alta Loma	Galveston	7,822,500	1973	2025	Allied Waste Services
Landfill	Beaumont	Jefferson	2,310,400	1991	2021	Allied Waste Services
Landfill	Tyler	Smith	3,087,300	1989	2020	City of Tyler
Hillside Landfill	Sherman	Grayson	2,526,400	1981	2023	Waste Management, Inc.
J.C. Elliot LF	Corpus Christi	Nueces	5,717,100	1972	2005	City of Corpus Christi, TX
Lacy-Lakeview LF	Waco	McLennan	1,306,200	1985	2020	Waste Management, Inc.
McCombs LF	El Paso	El Paso	4,137,100	1984	2046	City of El Paso
Mill Creek LF	Fort Worth	Tarrant	4,815,500	1973	2002	Allied Waste Services
Nelson Gardens LF	San Antonio	Bexar	11,800,000	1980	1993	City of San Antonio
Waste/Maxwell	Plano	Collin	6,083,700	1982	2004	North Texas Municipal Water District
Pine Hill LF	Longview	Gregg	12,141,700	1982	2060	4S Oil Company
Landfill	Jacksonville	Cherokee	1,044,200	1983	2030	Allied Waste Services
Skyline LF	Ferris	Ellis	8,191,000	1942	2040	Waste Management, Inc.
(Amarillo)	Canyon	Randall	3,393,200	1987	2025	Allied Waste Services
County LF	Sugarland	Fort Bend	1,664,372	1981	2020	The Sprint Companies
Sprint LF	Sugarland	Harris	2,041,600	1987	2005	Landfill Owner
Systems LF	Austin	Travis	4,408,900	1990	2050	Texas Disposal Systems
Environmental	Altair	Colorado	1,980,400	1976	2002	Safety Clean
Landfill	Dallas	Dallas	6,838,600	1969	2003	Allied Waste Services
Turkey Creek LF	Alvarado	Johnson	3,733,200	1983	2025	Allied Waste Services
LF	Aledo	Tarrant	9,955,600	1977	2005	Waste Management, Inc.
LF	Houston	Harris	6,405,000	1978	2017	Allied Waste Services
LF	Hutto	Williamson	2,134,700	1981	2040	Waste Management, Inc.
Systems Inc. LF	Alvin	Galveston	3,202,900	1994	2022	Waste Management, Inc.

Table 10-15. Landfill Gas-fired Power Plants: Potential.

Landfill Name	City	County	Waste In Place (tons)	Year Landfill Opened	Landfill Closure	Landfill Owner
Bell County/Sparks LF	Belton	Bell	343,200	1994	2001	Bell County
Bell Processing Inc. LF	Wichita Falls	Wichita	N/A	1990	2001	Bell Processing Inc
Best Pak Disposal Inc. LF	Pattison	Waller	N/A	N/A	2001	Waste Management, Inc.
BFI LF	Abilene	Taylor	745,888	1993	1997	Pine Street Salvage Company
City of Cleburne Landfill	Cleburne	Johnson	1,583,200	1976	N/A	Landfill Owner
City of Corsicana LF	Corsicana	Navarro	788,100	1993	2100	Landfill Owner
City of Richardson LF	Richardson	Collin	825,218	1975	1990	City of Richardson
ECD Landfill	Ennis	Ellis	N/A	1988	2089	Allied Waste Services
El Centro Landfill	Robstown	Nueces	N/A	2000	2013	Allied Waste Services
Ellis County LF	Palmer	Ellis	892,320	1994	N/A	Waste Management, Inc.
Gulfwest Facility	Anahuac	Chambers	N/A	1993	2017	Allied Waste Services
Hazelwood Enterprises, Inc. LF	N/A	N/A	N/A	N/A	N/A	Landfill Owner
Hutchins Landfill	Hutchins	Dallas	1,000,000	1978	1992	Allied Waste Services
Itasca Landfill	Itasca	Hill	N/A	1977	2017	Allied Waste Services
Kerrville Landfill	Kerrville	Kerr	N/A	1985	2006	City of Kerrville
Laidlaw/Wilmer LF	Wilmer	Dallas	686,400	1992	2001	Landfill Owner
Lewisville Landfill	Lewisville	Denton	N/A	1986	2003	Allied Waste Services
Maloy Landfill	Commerce	Hunt	610,000	1979	2030	Republic Services, Inc.
Mexia Landfill	Mexia	Limestone	N/A	1983	2019	Allied Waste Services
New Boston Landfill	New Boston	Bowie	N/A	N/A	N/A	N/A
Newton County Landfill	Mauriceville	Newton	N/A	N/A	N/A	N/A
North County C&D Landfill	League City	Galveston	N/A	N/A	N/A	Republic Services, Inc.
Paris Landfill	Paris	Lamar	N/A	N/A	N/A	N/A
Pecan Prairie Landfill	Kingston	Hunt	1,479,900	1984	1998	Waste Management, Inc.
Pleasant Oaks Landfill	Mount Pleasant	Titus	N/A	1960	2012	City of Mount Pleasant
Quail Canyon	Lubbock	Lubbock	200,200	1977	1993	Allied Waste Services
Rio Grande Valley	Donna	Hidalgo	N/A	N/A	N/A	Allied Waste Services
Sinton	Sinton	San Patricio	N/A	1972	2002	Allied Waste Services
Trashaway San Angelo Landfill	San Angelo	Tom Green	790,000	1984	N/A	Republic Services, Inc.

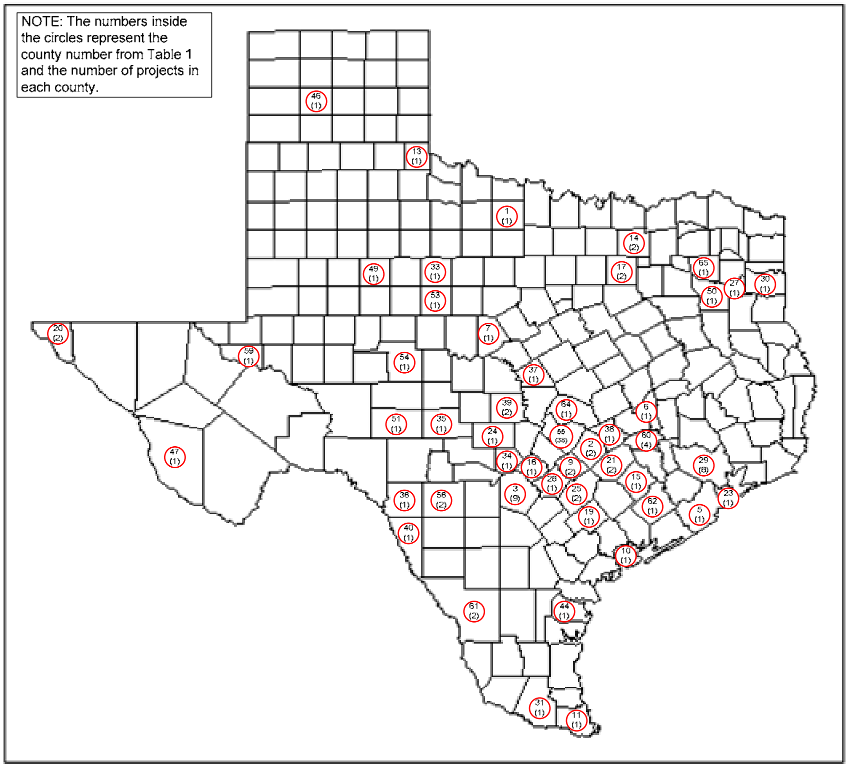


Figure 10-1. Solar Photovoltaic Projects throughout Texas.

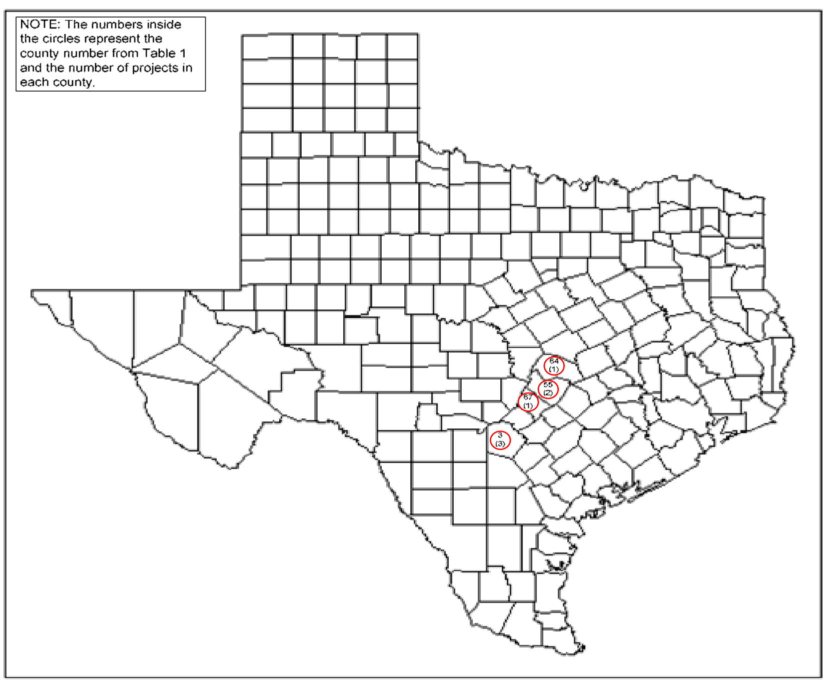


Figure 10-2. Solar Thermal Projects throughout Texas.

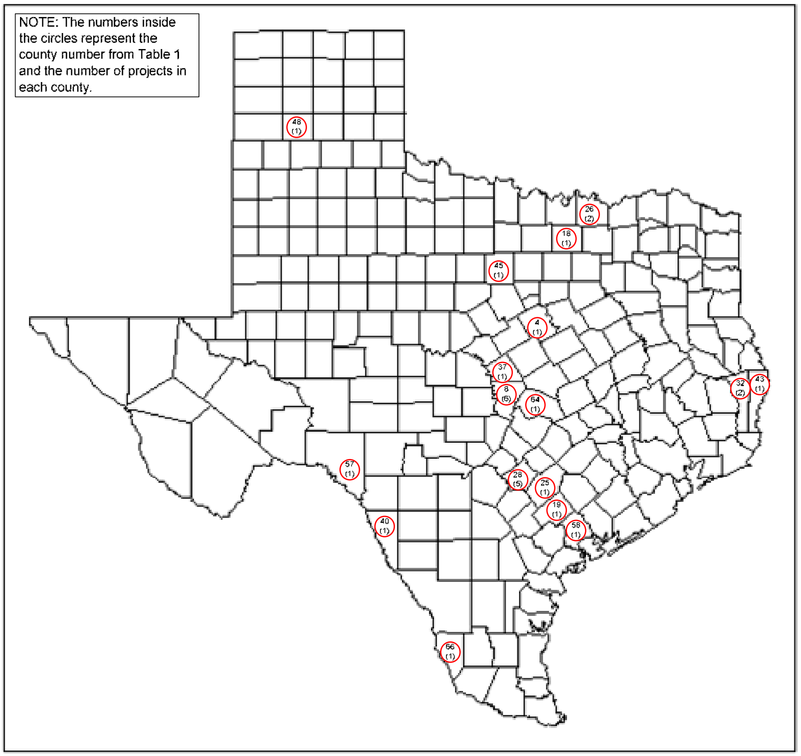


Figure 10-3. Hydroelectric Plants throughout Texas.

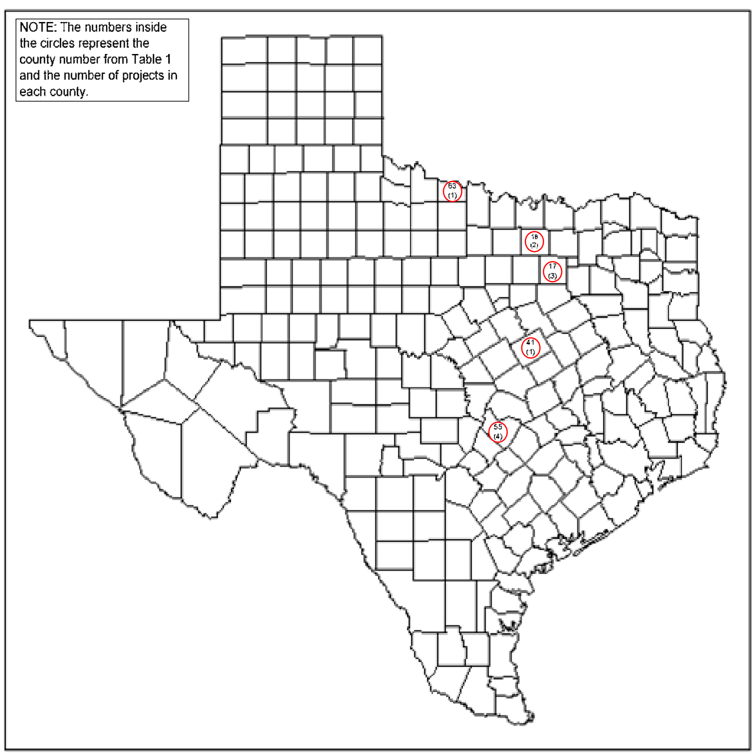


Figure 10-4. Geothermal Projects Installed throughout Texas.

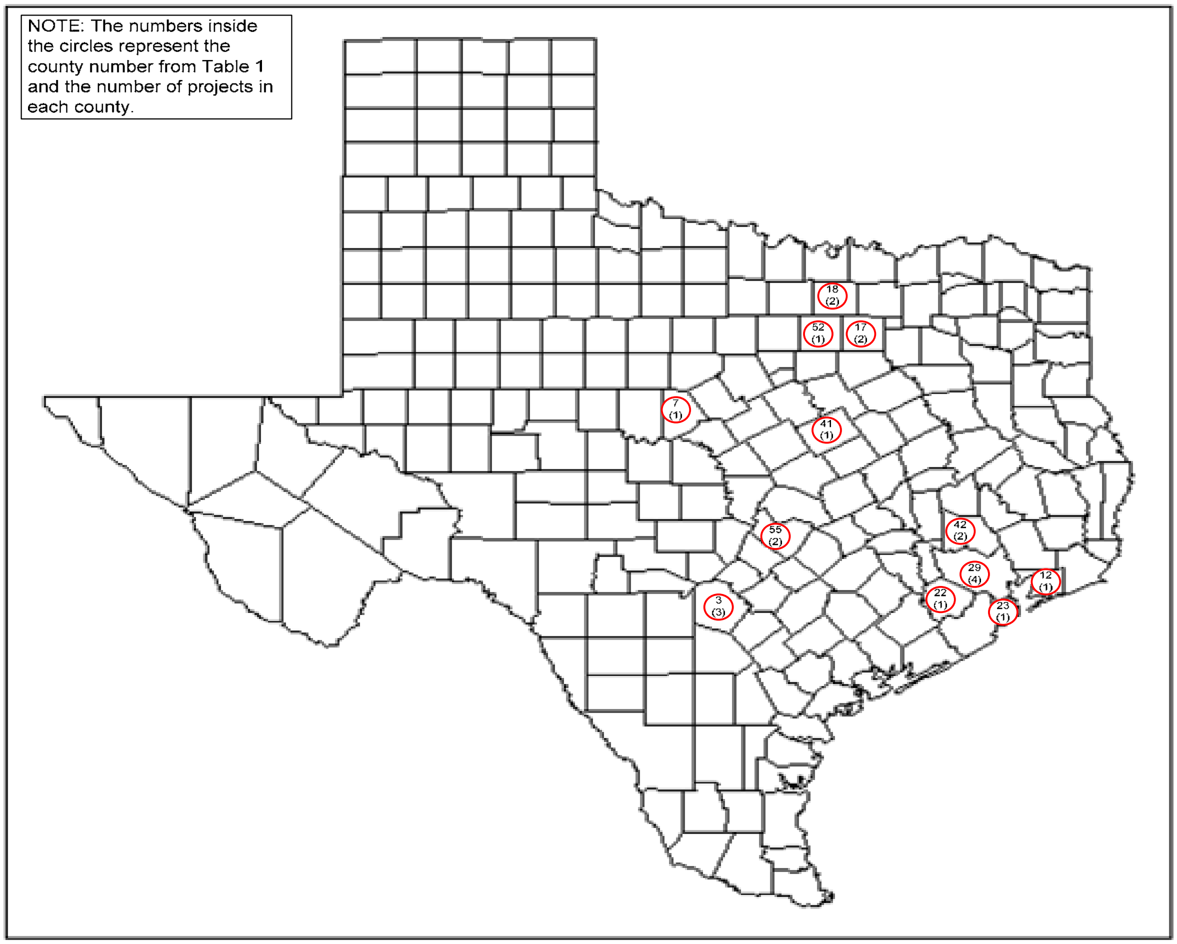


Figure 10-5. Landfill Gas-fired Power Projects Installed throughout Texas.

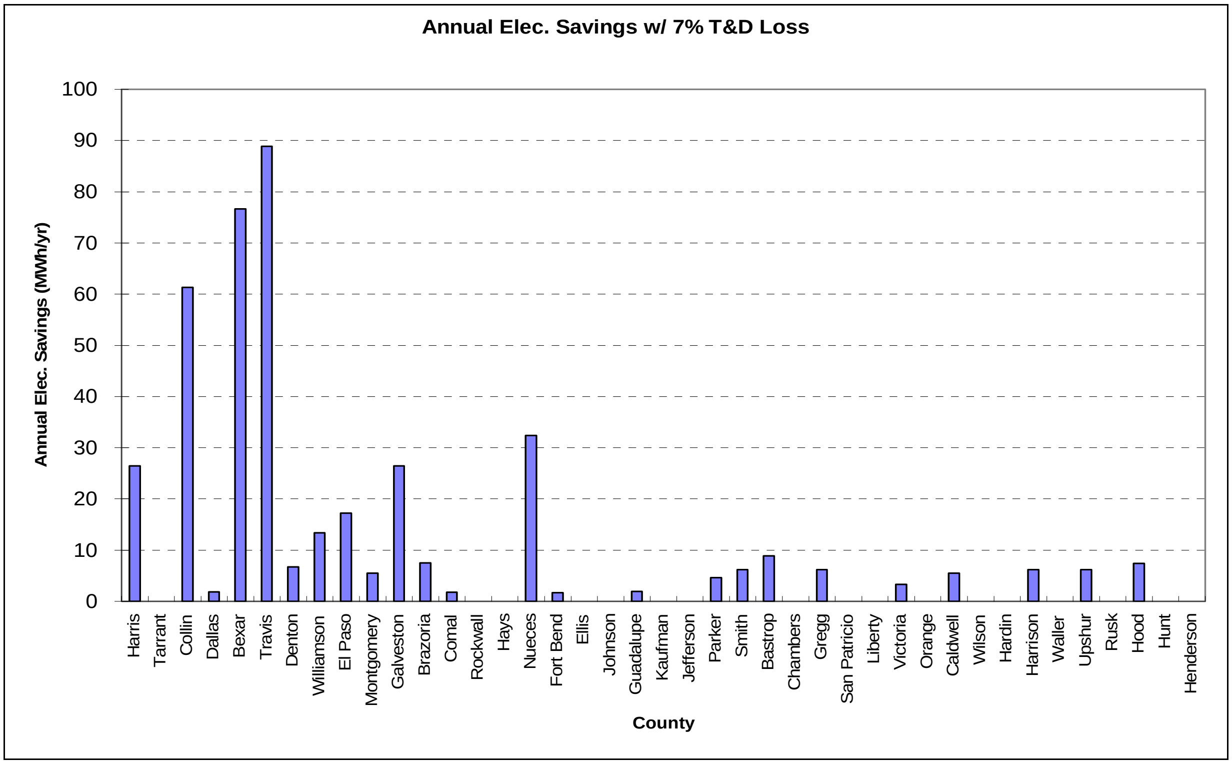


Figure 10-6. Annual Electric Savings per County from PV Projects.

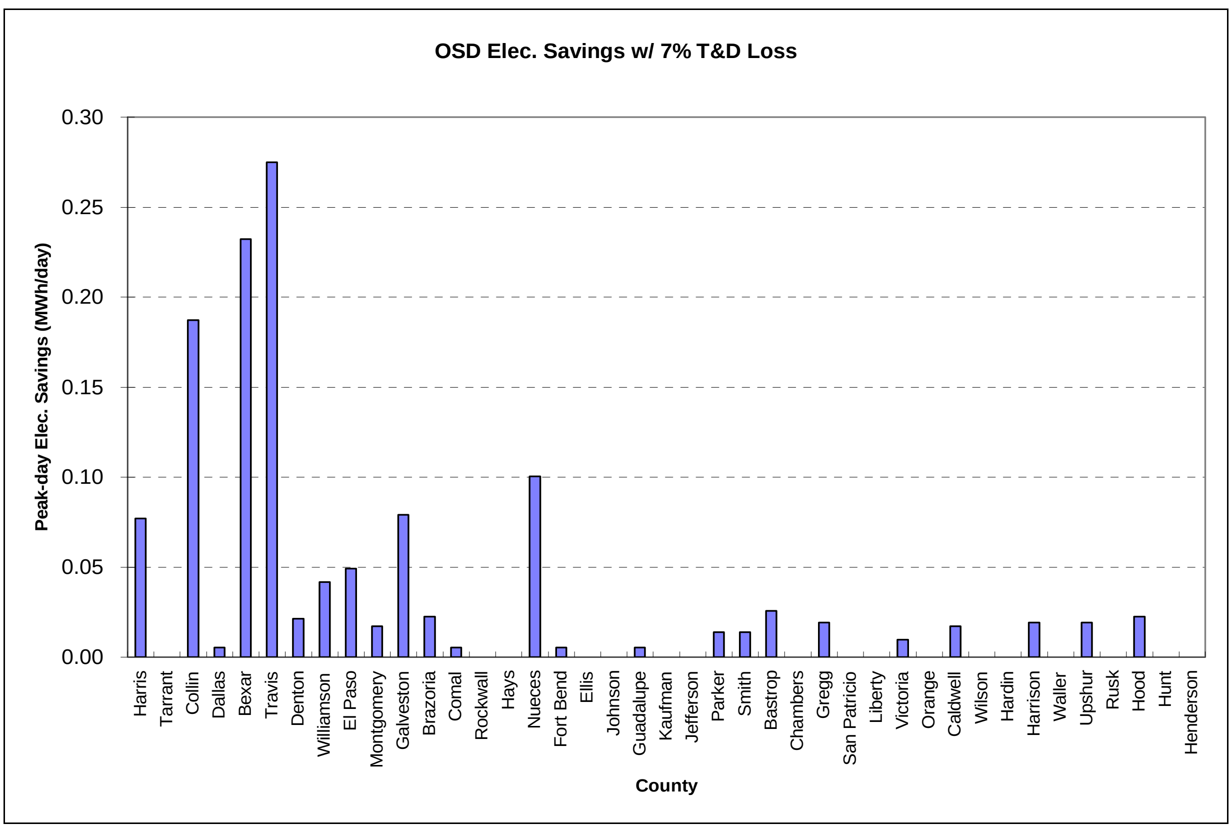


Figure 10-7. Ozone Season Day Electric Savings per County from PV Projects.

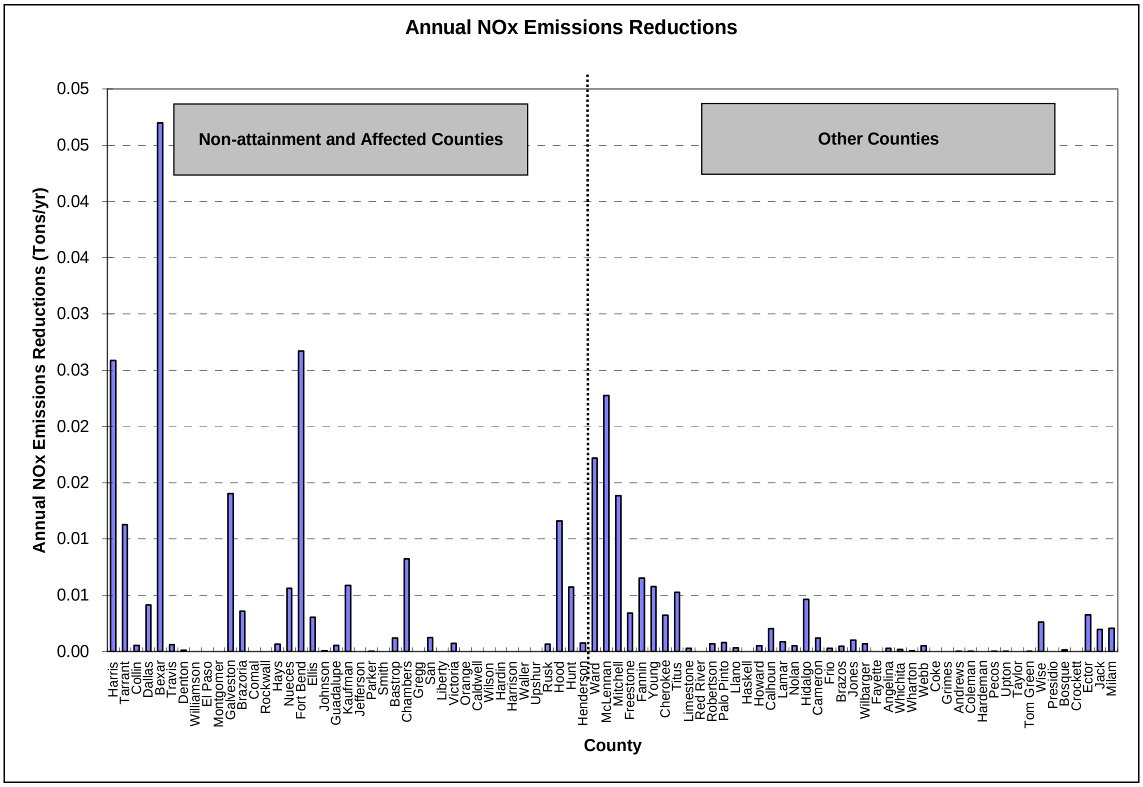


Figure 10-8. Annual NOx Emissions Reduction per County from PV Projects.

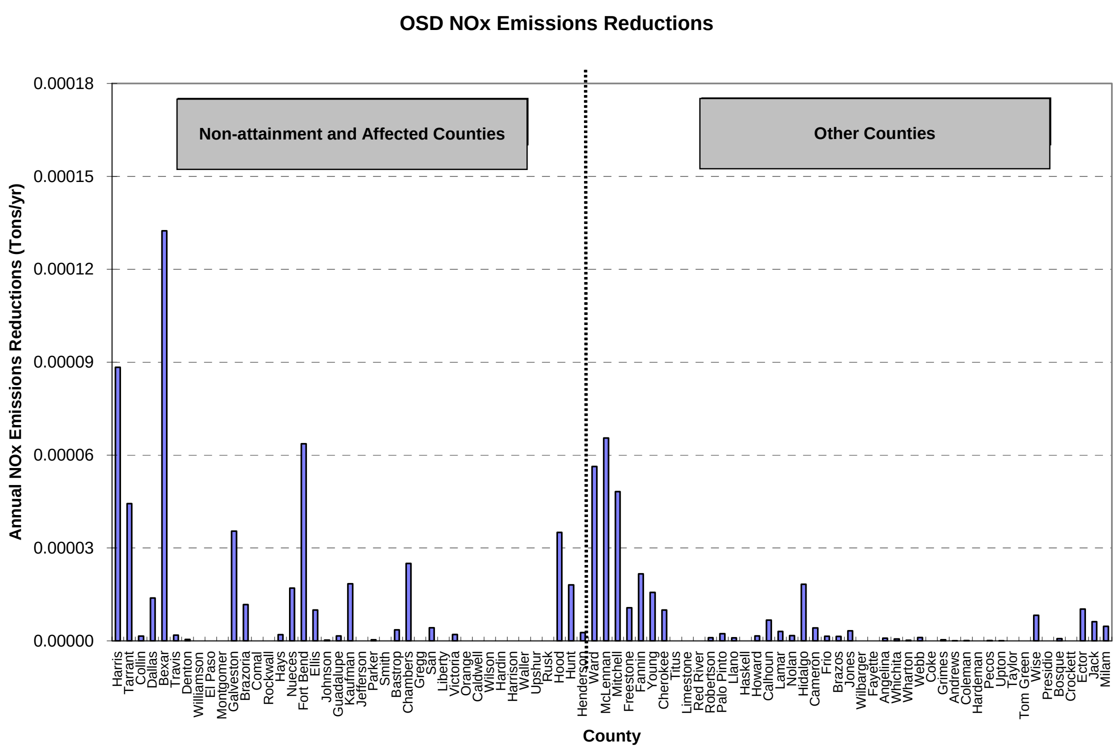


Table 10-16: eGrid table for the Annual NOx Emissions Reduction per County from PV Projects

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)
Houston-Galveston Area	Brazoria	0.00883113	0.3637229	0.010890729	0.037073327	0.006522185	0	0.003944232	0	0.0654443	3.733486105	0.014877	1.195203498	0.006262	0	0.0048171	0	0.121275	0.301484287	0.00816387	1.586751789	7.217721904	0.003608861
	Chambers	0.02176222	0.89630846	0.026955801	0.091760728	0.016072371	0	0.009076193	0	0.1649402	9.409560766	0.037472	3.010399333	0.015056	0	0.0095532	0	0.011519	0.028634711	0.01581859	3.074544221	16.51120822	0.008255604
	Fort Bend	0.07043123	2.90081178	0.087239726	0.296974327	0.052016606	0	0.029374182	0	0.5338124	30.45309284	0.121275	9.742853321	0.048726	0	0.030918	0	0.037279	0.09267335	0.05119528	9.950451771	53.43685738	0.026718429
	Galveston	0.03385674	1.39443856	0.041710519	0.141987529	0.025004711	0	0.015351589	0	0.2495874	14.23853766	0.056747	4.55886914	0.024143	0	0.0192972	0	0.567751	1.411404929	0.03283689	6.382265746	28.12750356	0.014063752
	Harris	0.06826733	2.81168839	0.084559408	0.287850206	0.050418468	0	0.028471701	0	0.5174117	29.51746409	0.117549	9.443517758	0.047229	0	0.0299681	0	0.036133	0.08982609	0.04962237	9.644738036	51.79508456	0.025897542
	Liberty	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Montgomery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Waller	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beaumont/ Port Arthur Area	Hardin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Orange	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dallas/ Fort Worth Area	Collin	0.00203914	0.08398472	0.003716345	0.012650876	0.001505992	0	0.005950953	0	0.0024815	0.141564132	0.000717	0.057605468	0.019166	0	0.0766809	0	0.000864	0.002148886	0.0040002	0.777489514	1.075443593	0.000537722
	Dallas	0.00453947	0.18696466	0.004683963	0.015944762	0.003352602	0	0.00774211	0	0.0020856	0.11898059	0.000681	0.054714119	0.007503	0	0.026717	0	0.007525	0.018706658	0.04037045	7.84651017	8.241820953	0.00412091
	Denton	0.00047388	0.01951744	0.000872802	0.002971119	0.000349982	0	0.001396994	0	0.0005854	0.033398553	0.000169	0.013574529	0.004544	0	0.0181872	0	0.000187	0.000463893	0.00084941	0.165092719	0.235018255	0.000117509
	Tarrant	0.01216249	0.50092976	0.012266309	0.041755965	0.008982543	0	0.020308652	0	0.0053165	0.303297586	0.001753	0.140790503	0.017326	0	0.0602168	0	0.020603	0.05121927	0.11064724	21.50569502	22.5436881	0.011271844
	Ellis	0.00327981	0.13508384	0.003307809	0.011260174	0.002422289	0	0.005476558	0	0.0014337	0.081789119	0.000473	0.037966445	0.004672	0	0.0162384	0	0.005556	0.013812108	0.02983782	5.799359839	6.079271528	0.003039636
	Johnson	0.00028606	0.01178173	0.000526868	0.00179352	0.000211267	0	0.000843297	0	0.0003534	0.020161082	0.000102	0.008194283	0.002743	0	0.0109787	0	0.000113	0.00028003	0.00051274	0.099658443	0.141869088	7.09345E-05
	Kaufman	0.00632545	0.26052287	0.006379446	0.021716386	0.004671629	0	0.010562096	0	0.002765	0.157738598	0.000911	0.073222134	0.009011	0	0.0313175	0	0.010715	0.026638048	0.05754527	11.18465271	11.72449075	0.005862245
	Parker	0.00021749	0.00895762	0.000400576	0.001363609	0.000160626	0	0.000641157	0	0.0002687	0.015328415	7.75E-05	0.006230091	0.002085	0	0.0083471	0	8.56E-05	0.000212906	0.00038984	0.075770042	0.10786268	5.39313E-05
	Rockwall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Henderson	0.00081989	0.03376855	0.000826893	0.002814843	0.000605529	0	0.001369042	0	0.0003584	0.020445822	0.000118	0.009490935	0.001168	0	0.0040593	0	0.001389	0.003452781	0.00745892	1.449736606	1.519709539	0.000759855
	Hood	0.01252711	0.51594706	0.012634039	0.043007761	0.009251829	0	0.020917482	0	0.0054759	0.312390101	0.001805	0.145011241	0.017846	0	0.062022	0	0.021221	0.052754765	0.11396431	22.15041113	23.21952206	0.011609761
	Hunt	0.00618756	0.2548435	0.006240374	0.021242971	0.004569788	0	0.010331844	0	0.0027047	0.154299914	0.000892	0.071625899	0.008815	0	0.0306347	0	0.010482	0.026057342	0.05629078	10.94082853	11.46889816	0.005734449
El Paso Area	El Paso	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Antonio Area	Bexar	0.03341375	1.37619345	0.051775843	0.176251083	0.024677545	0	0.090663423	0	0.0011418	0.065140112	1.143572	91.87074664	0.046874	0	0.0046695	0	0.00052	0.001291659	0.00250387	0.48665798	93.97628092	0.04698814
	Comal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Guadalupe	0.00200047	0.08239212	0.076378745	0.260002263	0.001477434	0	0.133848731	0	0.0012371	0.070576331	0.003555	0.285580495	0.001062	0	0.0018557	0	0.000402	0.000998654	0.00183516	0.356687577	1.056237441	0.000528119
	Wilson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austin Area	Bastrop	0.00450233	0.1854351	0.171901148	0.585171802	0.003325174	0	0.301245466	0	0.0027843	0.158841998	0.008001	0.642739224	0.00239	0	0.0041765	0	0.000904	0.002247613	0.0041303	0.80277575	2.377211487	0.001188606
	Caldwell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hays	0.0024586	0.10126095	0.093870431	0.31954603	0.001815785	0	0.164501762	0	0.0015205	0.086739193	0.004369	0.350981996	0.001305	0	0.0022807	0	0.000494	0.001227359	0.00225544	0.438373488	1.298129012	0.000649065
	Travis	0.00051001	0.02100537	0.299602906	1.019883659	0.000376663	0	0.033939476	0	0.0003347	0.01909457	0.000906	0.072794745	0.000271	0	0.0004717	0	0.000103	0.000256866	0.00046734	0.090832639	1.223867851	0.000611934
	Williamson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North East Texas Area	Gregg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Harrison	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rusk	0.00068596	0.02825245	0.00069182	0.002355037	0.000506616	0	0.001145408	0	0.0002999	0.017105991	9.88E-05	0.007940588	0.000977	0	0.0033962	0	0.001162	0.002888768	0.00624051	1.212921683	1.271464516	0.000635732
	Smith	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upshur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corpus Christi Area	Nueces	0.22756873	9.37274584	0.004556851	0.01551206	0.168069652	0	0.007612767	0	0.0016809	0.095891808	0.001627	0.130691372	0.046792	0	0.0072464	0	0.001609	0.004000963	0.00828339	1.609982905	11.22882495	0.005614412
	San Patricio	0.05031335	2.07222782	0.001007478	0.003429574	0.037158653	0	0.001683113	0	0.0003716	0.021200796	0.00036	0.028894659	0.010345	0	0.0016021	0	0.000356	0.000884576	0.00183138	0.355952399	2.482589827	0.001241295
Victoria Area	Victoria	0.02183674	0.8993774	0.002215582	0.007542103	0.016127403	0	0.003612695	0	0.0011996	0.068436355	0.000555	0.044618086	0.525456	0	0.0324127	0	0.000477	0.001185442	0.00225485	0.438258556	1.459417946	0.000729709
Other ERCOT counties	Andrews	2.4742E-05	0.00101904	2.49533E-05	8.49439E-05	1.82731E-05	0	4.13138E-05	0	1.082E-05	0.000616996	3.57E-06	0.000286409	3.52E-05	0	0.0001225	0	4.19E-05	0.000104195	0.00022509	0.043748902	0.045860485	2.29302E-05
	Angelina	0.00031082	0.01280157	0.000313473	0.001067099	0.000229554	0	0.000519	0	0.0001359	0.007750955	4.48E-05	0.003597987	0.000443	0	0.0015389	0	0.000527	0.00130894	0.00282766	0.549591171	0.576117718	0.000288059
	Bosque	0.00059539	0.02452207	0.001096604	0.003732968	0.000439723	0	0.001755208	0	0.0007356	0.041962546	0.000212	0.017055283	0.005709	0	0.0228507	0	0.000234	0.000582844	0.00106721	0.207425478	0.295281187	0.000147641
	Brazos	0.00193973	0.07989038	0.003572622	0.012161627	0.001432574	0	0.005718288	0	0.0023964	0.136709663	0.000692	0.05556436	0.018599	0	0.0744451	0	0.000764	0.001898845	0.00347685	0.675770891	0.961995762	0.000480998
	Calhoun	0.08269981	3.40611071	0.001655986	0.005637173	0.061077496	0	0.002766524	0	0.0006108	0.034847644	0.000591	0.04749401	0.017004	0	0.0026334	0	0.000585	0.001453973	0.00301023	0.585077212	4.08062072	0.00204031
	Cameron	0.04837175	1.99226005	0.000968599	0.003297226	0.297964476	0	0.001618161	0	0.0003573	0.020382652	0.000346	0.027779607	0.009946	0	0.0015403	0	0.000342	0.00085044	0.00176071	0.342216111	2.38678609	0.001193393
	Cherokee	0.0035039	0.14431312	0.003533808	0.012029498	0.002587786	0	0.00585073	0	0.0015316	0.087377163	0.000505	0.040560411	0.004992	0	0.0173479	0	0.005936	0.014755787	0.03187642	6.19558715	6.494623131	0.003247312
	Coke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coleman	0.00129879	0.05349241	2.6007E-05	8.85309E-05	0.000959212	0	4.34478E-05	0	9.593E-06	0.000547277	9.28E-06	0.000745886	0.000267	0	4.136E-05	0	9.19E-06	2.28344E-05	4.7275E-05	0.009188541	0.064085477	3.20427E-05
	Crockett	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ector	0.00353575	0.14562486	0.003565928	0.012138841	0.002611307	0	0.005903911	0	0.0015456	0.088171379	0.000509	0.040929085	0.005037	0	0.0175056	0	0.00599	0.01488991	0.03216616	6.251902019	6.553656092	0.003276828
	Fannin	0.00705631	0.29062448	0.007116546	0.024225564	0.005211403	0	0.011782473	0	0.0030845	0.175964199	0.001017	0.081682444	0.010052	0	0.034936	0	0.011954	0.02971589	0.06419422	12.47696179	13.07917436	0.006539587
	Fayette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Freestone	0.00367718	0.15144985	0.003708565	0.012624394	0.00271576	0	0.006140067	0	0.0016074	0.091698234	0.00053	0.042566249	0.005238	0	0.0182058	0	0.006229	0.015485506	0.03345281	6.5019781	6.815802336	0.003407901
	Frio	0.00858833	0.35372293	0.000871383	0.002966291	0.006342868	0	0.001420864	0	0.0004718	0.026915851	0.000218	0.017548184	0.206661	0	0.0127478	0	0.000188	0.000466231	0.00088683	0.172366017	0.573985504	0.000286993
	Grimes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hardeman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haskell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hidalgo	0.18852746	7.76477475	0.003775086	0.012850839	0.139235931	0	0.006306735	0	0.0013925	0.079440785	0.001348	0.1082702	0.038764	0	0.0060032	0	0.001333	0.003314565	0.00686231	1.33377719	9.302428329	0.004651214
	Howard	0.00055511	0.02286313	0.000559851	0.0019058	0.000409976	0	0.000926915	0	0.0002427	0.013842923	8E-05	0.006425874	0.000791	0	0.0027484	0	0.00094	0.002337719	0.00505009	0.981549799	1.028925246	0.000514463
	Jack	0.00212145	0.08737491	0.002139557	0.007283304	0.001566784	0	0.003542346	0	0.0009273	0.052902828	0.000306	0.024557451	0.003022	0	0.0105033	0	0.003594	0.008933946	0.0192997	3.751141212	3.932193655	0.001966097
	Jones	0.04071872	1.67705921	0.000815354	0.002775563	0.030072592	0	0.001362147	0	0.0003008	0.017157858	0.000291	0.023384521	0.008372	0	0.0012966	0	0.000288	0.00071589	0.00148214	0.288073175	2.009166213	0.001004583
	Lamar	0.00095084	0.03916163	0.000958954	0.003264393	0.000702236	0	0.001587687	0	0.0004156	0.023711162	0.000137	0.011006703	0.001355	0	0.0047076	0	0.001611	0.004004214	0.00865017	1.681269609	1.762417706	0.000881209
	Limestone	0.00071976	0.02964422	0.000891528	0.003034865	0.000531572	0	0.000300183	0	0.0054552	0.311208806	0.001239	0.099564986	0.000498	0	0.000316	0	0.000381	0.000947055	0.00052318	0.101686493	0.546086424	0.000273043
	Llano	0.00123817	0.05099598	0.047274044	0.160926425	0.000914447	0	0.082844655	0	0.0007657	0.043682684	0.0022	0.176757877	0.000657	0	0.0011486	0	0.000249	0.00061811	0.00113586	0.220769065	0.653750138	0.000326875
	McLennan	0.02453432	1.01048119	0.024743738	0.084230606	0.018119687	0	0.040966843	0	0.0107245	0.611815326	0.003535	0.284004196	0.034951	0	0.1214699	0	0.041562	0.103320091	0.22319886	43.38153155	45.47538295	0.022737691
	Milam	0.0022454	0.09248023	0.002264571	0.007708868	0.001658332	0	0.003749326	0	0.0009815	0.055993942	0.000324	0.025992344	0.003199	0	0.011117	0	0.003804	0.009455957	0.02042738	3.970320558	4.161951904	0.002080976
	Mitchell	0.01494317	0.61545592	0.015070721	0.051302514	0.011036196	0	0.024951762	0	0.006532	0.37263966	0.002153	0.172979039	0.021288	0	0.073984	0	0.025314	0.062929388	0.1359442	26.42248157	27.69778809	0.013848894
	Nolan	0.00056465	0.02325608	0.000569473	0.001938555	0.000417022	0	0.000942846	0	0.0002468	0.01408084	8.14E-05	0.006536315	0.000804	0	0.0027956	0	0.000957	0.002377897	0.00513689	0.998419568	1.04660925	0.000523305
	Palo Pinto	0.003207	0.13208484	0.005906709	0.020107135	0.002368511	0	0.009454195	0	0.003962	0.226025657	0.001144	0.091866008	0.03075	0	0.1230821	0	0.001263	0.00313941	0.00574838	1.117269664	1.590492719	0.000795246
	Pecos	4.0968E-05	0.00168731	4.13174E-05	0.000140649	3.02565E-05	0	6.84069E-05	0	1.791E-05	0.001021616	5.9E-06	0.000474233	5.84E-05	0	0.0002028	0	6.94E-05	0.000172525	0.0003727	0.072438969	0.075935306	3.79677E-05
	Presidio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Robertson	0.00073771	0.03038356	0.000835096	0.002842767	0.00054483	0	0.000735917	0	0.0031497	0.17968379	0.000731	0.058716087	0.000761	0	0.0018663	0	0.191633	0.476390136	0.00339774	0.660393393	1.408409729	0.000704205
	Taylor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Titus	0.00569644	0.23461598	0.005745061	0.019556867	0.004207073	0	0.009511781	0	0.00249	0.142052768	0.000821	0.065940784	0.008115	0	0.0282032	0	0.00965	0.02398911	0.05182285	10.07242937	10.55858487	0.005279292
	Tom Green	0.00148245	0.06105676	2.96846E-05	0.00010105	0.001094854	0	4.95918E-05	0	1.095E-05	0.000624667	1.06E-05	0.000851361	0.000305	0	4.72E-05	0	1.05E-05	2.60634E-05	5.396E-05	0.010487891	0.07314779	3.65739E-05
	Upton	3.1166E-05	0.00128362	3.14322E-05	0.000106999	2.30176E-05	0	5.20405E-05	0	1.362E-05	0.000777194	4.49E-06	0.000360773	4.44E-05	0	0.0001543	0	5.28E-05	0.000131248	0.00028353	0.055107884	0.057767719	2.88839E-05
	Ward	0.01855953	0.76440091	0.01871795	0.063718111	0.013707039	0	0.030990277	0	0.0081128	0.462821277	0.002674	0.214841275	0.02644	0	0.0918886	0	0.03144	0.078158775	0.16884373	32.81692201	34.40086236	0.017200431
	Webb	0.02001433	0.82431889	0.000400768	0.001364262	0.014781473	0	0.000669531	0	0.0001478	0.00843354	0.000143	0.011494109	0.004115	0	0.0006373	0	0.000142	0.000351879	0.00072851	0.141595573	0.987558251	0.000493779
	Wharton	0.00014434	0.00594484	0.000178787	0.00060861	0.000106601	0	6.01986E-05	0	0.001094	0.062409672	0.000249	0.019966717	9.99E-05	0	6.336E-05	0	7.64E-05	0.000189922	0.00010492	0.020392163	0.109511923	5.4756E-05
	Wichita	0.00020763	0.00855167	0.000209406	0.000712841	0.000153346	0	0.000346701	0	9.076E-05	0.005177775	2.99E-05	0.002403519	0.000296	0	0.001028	0	0.000352	0.000874395	0.00188893	0.367136634	0.384856837	0.000192428
	Wilbarger	0.02861682	1.17862486	0.000573025	0.001950645	0.021134796	0	0.000957307	0	0.0002114	0.012058416	0.000205	0.016434469	0.005884	0	0.0009112	0	0.000202	0.000503122	0.00104164	0.202455706	1.412027219	0.000706014
	Wise	0.00284449	0.11715432	0.002882008	0.009810696	0.002100781	0	0.00476997	0	0.0012561	0.071656974	0.000413	0.033198429	0.004182	0	0.0146143	0	0.004798	0.011927482	0.02576141	5.007057257	5.250805153	0.002625403
	Young	0.00623586	0.25683272	0.006289085	0.021408786	0.004605458	0	0.010412491	0	0.0027258	0.155504326	0.000899	0.072184987	0.008883	0	0.0308739	0	0.010564	0.026260737	0.05673017	11.02622889	11.55842045	0.00577921
	Total	**1.12183722**	**46.2044813**	**1.172570094**	**3.991567018**	**1.090766584**	**0**	**1.189130767**	**0**	**1.62936**	**92.95223156**	**1.542363**	**123.9082787**	**1.359386**	**0**	**1.2316428**	**0**	**1.221806**	**3.037356984**	**1.52878695**	**297.1391478**	**567.2330634**	**0.283616532**
Energy Savings by PCA (MWh)		41.19		3.40		0.00		0.00		57.05		80.34		0.00		0.00		2.49		194.36			

Table 10-17: eGrid table for the Average Ozone Day NOx Emissions Reduction per County from Solar PV Projects.

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)
Houston-Galveston Area	Brazoria	0.00957217	0.00121882	0.011806715	0.000124446	0.007069474	0	0.004263638	0	0.0710018	0.01206395	0.01614	0.003920339	0.006781	0	0.0051797	0	0.126288	0.00095283	0.008772	0.005234084	0.023514473	1.17572E-05
	Chambers	0.0218814	0.00278616	0.027103415	0.000285678	0.016160386	0	0.009125896	0	0.1658435	0.028178555	0.037677	0.009151488	0.015138	0	0.0096055	0	0.011582	8.73825E-05	0.015905	0.009490707	0.049979967	2.499E-05
	Fort Bend	0.05569551	0.00709171	0.068987309	0.000727145	0.041133619	0	0.023228475	0	0.4221274	0.071723902	0.095902	0.023293614	0.038531	0	0.0244493	0	0.029479	0.000222418	0.040484	0.024157041	0.12721583	6.36079E-05
	Galveston	0.02755599	0.0035087	0.033893644	0.000357248	0.020351324	0	0.012791501	0	0.2014466	0.03422791	0.045813	0.011127402	0.019824	0	0.0167751	0	0.594657	0.004486621	0.028709	0.017131044	0.070838929	3.54195E-05
	Harris	0.07736057	0.00985032	0.09582276	0.001009999	0.057134232	0	0.032264145	0	0.5863312	0.099623864	0.133207	0.032354624	0.05352	0	0.0339599	0	0.040946	0.000308936	0.056232	0.033553915	0.17670166	8.83508E-05
	Liberty	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Montgomery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Waller	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beaumont/ Port Arthur Area	Hardin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Orange	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dallas/ Fort Worth Area	Collin	0.00176365	0.00022457	0.003151138	3.32139E-05	0.001302533	0	0.005050143	0	0.0020858	0.000354391	0.000604	0.000146725	0.015958	0	0.0637888	0	0.000846	6.38401E-06	0.004013	0.002394697	0.003159976	1.57999E-06
	Dallas	0.00504555	0.00064245	0.005305276	5.59191E-05	0.003726366	0	0.008757286	0	0.0024131	0.000410009	0.000782	0.000190004	0.00931	0	0.033672	0	0.008209	6.19374E-05	0.044002	0.026256278	0.027616597	1.38083E-05
	Denton	0.00063576	8.0951E-05	0.001170951	1.23421E-05	0.000469535	0	0.001874207	0	0.0007854	0.000133453	0.000227	5.50609E-05	0.006096	0	0.0243999	0	0.00025	1.88886E-06	0.00114	0.000679981	0.000963677	4.81839E-07
	Tarrant	0.01557224	0.00198281	0.015705165	0.000165537	0.011500796	0	0.026002176	0	0.006807	0.001156579	0.002244	0.000545002	0.022184	0	0.0770985	0	0.02638	0.000199031	0.141667	0.084533355	0.088582317	4.42912E-05
	Ellis	0.00350282	0.00044601	0.003532723	3.72359E-05	0.002586991	0	0.005848935	0	0.0015312	0.000260161	0.000505	0.000122593	0.00499	0	0.0173426	0	0.005934	4.47702E-05	0.031867	0.01901495	0.019925725	9.96286E-06
	Johnson	0.00033718	4.2933E-05	0.000621017	6.54569E-06	0.00024902	0	0.000993991	0	0.0004166	7.07772E-05	0.00012	2.92017E-05	0.003233	0	0.0129406	0	0.000133	1.00176E-06	0.000604	0.00036063	0.000511089	2.55545E-07
	Kaufman	0.00649275	0.00082672	0.006548174	6.90196E-05	0.004795187	0	0.01084145	0	0.0028381	0.000482228	0.000936	0.000227235	0.009249	0	0.0321458	0	0.010999	8.29849E-05	0.059067	0.035245671	0.036933861	1.84669E-05
	Parker	0.00047595	6.0603E-05	0.000876616	9.23978E-06	0.000351511	0	0.0014031	0	0.000588	9.99078E-05	0.00017	4.12206E-05	0.004564	0	0.0182667	0	0.000187	1.41407E-06	0.000853	0.000509059	0.000721444	3.60722E-07
	Rockwall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Henderson	0.00095027	0.000121	0.000958382	1.01016E-05	0.000701818	0	0.001586741	0	0.0004154	7.05783E-05	0.000137	3.32578E-05	0.001354	0	0.0047048	0	0.00161	1.21456E-05	0.008645	0.005158512	0.005405593	2.7028E-06
	Hood	0.01232788	0.00156971	0.012433111	0.000131048	0.00910469	0	0.020584816	0	0.0053888	0.000915614	0.001776	0.000431455	0.017562	0	0.0610356	0	0.020884	0.000157565	0.112152	0.066921458	0.070126849	3.50634E-05
	Hunt	0.00635121	0.0008087	0.006405424	6.7515E-05	0.004690653	0	0.010605108	0	0.0027763	0.000471716	0.000915	0.000222281	0.009048	0	0.031445	0	0.010759	8.11759E-05	0.05778	0.034477319	0.036128707	1.80644E-05
El Paso Area	El Paso	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Antonio Area	Bexar	0.03112811	0.00396354	0.048234164	0.000508401	0.0229895	0	0.084461674	0	0.0010637	0.00018074	1.065347	0.258762077	0.043667	0	0.0043501	0	0.000484	3.65204E-06	0.002333	0.001391866	0.264810279	0.000132405
	Comal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Guadalupe	0.00200761	0.00025563	0.076651484	0.000807928	0.00148271	0	0.134326688	0	0.0012416	0.000210953	0.003567	0.000866508	0.001066	0	0.0018623	0	0.000403	3.04175E-06	0.001842	0.00109896	0.003243019	1.62151E-06
	Wilson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austin Area	Bastrop	0.00446951	0.0005691	0.170648096	0.001798678	0.003300936	0	0.299049574	0	0.002764	0.000469641	0.007942	0.001929094	0.002372	0	0.0041461	0	0.000898	6.77179E-06	0.0041	0.0024466	0.007219887	3.60994E-06
	Caldwell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hays	0.00246935	0.00031442	0.094281013	0.000993748	0.001823727	0	0.165221279	0	0.0015271	0.000259471	0.004388	0.001065801	0.001311	0	0.0022907	0	0.000496	3.74133E-06	0.002265	0.001351717	0.003988901	1.99445E-06
	Travis	0.00050761	6.4634E-05	0.298194277	0.003143051	0.000374892	0	0.033779905	0	0.0003331	5.66032E-05	0.000902	0.000219053	0.00027	0	0.0004695	0	0.000103	7.75925E-07	0.000465	0.00027755	0.003761666	1.88083E-06
	Williamson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North East Texas Area	Gregg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Harrison	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rusk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Smith	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upshur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corpus Christi Area	Nueces	0.22352453	0.02846138	0.00447587	4.71769E-05	0.165082827	0	0.007477478	0	0.001651	0.000280525	0.001598	0.00038811	0.04596	0	0.0071176	0	0.001581	1.19272E-05	0.008136	0.004854895	0.034044013	1.7022E-05
	San Patricio	0.05533089	0.00704528	0.001107949	1.16781E-05	0.040864326	0	0.001850962	0	0.0004087	6.94407E-05	0.000396	9.60722E-05	0.011377	0	0.0017619	0	0.000391	2.95243E-06	0.002014	0.001201773	0.008427198	4.2136E-06
Victoria Area	Victoria	0.02060475	0.0026236	0.002090584	2.20353E-05	0.015217528	0	0.003408874	0	0.0011319	0.000192329	0.000524	0.000127288	0.495811	0	0.0305841	0	0.00045	3.39484E-06	0.002128	0.001269568	0.004238218	2.11911E-06
Other ERCOT counties	Andrews	2.5653E-05	3.2664E-06	2.58716E-05	2.72694E-07	1.89456E-05	0	4.28342E-05	0	1.121E-05	1.90527E-06	3.7E-06	8.97799E-07	3.65E-05	0	0.000127	0	4.35E-05	3.27871E-07	0.000233	0.000139255	0.000145925	7.29623E-08
	Angelina	0.00032149	4.0935E-05	0.000324234	3.41752E-06	0.000237435	0	0.000536817	0	0.0001405	2.38777E-05	4.63E-05	1.12516E-05	0.000458	0	0.0015917	0	0.000545	4.10902E-06	0.002925	0.001745198	0.001828789	9.14394E-07
	Bosque	0.00093945	0.00011962	0.001730301	1.82379E-05	0.000693828	0	0.002769496	0	0.0011606	0.000197202	0.000335	8.1363E-05	0.009008	0	0.0360555	0	0.00037	2.79115E-06	0.001684	0.001004801	0.001424016	7.12008E-07
	Brazos	0.00191393	0.0002437	0.003525105	3.71556E-05	0.00141352	0	0.005642234	0	0.0023645	0.000401755	0.000682	0.000165759	0.018351	0	0.073455	0	0.000754	5.68636E-06	0.003431	0.00204706	0.002901116	1.45056E-06
	Calhoun	0.08852525	0.01127192	0.001772635	1.86841E-05	0.065379841	0	0.0029614	0	0.0006539	0.0001111	0.000633	0.000153708	0.018202	0	0.0028189	0	0.000626	4.72366E-06	0.003222	0.001922746	0.013482881	6.74144E-06
	Cameron	0.05467229	0.00696142	0.001094762	1.15391E-05	0.285623104	0	0.001828931	0	0.0004038	6.86142E-05	0.000391	9.49287E-05	0.011242	0	0.0017409	0	0.000387	2.91728E-06	0.00199	0.001187468	0.00832689	4.16344E-06
	Cherokee	0.003513	0.00044731	0.003542982	3.7344E-05	0.002594504	0	0.005865919	0	0.0015356	0.000260916	0.000506	0.000122949	0.005005	0	0.0173929	0	0.005951	4.49002E-05	0.031959	0.019070166	0.019983585	9.99179E-06
	Coke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coleman	0.0013551	0.00017254	2.71346E-05	2.86006E-07	0.001000801	0	4.53316E-05	0	1.001E-05	1.70066E-06	9.69E-06	2.35289E-06	0.000279	0	4.315E-05	0	9.58E-06	7.23074E-08	4.93E-05	2.94324E-05	0.000206389	1.03195E-07
	Crockett	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ector	0.00362926	0.00046211	0.003660242	3.858E-05	0.002680373	0	0.006060061	0	0.0015864	0.000269552	0.000523	0.000127018	0.00517	0	0.0179686	0	0.006148	4.63862E-05	0.033017	0.019701325	0.020644975	1.03225E-05
	Fannin	0.00762852	0.00097134	0.007693632	8.1093E-05	0.005633999	0	0.012737922	0	0.0033346	0.000566584	0.001099	0.000266985	0.010867	0	0.0377689	0	0.012923	9.75013E-05	0.0694	0.041411122	0.043394624	2.16973E-05
	Fayette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Freestone	0.00377443	0.0004806	0.003806652	4.01232E-05	0.002787588	0	0.006302464	0	0.0016499	0.000280334	0.000544	0.000132099	0.005377	0	0.0186873	0	0.006394	4.82417E-05	0.034338	0.020489378	0.021470774	1.07354E-05
	Frio	0.01476384	0.00187988	0.001497957	1.57889E-05	0.010903753	0	0.002442547	0	0.0008111	0.000137809	0.000375	9.12049E-05	0.355262	0	0.0219143	0	0.000322	2.43249E-06	0.001525	0.000909679	0.003036793	1.5184E-06
	Grimes	0.00055442	7.0595E-05	0.001021149	1.07632E-05	0.000409467	0	0.001634436	0	0.0006849	0.00011638	0.000198	4.80169E-05	0.005316	0	0.0212784	0	0.000218	1.64722E-06	0.000994	0.00059299	0.000840392	4.20196E-07
	Hardeman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haskell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hidalgo	0.239737	0.03052571	0.004800509	5.05987E-05	0.177056459	0	0.008019827	0	0.0017708	0.000300872	0.001714	0.00041626	0.049294	0	0.0076338	0	0.001695	1.27922E-05	0.008726	0.005207026	0.036513261	1.82566E-05
	Howard	0.00058508	7.4498E-05	0.000590075	6.21955E-06	0.000432108	0	0.000976955	0	0.0002558	4.3455E-05	8.43E-05	2.04768E-05	0.000833	0	0.0028967	0	0.000991	7.47802E-06	0.005323	0.00317609	0.003328218	1.66411E-06
	Jack	0.00217756	0.00027727	0.002196145	2.3148E-05	0.001608224	0	0.003636037	0	0.0009519	0.000161731	0.000314	7.62108E-05	0.003102	0	0.0107811	0	0.003689	2.78317E-05	0.01981	0.011820795	0.012386985	6.19349E-06
	Jones	0.04250012	0.00541154	0.000851025	8.97004E-06	0.031388236	0	0.00142174	0	0.0003139	5.3338E-05	0.000304	7.37939E-05	0.008739	0	0.0013533	0	0.000301	2.26778E-06	0.001547	0.000923092	0.006473002	3.2365E-06
	Lamar	0.00107998	0.00013751	0.001089199	1.14805E-05	0.000797614	0	0.001803327	0	0.0004721	8.02121E-05	0.000156	3.77974E-05	0.001539	0	0.005347	0	0.00183	1.38034E-05	0.009825	0.005862635	0.006143442	3.07172E-06
	Limestone	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Llano	0.00124346	0.00015833	0.047475864	0.000500409	0.000918351	0	0.083198331	0	0.000769	0.000130658	0.00221	0.000536691	0.00066	0	0.0011535	0	0.00025	1.88398E-06	0.001141	0.000680666	0.002008639	1.00432E-06
	McLennan	0.02303137	0.00293258	0.023227961	0.000244829	0.017009692	0	0.038457253	0	0.0100675	0.001710581	0.003319	0.000806058	0.03281	0	0.1140288	0	0.039015	0.000294368	0.209526	0.125024945	0.131013365	6.55067E-05
	Milam	0.00165249	0.00021041	0.001666598	1.75664E-05	0.001220439	0	0.002759294	0	0.0007223	0.000122734	0.000238	5.78344E-05	0.002354	0	0.0081815	0	0.002799	2.11208E-05	0.015033	0.008970493	0.00940016	4.70008E-06
	Mitchell	0.01696145	0.0021597	0.017106233	0.000180304	0.012526789	0	0.028321847	0	0.0074142	0.001259758	0.002444	0.000593622	0.024163	0	0.0839765	0	0.028733	0.000216787	0.154305	0.09207463	0.096484803	4.82424E-05
	Nolan	0.00060327	7.6815E-05	0.000608422	6.41294E-06	0.000445544	0	0.001007331	0	0.0002637	4.48062E-05	8.69E-05	2.11135E-05	0.000859	0	0.0029868	0	0.001022	7.71053E-06	0.005488	0.003274845	0.003431703	1.71585E-06
	Palo Pinto	0.00307488	0.00039152	0.00566337	5.96935E-05	0.002270935	0	0.00906471	0	0.0037988	0.000645453	0.001096	0.000266305	0.029483	0	0.1180115	0	0.001211	9.1356E-06	0.005512	0.003288769	0.004660881	2.33044E-06
	Pecos	4.2262E-05	5.3812E-06	4.26225E-05	4.49253E-07	3.12122E-05	0	7.05678E-05	0	1.847E-05	3.13886E-06	6.09E-06	1.47909E-06	6.02E-05	0	0.0002092	0	7.16E-05	5.40155E-07	0.000384	0.000229417	0.000240405	1.20203E-07
	Presidio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Robertson	0.00035926	4.5744E-05	0.000406685	4.28657E-06	0.000265328	0	0.000358385	0	0.0015339	0.00026062	0.000356	8.64519E-05	0.000371	0	0.0009089	0	0.093323	0.000704115	0.001655	0.000987348	0.002088566	1.04428E-06
	Taylor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Titus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tom Green	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upton	3.2238E-05	4.1049E-06	3.25131E-05	3.42697E-07	2.38092E-05	0	5.38302E-05	0	1.409E-05	2.39437E-06	4.65E-06	1.12827E-06	4.59E-05	0	0.0001596	0	5.46E-05	4.12039E-07	0.000293	0.000175003	0.000183385	9.16924E-08
	Ward	0.01980763	0.0025221	0.0199767	0.00021056	0.014628815	0	0.033074321	0	0.0086584	0.001471148	0.002854	0.000693233	0.028218	0	0.098068	0	0.033554	0.000253165	0.180198	0.107524974	0.112675185	5.63376E-05
	Webb	0.01418005	0.00180555	0.000283942	2.99283E-06	0.010472596	0	0.000474359	0	0.0001047	1.77961E-05	0.000101	2.46211E-05	0.002916	0	0.0004515	0	0.0001	7.5664E-07	0.000516	0.000307987	0.002159699	1.07985E-06
	Wharton	0.00015439	1.9658E-05	0.000191235	2.01567E-06	0.000114024	0	6.43902E-05	0	0.0011702	0.000198821	0.000266	6.45707E-05	0.000107	0	6.777E-05	0	8.17E-05	6.1655E-07	0.000112	6.69642E-05	0.000352647	1.76323E-07
	Wichita	0.00021984	2.7993E-05	0.000221719	2.33699E-06	0.000162364	0	0.000367089	0	9.61E-05	1.63281E-05	3.17E-05	7.69412E-06	0.000313	0	0.0010884	0	0.000372	2.80985E-06	0.002	0.001193409	0.001250571	6.25286E-07
	Wilbarger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Wise	0.00291847	0.00037161	0.002955932	3.11563E-05	0.002155421	0	0.004892446	0	0.0012878	0.000218803	0.000424	0.000102919	0.004281	0	0.0149528	0	0.004924	3.71537E-05	0.026441	0.015777168	0.016538808	8.2694E-06
	Young	0.00549666	0.00069989	0.005543579	5.84309E-05	0.004059529	0	0.009178198	0	0.0024027	0.000408247	0.000792	0.000192374	0.00783	0	0.0272141	0	0.009311	7.02537E-05	0.050005	0.02983842	0.031267614	1.56338E-05
	Total	**1.14303735**	**0.14554295**	**1.154658244**	**0.012170419**	**1.089429227**	**0**	**1.180868675**	**0**	**1.5393506**	**0.261551921**	**1.443965**	**0.350724672**	**1.481727**	**0**	**1.2697054**	**0**	**1.151969**	**0.008691482**	**1.517783**	**0.905666927**	**1.684348366**	**0.000842174**

Energy Savings by PCA (MWh)		American Electric Power - West (ERCOT) /PCA		Austin Energy/PCA		Brownsville Public Utils Board/PCA		Lower Colorado River Auhotrity /PCA		Reliant Energy HL&P/PCA		San Antonio Public Service Bd/PCA		South Texas Electric Coop INC/PCA		Texas Municipal Power Pool/PCA		Texas-New Mexico Power Co/PCA		TXU Electric/PCA
		0.13		0.01		0.00		0.00		0.17		0.24		0.00		0.00		0.01		0.60

Figure 10-9. Ozone Season Day NOx Emissions Reduction per County from PV Projects.

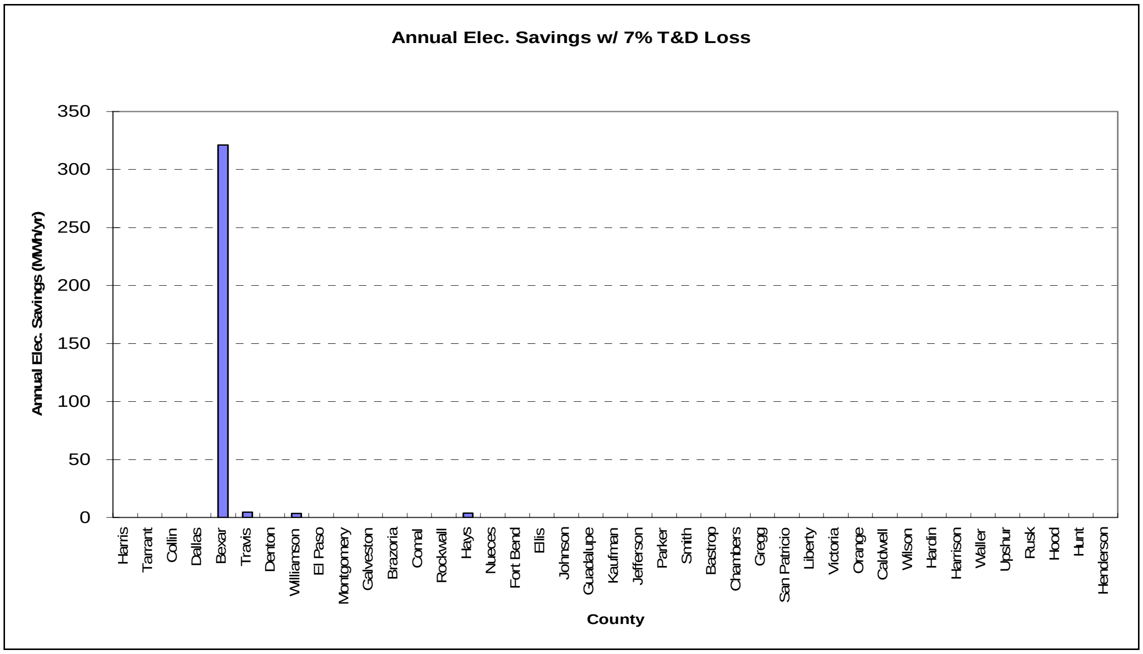


Figure 10-10. Annual Electric Savings per County from Solar Thermal Projects.

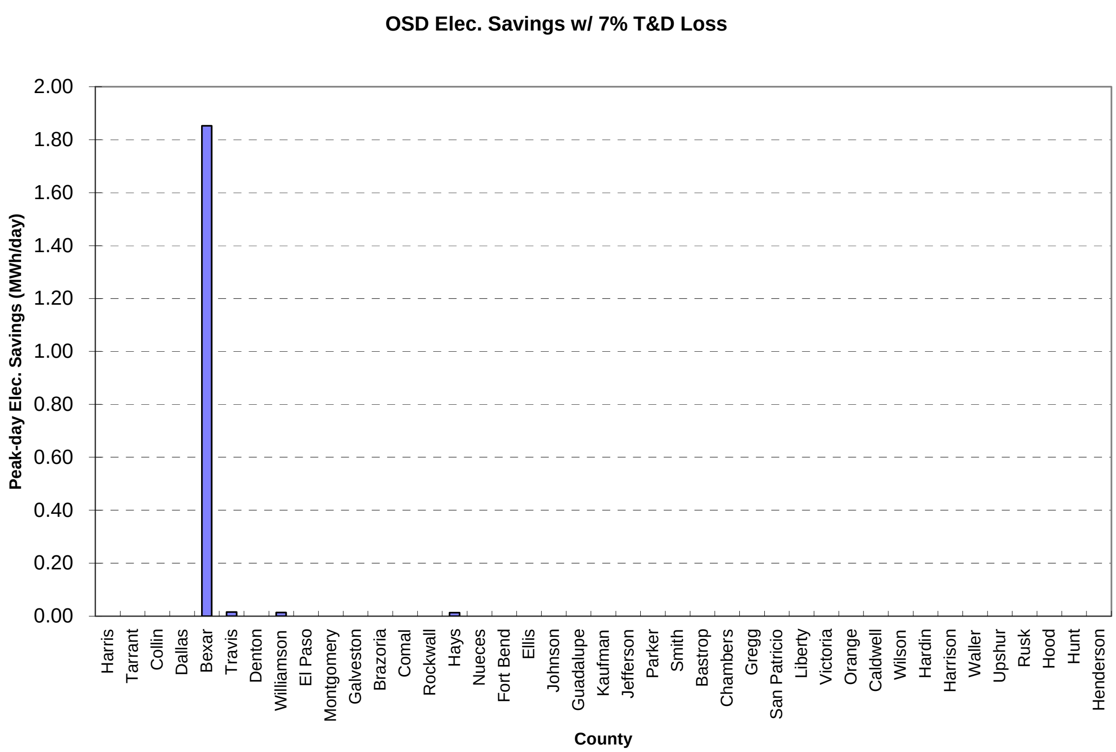


Figure 10-11. Ozone Season Day Electric Savings per County from Solar Thermal Projects.

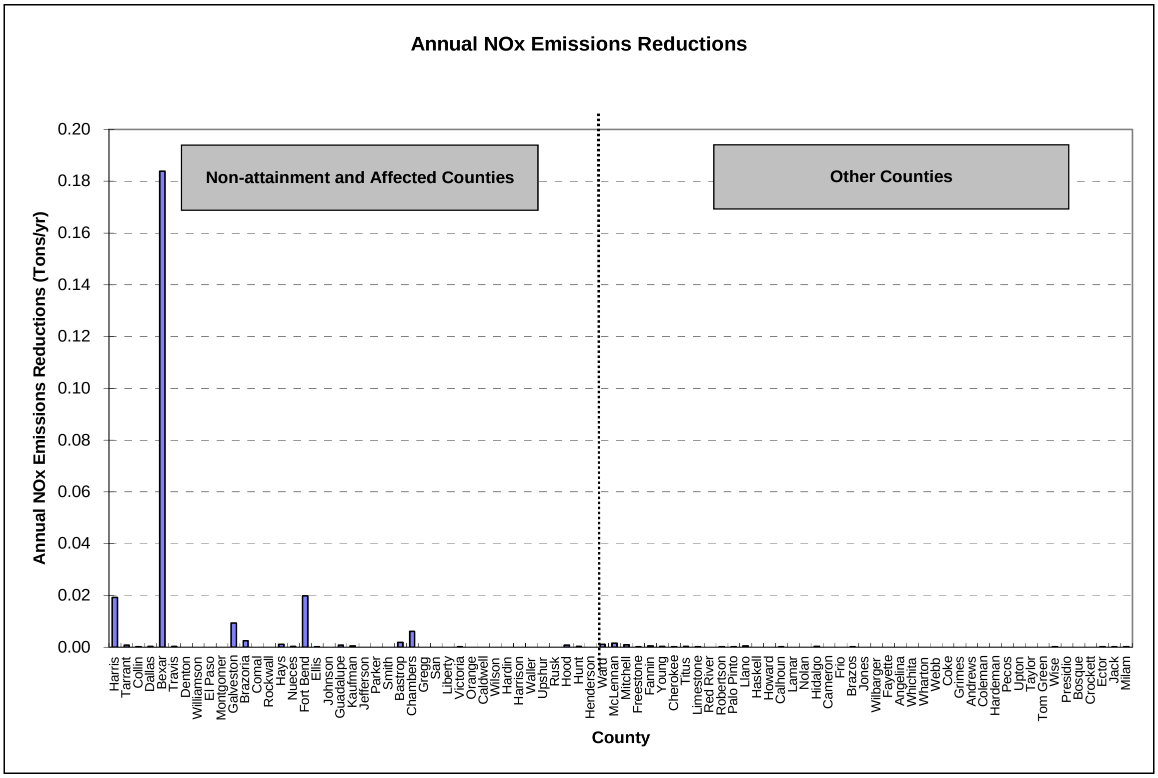


Figure 10-12. NOx Emissions Reduction per County from Solar Thermal Projects.

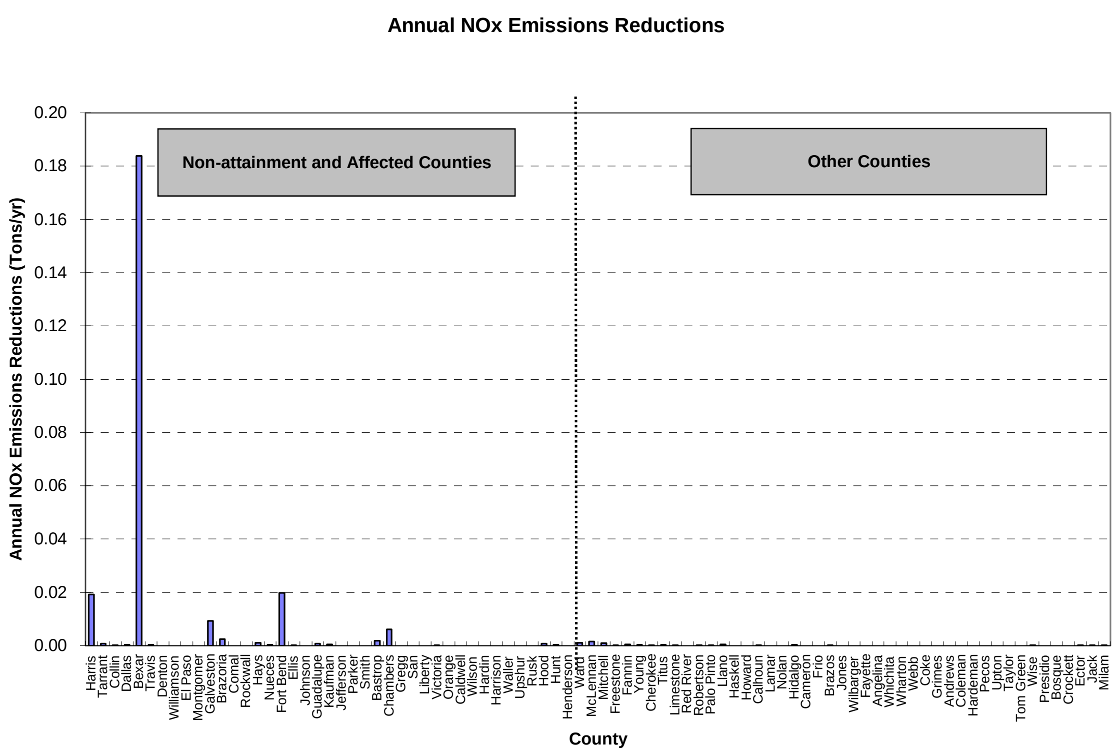


Figure 10-13. Ozone Season Day NOx Emissions Reduction per County from Solar Thermal Projects.

Table 10-18: eGrid table for the Annual NOx Emissions Reduction per County from Solar Thermal Projects.

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)
Houston-Galveston Area	Brazoria	0.00883113	0	0.010890729	0.002848453	0.006522185	0	0.003944232	0.014640318	0.0654443	0	0.014877	4.780224993	0.006262	0	0.0048171	0	0.121275	0	0.00816387	0.062025833	4.859739597	0.00242987
	Chambers	0.02176222	0	0.026955801	0.007050248	0.016072371	0	0.009076193	0.033689286	0.1649402	0	0.037472	12.0401138	0.015056	0	0.0095532	0	0.011519	0	0.01581859	0.120183362	12.2010367	0.006100518
	Fort Bend	0.07043123	0	0.087239726	0.022817415	0.052016606	0	0.029374182	0.10903197	0.5338124	0	0.121275	38.966612	0.048726	0	0.030918	0	0.037279	0	0.05119528	0.388961311	39.48742269	0.019743711
	Galveston	0.03385674	0	0.041710519	0.010909321	0.025004711	0	0.015351589	0.056982487	0.2495874	0	0.056747	18.23322994	0.024143	0	0.0192972	0	0.567751	0	0.03283689	0.249481582	18.55060333	0.009275302
	Harris	0.06826733	0	0.084559408	0.022116382	0.050418468	0	0.028471701	0.105682115	0.5174117	0	0.117549	37.76941726	0.047229	0	0.0299681	0	0.036133	0	0.04962237	0.377011018	38.27422677	0.019137113
	Liberty	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Montgomery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Waller	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beaumont/ Port Arthur Area	Hardin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Orange	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dallas/ Fort Worth Area	Collin	0.00203914	0	0.003716345	0.000972004	0.001505992	0	0.005950953	0.022088925	0.0024815	0	0.000717	0.230393486	0.019166	0	0.0766809	0	0.000864	0	0.0040002	0.030391921	0.283846335	0.000141923
	Dallas	0.00453947	0	0.004683963	0.001225083	0.003352602	0	0.00774211	0.028737396	0.0020856	0	0.000681	0.218829512	0.007503	0	0.026717	0	0.007525	0	0.04037045	0.306718625	0.555510616	0.000277755
	Denton	0.00047388	0	0.000872802	0.00022828	0.000349982	0	0.001396994	0.005185404	0.0005854	0	0.000169	0.054291425	0.004544	0	0.0181872	0	0.000187	0	0.00084941	0.006453444	0.066158552	3.30793E-05
	Tarrant	0.01216249	0	0.012266309	0.003208234	0.008982543	0	0.020308652	0.075382264	0.0053165	0	0.001753	0.563092629	0.017326	0	0.0602168	0	0.020603	0	0.11064724	0.840653623	1.48233675	0.000741168
	Ellis	0.00327981	0	0.003307809	0.000865152	0.002422289	0	0.005476558	0.020328051	0.0014337	0	0.000473	0.15184707	0.004672	0	0.0162384	0	0.005556	0	0.02983782	0.226695899	0.399736173	0.000199868
	Johnson	0.00028606	0	0.000526868	0.000137801	0.000211267	0	0.000843297	0.003130176	0.0003534	0	0.000102	0.032773092	0.002743	0	0.0109787	0	0.000113	0	0.00051274	0.00389563	0.039936699	1.99683E-05
	Kaufman	0.00632545	0	0.006379446	0.001668534	0.004671629	0	0.010562096	0.039204706	0.002765	0	0.000911	0.292852451	0.009011	0	0.0313175	0	0.010715	0	0.05754527	0.437205997	0.770931688	0.000385466
	Parker	0.00021749	0	0.000400576	0.00010477	0.000160626	0	0.000641157	0.002379864	0.0002687	0	7.75E-05	0.024917292	0.002085	0	0.0083471	0	8.56E-05	0	0.00038984	0.002961837	0.030363764	1.51819E-05
	Rockwall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Henderson	0.00081989	0	0.000826893	0.000216273	0.000605529	0	0.001369042	0.005081651	0.0003584	0	0.000118	0.037959061	0.001168	0	0.0040593	0	0.001389	0	0.00745892	0.056669935	0.099926919	4.99635E-05
	Hood	0.01252711	0	0.012634039	0.003304413	0.009251829	0	0.020917482	0.077642138	0.0054759	0	0.001805	0.579973501	0.017846	0	0.062022	0	0.021221	0	0.11396431	0.865855456	1.526775508	0.000763388
	Hunt	0.00618756	0	0.006240374	0.00163216	0.004569788	0	0.010331844	0.038350048	0.0027047	0	0.000892	0.2864683	0.008815	0	0.0306347	0	0.010482	0	0.05629078	0.427674955	0.754125463	0.000377063
El Paso Area	El Paso	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Antonio Area	Bexar	0.03341375	0	0.051775843	0.013541892	0.024677545	0	0.090663423	0.336527214	0.0011418	0	1.143572	367.4377125	0.046874	0	0.0046695	0	0.00052	0	0.00250387	0.01902337	367.806805	0.183903403
	Comal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Guadalupe	0.00200047	0	0.076378745	0.019976742	0.001477434	0	0.133848731	0.496823733	0.0012371	0	0.003555	1.142181245	0.001062	0	0.0018557	0	0.000402	0	0.00183516	0.013942851	1.672924572	0.000836462
	Wilson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austin Area	Bastrop	0.00450233	0	0.171901148	0.044960479	0.003325174	0	0.301245466	1.118171957	0.0027843	0	0.008001	2.570640153	0.00239	0	0.0041765	0	0.000904	0	0.0041303	0.031380355	3.765152943	0.001882576
	Caldwell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hays	0.0024586	0	0.093870431	0.024551666	0.001815785	0	0.164501762	0.610602576	0.0015205	0	0.004369	1.403755021	0.001305	0	0.0022807	0	0.000494	0	0.00225544	0.017135938	2.056045201	0.001028023
	Travis	0.00051001	0	0.299602906	0.078360675	0.000376663	0	0.033939476	0.125977566	0.0003347	0	0.000906	0.291143105	0.000271	0	0.0004717	0	0.000103	0	0.00046734	0.003550631	0.499031977	0.000249516
	Williamson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North East Texas Area	Gregg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Harrison	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rusk	0.00068596	0	0.00069182	0.000180944	0.000506616	0	0.001145408	0.004251561	0.0002999	0	9.88E-05	0.031758437	0.000977	0	0.0033962	0	0.001162	0	0.00624051	0.047412883	0.083603826	4.18019E-05
	Smith	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upshur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corpus Christi Area	Nueces	0.22756873	0	0.004556851	0.001191837	0.168069652	0	0.007612767	0.028257297	0.0016809	0	0.001627	0.522701083	0.046792	0	0.0072464	0	0.001609	0	0.00828339	0.062933933	0.615084151	0.000307542
	San Patricio	0.05031335	0	0.001007478	0.000263504	0.037158653	0	0.001683113	0.006247428	0.0003716	0	0.00036	0.115564398	0.010345	0	0.0016021	0	0.000356	0	0.00183138	0.013914113	0.135989443	6.79947E-05
Victoria Area	Victoria	0.02183674	0	0.002215582	0.000579482	0.016127403	0	0.003612695	0.013409711	0.0011996	0	0.000555	0.178450357	0.525456	0	0.0324127	0	0.000477	0	0.00225485	0.017131446	0.209570996	0.000104785
Other ERCOT counties	Andrews	2.4742E-05	0	2.49533E-05	6.52649E-06	1.82731E-05	0	4.13138E-05	0.00015335	1.082E-05	0	3.57E-06	0.001145496	3.52E-05	0	0.0001225	0	4.19E-05	0	0.00022509	0.001710136	0.003015508	1.50775E-06
	Angelina	0.00031082	0	0.000313473	8.19884E-05	0.000229554	0	0.000519	0.00192644	0.0001359	0	4.48E-05	0.014390176	0.000443	0	0.0015389	0	0.000527	0	0.00282766	0.021483417	0.037882021	1.8941E-05
	Bosque	0.00059539	0	0.001096604	0.000286815	0.000439723	0	0.001755208	0.006515035	0.0007356	0	0.000212	0.068212728	0.005709	0	0.0228507	0	0.000234	0	0.00106721	0.008108223	0.083122801	4.15614E-05
	Brazos	0.00193973	0	0.003572622	0.000934414	0.001432574	0	0.005718288	0.021225314	0.0023964	0	0.000692	0.222230058	0.018599	0	0.0744451	0	0.000764	0	0.00347685	0.026415759	0.270805544	0.000135403
	Calhoun	0.08269981	0	0.001655986	0.000433121	0.061077496	0	0.002766524	0.010268867	0.0006108	0	0.000591	0.189952633	0.017004	0	0.0026334	0	0.000585	0	0.00301023	0.02287056	0.223525181	0.000111763
	Cameron	0.04837175	0	0.000968599	0.000253336	0.297964476	0	0.001618161	0.006006339	0.0003573	0	0.000346	0.11110474	0.009946	0	0.0015403	0	0.000342	0	0.00176071	0.013377164	0.130741578	6.53708E-05
	Cherokee	0.0035039	0	0.003533808	0.000924262	0.002587786	0	0.00585073	0.021716917	0.0015316	0	0.000505	0.162221656	0.004992	0	0.0173479	0	0.005936	0	0.03187642	0.242184351	0.427047185	0.000213524
	Coke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coleman	0.00129879	0	2.6007E-05	6.80209E-06	0.000959212	0	4.34478E-05	0.000161271	9.593E-06	0	9.28E-06	0.002983175	0.000267	0	4.136E-05	0	9.19E-06	0	4.7275E-05	0.000359178	0.003510426	1.75521E-06
	Crockett	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ector	0.00353575	0	0.003565928	0.000932663	0.002611307	0	0.005903911	0.021914313	0.0015456	0	0.000509	0.163696172	0.005037	0	0.0175056	0	0.00599	0	0.03216616	0.244385688	0.430928836	0.000215464
	Fannin	0.00705631	0	0.007116546	0.001861322	0.005211403	0	0.011782473	0.043734538	0.0030845	0	0.001017	0.326689521	0.010052	0	0.034936	0	0.011954	0	0.06419422	0.487722118	0.860007499	0.000430004
	Fayette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Freestone	0.00367718	0	0.003708565	0.00096997	0.00271576	0	0.006140067	0.022790885	0.0016074	0	0.00053	0.170244019	0.005238	0	0.0182058	0	0.006229	0	0.03345281	0.254161116	0.448165989	0.000224083
	Frio	0.00858833	0	0.000871383	0.000227909	0.006342868	0	0.001420864	0.005274006	0.0004718	0	0.000218	0.070184088	0.206661	0	0.0127478	0	0.000188	0	0.00088683	0.006737756	0.082423759	4.12119E-05
	Grimes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hardeman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haskell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hidalgo	0.18852746	0	0.003775086	0.000987368	0.139235931	0	0.006306735	0.023409527	0.0013925	0	0.001348	0.433027444	0.038764	0	0.0060032	0	0.001333	0	0.00686231	0.052137103	0.509561441	0.000254781
	Howard	0.00055511	0	0.000559851	0.000146428	0.000409976	0	0.000926915	0.003440551	0.0002427	0	8E-05	0.02570033	0.000791	0	0.0027484	0	0.00094	0	0.00505009	0.038368599	0.067655909	3.3828E-05
	Jack	0.00212145	0	0.002139557	0.000559598	0.001566784	0	0.003542346	0.013148588	0.0009273	0	0.000306	0.098217703	0.003022	0	0.0105033	0	0.003594	0	0.0192997	0.146631413	0.258557302	0.000129279
	Jones	0.04071872	0	0.000815354	0.000213255	0.030072592	0	0.001362147	0.005056059	0.0003008	0	0.000291	0.093526559	0.008372	0	0.0012966	0	0.000288	0	0.00148214	0.011260727	0.1100566	5.50283E-05
	Lamar	0.00095084	0	0.000958954	0.000250813	0.000702236	0	0.001587687	0.005893225	0.0004156	0	0.000137	0.044021387	0.001355	0	0.0047076	0	0.001611	0	0.00865017	0.065720517	0.115885942	5.7943E-05
	Limestone	0.00071976	0	0.000891528	0.000233178	0.000531572	0	0.000300183	0.001114229	0.0054552	0	0.001239	0.398210876	0.000498	0	0.000316	0	0.000381	0	0.00052318	0.003974906	0.403533189	0.000201767
	Llano	0.00123817	0	0.047274044	0.012364453	0.000914447	0	0.082844655	0.307505274	0.0007657	0	0.0022	0.706944402	0.000657	0	0.0011486	0	0.000249	0	0.00113586	0.008629822	1.035443951	0.000517722
	McLennan	0.02453432	0	0.024743738	0.006471686	0.018119687	0	0.040966843	0.152061957	0.0107245	0	0.003535	1.135876828	0.034951	0	0.1214699	0	0.041562	0	0.22319886	1.695776008	2.99018648	0.001495093
	Milam	0.0022454	0	0.002264571	0.000592295	0.001658332	0	0.003749326	0.01391686	0.0009815	0	0.000324	0.103956568	0.003199	0	0.011117	0	0.003804	0	0.02042738	0.155199093	0.273664816	0.000136832
	Mitchell	0.01494317	0	0.015070721	0.003941724	0.011036196	0	0.024951762	0.092616699	0.006532	0	0.002153	0.691830913	0.021288	0	0.073984	0	0.025314	0	0.1359442	1.032849896	1.821239231	0.00091062
	Nolan	0.00056465	0	0.000569473	0.000148945	0.000417022	0	0.000942846	0.003499684	0.0002468	0	8.14E-05	0.026142038	0.000804	0	0.0027956	0	0.000957	0	0.00513689	0.039028035	0.068818702	3.44094E-05
	Palo Pinto	0.003207	0	0.005906709	0.001544891	0.002368511	0	0.009454195	0.035092366	0.003962	0	0.001144	0.367418759	0.03075	0	0.1230821	0	0.001263	0	0.00574838	0.043673864	0.447729879	0.000223865
	Pecos	4.0968E-05	0	4.13174E-05	1.08065E-05	3.02565E-05	0	6.84069E-05	0.000253915	1.791E-05	0	5.9E-06	0.0018967	5.84E-05	0	0.0002028	0	6.94E-05	0	0.0003727	0.002831626	0.004993047	2.49652E-06
	Presidio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Robertson	0.00073771	0	0.000835096	0.000218418	0.00054483	0	0.000735917	0.002731599	0.0031497	0	0.000731	0.234835414	0.000761	0	0.0018663	0	0.191633	0	0.00339774	0.025814655	0.263600087	0.0001318
	Taylor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Titus	0.00569644	0	0.005745061	0.001502612	0.004207073	0	0.009511781	0.035306115	0.00249	0	0.000821	0.263730641	0.008115	0	0.0282032	0	0.00965	0	0.05182285	0.393729393	0.69426876	0.000347134
	Tom Green	0.00148245	0	2.96846E-05	7.76397E-06	0.001094854	0	4.95918E-05	0.000184076	1.095E-05	0	1.06E-05	0.003405025	0.000305	0	4.72E-05	0	1.05E-05	0	5.396E-05	0.00040997	0.004006835	2.00342E-06
	Upton	3.1166E-05	0	3.14322E-05	8.22103E-06	2.30176E-05	0	5.20405E-05	0.000193165	1.362E-05	0	4.49E-06	0.001442913	4.44E-05	0	0.0001543	0	5.28E-05	0	0.00028353	0.002154157	0.003798456	1.89923E-06
	Ward	0.01855953	0	0.01871795	0.004895651	0.013707039	0	0.030990277	0.115030641	0.0081128	0	0.002674	0.859259227	0.02644	0	0.0918886	0	0.03144	0	0.16884373	1.282807384	2.261992904	0.001130996
	Webb	0.02001433	0	0.000400768	0.00010482	0.014781473	0	0.000669531	0.002485187	0.0001478	0	0.000143	0.045970773	0.004115	0	0.0006373	0	0.000142	0	0.00072851	0.005534945	0.054095725	2.70479E-05
	Wharton	0.00014434	0	0.000178787	4.67613E-05	0.000106601	0	6.01986E-05	0.000223447	0.001094	0	0.000249	0.079857028	9.99E-05	0	6.336E-05	0	7.64E-05	0	0.00010492	0.000797126	0.080924362	4.04622E-05
	Wichita	0.00020763	0	0.000209406	5.47697E-05	0.000153346	0	0.000346701	0.001286896	9.076E-05	0	2.99E-05	0.009612892	0.000296	0	0.001028	0	0.000352	0	0.00188893	0.014351303	0.025305861	1.26529E-05
	Wilbarger	0.02861682	0	0.000573025	0.000149874	0.021134796	0	0.000957307	0.003553361	0.0002114	0	0.000205	0.065729777	0.005884	0	0.0009112	0	0.000202	0	0.00104164	0.007913956	0.077346968	3.86735E-05
	Wise	0.00284449	0	0.002882008	0.000753785	0.002100781	0	0.00476997	0.017705319	0.0012561	0	0.000413	0.132777356	0.004182	0	0.0146143	0	0.004798	0	0.02576141	0.195724938	0.346961398	0.000173481
	Young	0.00623586	0	0.006289085	0.0016449	0.004605458	0	0.010412491	0.038649395	0.0027258	0	0.000899	0.288704374	0.008883	0	0.0308739	0	0.010564	0	0.05673017	0.431013239	0.760011908	0.000380006
	Total	**1.12183722**	**0**	**1.172570094**	**0.306683889**	**1.090766584**	**0**	**1.189130767**	**4.413851254**	**1.62936**	**0**	**1.542363**	**495.5720525**	**1.359386**	**0**	**1.2316428**	**0**	**1.221806**	**0**	**1.52878695**	**11.61511408**	**511.9077018**	**0.255953851**

Energy Savings by PCA (MWh)		AEP		Austin		Brownsville		LCRA		Reliant		SAPS		STEC		TMPA		TNMP		TXU	
		0.00		0.26		0.00		3.71		0.00		321.31		0.00		0.00		0.00		7.60	

Table 10-19: eGrid table for the Average Ozone Day NOx Emissions Reduction per County from Solar Thermal Projects.

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)
Houston-Galveston Area	Brazoria	0.00957217	0	0.011806715	1.13515E-05	0.007069474	0	0.004263638	5.47451E-05	0.0710018	0	0.01614	0.029899928	0.006781	0	0.0051797	0	0.126288	0	0.008772	0.00024498	0.030211005	1.51055E-05
	Chambers	0.0218814	0	0.027103415	2.60584E-05	0.016160386	0	0.009125896	0.000117177	0.1658435	0	0.037677	0.069797226	0.015138	0	0.0096055	0	0.011582	0	0.015905	0.00044421	0.070384671	3.51923E-05
	Fort Bend	0.05569551	0	0.068987309	6.63275E-05	0.041133619	0	0.023228475	0.000298254	0.4221274	0	0.095902	0.177657421	0.038531	0	0.0244493	0	0.029479	0	0.040484	0.001130663	0.179152666	8.95763E-05
	Galveston	0.02755599	0	0.033893644	3.25868E-05	0.020351324	0	0.012791501	0.000164243	0.2014466	0	0.045813	0.084867272	0.019824	0	0.0167751	0	0.594657	0	0.028709	0.000801814	0.085865916	4.2933E-05
	Harris	0.07736057	0	0.09582276	9.21282E-05	0.057134232	0	0.032264145	0.000414272	0.5863312	0	0.133207	0.246764583	0.05352	0	0.0339599	0	0.040946	0	0.056232	0.001570481	0.248841464	0.000124421
	Liberty	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Montgomery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Waller	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beaumont/ Port Arthur Area	Hardin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Orange	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dallas/ Fort Worth Area	Collin	0.00176365	0	0.003151138	3.02964E-06	0.001302533	0	0.005050143	6.48438E-05	0.0020858	0	0.000604	0.001119053	0.015958	0	0.0637888	0	0.000846	0	0.004013	0.000112083	0.001299009	6.49505E-07
	Dallas	0.00504555	0	0.005305276	5.10073E-06	0.003726366	0	0.008757286	0.000112444	0.0024131	0	0.000782	0.001449136	0.00931	0	0.033672	0	0.008209	0	0.044002	0.001228917	0.002795597	1.3978E-06
	Denton	0.00063576	0	0.001170951	1.1258E-06	0.000469535	0	0.001874207	2.40648E-05	0.0007854	0	0.000227	0.000419943	0.006096	0	0.0243999	0	0.00025	0	0.00114	3.18263E-05	0.00047696	2.3848E-07
	Tarrant	0.01557224	0	0.015705165	1.50996E-05	0.011500796	0	0.026002176	0.000333868	0.006807	0	0.002244	0.004156657	0.022184	0	0.0770985	0	0.02638	0	0.141667	0.003956559	0.008462184	4.23109E-06
	Ellis	0.00350282	0	0.003532723	3.39652E-06	0.002586991	0	0.005848935	7.51003E-05	0.0015312	0	0.000505	0.000934999	0.00499	0	0.0173426	0	0.005934	0	0.031867	0.000889989	0.001903485	9.51743E-07
	Johnson	0.00033718	0	0.000621017	5.97073E-07	0.00024902	0	0.000993991	1.27628E-05	0.0004166	0	0.00012	0.000222718	0.003233	0	0.0129406	0	0.000133	0	0.000604	1.68792E-05	0.000252957	1.26478E-07
	Kaufman	0.00649275	0	0.006548174	6.2957E-06	0.004795187	0	0.01084145	0.000139204	0.0028381	0	0.000936	0.001733093	0.009249	0	0.0321458	0	0.010999	0	0.059067	0.001649663	0.003528256	1.76413E-06
	Parker	0.00047595	0	0.000876616	8.42818E-07	0.000351511	0	0.0014031	1.80158E-05	0.000588	0	0.00017	0.000314385	0.004564	0	0.0182667	0	0.000187	0	0.000853	2.38264E-05	0.00035707	1.78535E-07
	Rockwall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Henderson	0.00095027	0	0.000958382	9.21431E-07	0.000701818	0	0.001586741	2.03738E-05	0.0004154	0	0.000137	0.000253653	0.001354	0	0.0047048	0	0.00161	0	0.008645	0.000241443	0.000516391	2.58196E-07
	Hood	0.01232788	0	0.012433111	1.19537E-05	0.00910469	0	0.020584816	0.000264309	0.0053888	0	0.001776	0.003290649	0.017562	0	0.0610356	0	0.020884	0	0.112152	0.003132239	0.006699151	3.34958E-06
	Hunt	0.00635121	0	0.006405424	6.15846E-06	0.004690653	0	0.010605108	0.00013617	0.0027763	0	0.000915	0.001695312	0.009048	0	0.031445	0	0.010759	0	0.05778	0.001613701	0.003451341	1.72567E-06
El Paso Area	El Paso	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Antonio Area	Bexar	0.03112811	0	0.048234164	4.63745E-05	0.0229895	0	0.084461674	0.001084488	0.0010637	0	1.065347	1.973545302	0.043667	0	0.0043501	0	0.000484	0	0.002333	6.51459E-05	1.97474131	0.000987371
	Comal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Guadalupe	0.00200761	0	0.076651484	7.36961E-05	0.00148271	0	0.134326688	0.001724755	0.0012416	0	0.003567	0.006608743	0.001066	0	0.0018623	0	0.000403	0	0.001842	5.14365E-05	0.00845863	4.22932E-06
	Wilson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austin Area	Bastrop	0.00446951	0	0.170648096	0.000164069	0.003300936	0	0.299049574	0.003839797	0.002764	0	0.007942	0.01471295	0.002372	0	0.0041461	0	0.000898	0	0.0041	0.000114512	0.018831327	9.41566E-06
	Caldwell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hays	0.00246935	0	0.094281013	9.06459E-05	0.001823727	0	0.165221279	0.002121441	0.0015271	0	0.004388	0.008128727	0.001311	0	0.0022907	0	0.000496	0	0.002265	6.32667E-05	0.010404081	5.20204E-06
	Travis	0.00050761	0	0.298194277	0.000286697	0.000374892	0	0.033779905	0.000433734	0.0003331	0	0.000902	0.001670689	0.00027	0	0.0004695	0	0.000103	0	0.000465	1.29906E-05	0.002404111	1.20206E-06
	Williamson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North East Texas Area	Gregg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Harrison	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rusk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Smith	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upshur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corpus Christi Area	Nueces	0.22352453	0	0.00447587	4.3033E-06	0.165082827	0	0.007477478	9.60108E-05	0.001651	0	0.001598	0.002960069	0.04596	0	0.0071176	0	0.001581	0	0.008136	0.000227232	0.003287615	1.64381E-06
	San Patricio	0.05533089	0	0.001107949	1.06523E-06	0.040864326	0	0.001850962	2.37664E-05	0.0004087	0	0.000396	0.00073273	0.011377	0	0.0017619	0	0.000391	0	0.002014	5.62486E-05	0.000813811	4.06905E-07
Victoria Area	Victoria	0.02060475	0	0.002090584	2.00998E-06	0.015217528	0	0.003408874	4.37699E-05	0.0011319	0	0.000524	0.000970807	0.495811	0	0.0305841	0	0.00045	0	0.002128	5.94218E-05	0.001076009	5.38004E-07
Other ERCOT counties	Andrews	2.5653E-05	0	2.58716E-05	2.48741E-08	1.89456E-05	0	4.28342E-05	5.49992E-07	1.121E-05	0	3.7E-06	6.8474E-06	3.65E-05	0	0.000127	0	4.35E-05	0	0.000233	6.51777E-06	1.394E-05	6.97002E-09
	Angelina	0.00032149	0	0.000324234	3.11733E-07	0.000237435	0	0.000536817	6.89273E-06	0.0001405	0	4.63E-05	8.58145E-05	0.000458	0	0.0015917	0	0.000545	0	0.002925	8.16835E-05	0.000174702	8.73512E-08
	Bosque	0.00093945	0	0.001730301	1.66359E-06	0.000693828	0	0.002769496	3.55603E-05	0.0011606	0	0.000335	0.000620545	0.009008	0	0.0360555	0	0.00037	0	0.001684	4.70294E-05	0.000704798	3.52399E-07
	Brazos	0.00191393	0	0.003525105	3.38919E-06	0.00141352	0	0.005642234	7.24463E-05	0.0023645	0	0.000682	0.001264223	0.018351	0	0.073455	0	0.000754	0	0.003431	9.5812E-05	0.00143587	7.17935E-07
	Calhoun	0.08852525	0	0.001772635	1.70429E-06	0.065379841	0	0.0029614	3.80244E-05	0.0006539	0	0.000633	0.001172313	0.018202	0	0.0028189	0	0.000626	0	0.003222	8.99936E-05	0.001302036	6.51018E-07
	Cameron	0.05467229	0	0.001094762	1.05255E-06	0.285623104	0	0.001828931	2.34835E-05	0.0004038	0	0.000391	0.000724009	0.011242	0	0.0017409	0	0.000387	0	0.00199	5.55791E-05	0.000804124	4.02062E-07
	Cherokee	0.003513	0	0.003542982	3.40638E-06	0.002594504	0	0.005865919	7.53184E-05	0.0015356	0	0.000506	0.000937714	0.005005	0	0.0173929	0	0.005951	0	0.031959	0.000892574	0.001909013	9.54506E-07
	Coke	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coleman	0.0013551	0	2.71346E-05	2.60884E-08	0.001000801	0	4.53316E-05	5.82058E-07	1.001E-05	0	9.69E-06	1.79452E-05	0.000279	0	4.315E-05	0	9.58E-06	0	4.93E-05	1.37758E-06	1.99309E-05	9.96545E-09
	Crockett	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ector	0.00362926	0	0.003660242	3.51912E-06	0.002680373	0	0.006060061	7.78112E-05	0.0015864	0	0.000523	0.00096875	0.00517	0	0.0179686	0	0.006148	0	0.033017	0.000922115	0.001972195	9.86097E-07
	Fannin	0.00762852	0	0.007693632	7.397E-06	0.005633999	0	0.012737922	0.000163555	0.0033346	0	0.001099	0.00203626	0.010867	0	0.0377689	0	0.012923	0	0.0694	0.001938236	0.004145447	2.07272E-06
	Fayette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Freestone	0.00377443	0	0.003806652	3.65988E-06	0.002787588	0	0.006302464	8.09236E-05	0.0016499	0	0.000544	0.0010075	0.005377	0	0.0186873	0	0.006394	0	0.034338	0.000958999	0.002051083	1.02554E-06
	Frio	0.01476384	0	0.001497957	1.4402E-06	0.010903753	0	0.002442547	3.13623E-05	0.0008111	0	0.000375	0.000695608	0.355262	0	0.0219143	0	0.000322	0	0.001525	4.25772E-05	0.000770988	3.85494E-07
	Grimes	0.00055442	0	0.001021149	9.81778E-07	0.000409467	0	0.001634436	2.09862E-05	0.0006849	0	0.000198	0.000366219	0.005316	0	0.0212784	0	0.000218	0	0.000994	2.77547E-05	0.000415941	2.07971E-07
	Hardeman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haskell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hidalgo	0.239737	0	0.004800509	4.61542E-06	0.177056459	0	0.008019827	0.000102975	0.0017708	0	0.001714	0.003174766	0.049294	0	0.0076338	0	0.001695	0	0.008726	0.000243713	0.003526069	1.76303E-06
	Howard	0.00058508	0	0.000590075	5.67324E-07	0.000432108	0	0.000976955	1.25441E-05	0.0002558	0	8.43E-05	0.000156174	0.000833	0	0.0028967	0	0.000991	0	0.005323	0.000148656	0.000317941	1.58971E-07
	Jack	0.00217756	0	0.002196145	2.11147E-06	0.001608224	0	0.003636037	4.66867E-05	0.0009519	0	0.000314	0.00058125	0.003102	0	0.0107811	0	0.003689	0	0.01981	0.000553269	0.001183317	5.91658E-07
	Jones	0.04250012	0	0.000851025	8.18213E-07	0.031388236	0	0.00142174	1.82551E-05	0.0003139	0	0.000304	0.000562816	0.008739	0	0.0013533	0	0.000301	0	0.001547	4.3205E-05	0.000625095	3.12547E-07
	Lamar	0.00107998	0	0.001089199	1.0472E-06	0.000797614	0	0.001803327	2.31547E-05	0.0004721	0	0.000156	0.000288276	0.001539	0	0.005347	0	0.00183	0	0.009825	0.000274399	0.000586877	2.93439E-07
	Limestone	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Llano	0.00124346	0	0.047475864	4.56454E-05	0.000918351	0	0.083198331	0.001068267	0.000769	0	0.00221	0.004093277	0.00066	0	0.0011535	0	0.00025	0	0.001141	3.18584E-05	0.005239048	2.61952E-06
	McLennan	0.02303137	0	0.023227961	2.23324E-05	0.017009692	0	0.038457253	0.000493791	0.0100675	0	0.003319	0.006147702	0.03281	0	0.1140288	0	0.039015	0	0.209526	0.005851756	0.012515582	6.25779E-06
	Milam	0.00165249	0	0.001666598	1.60234E-06	0.001220439	0	0.002759294	3.54293E-05	0.0007223	0	0.000238	0.000441095	0.002354	0	0.0081815	0	0.002799	0	0.015033	0.000419861	0.000897988	4.48994E-07
	Mitchell	0.01696145	0	0.017106233	1.64467E-05	0.012526789	0	0.028321847	0.000363653	0.0074142	0	0.002444	0.004527476	0.024163	0	0.0839765	0	0.028733	0	0.154305	0.004309526	0.009217101	4.60855E-06
	Nolan	0.00060327	0	0.000608422	5.84964E-07	0.000445544	0	0.001007331	1.29341E-05	0.0002637	0	8.69E-05	0.00016103	0.000859	0	0.0029868	0	0.001022	0	0.005488	0.000153278	0.000327827	1.63914E-07
	Palo Pinto	0.00307488	0	0.00566337	5.44501E-06	0.002270935	0	0.00906471	0.000116391	0.0037988	0	0.001096	0.002031077	0.029483	0	0.1180115	0	0.001211	0	0.005512	0.00015393	0.002306843	1.15342E-06
	Pecos	4.2262E-05	0	4.26225E-05	4.09792E-08	3.12122E-05	0	7.05678E-05	9.0609E-07	1.847E-05	0	6.09E-06	1.12808E-05	6.02E-05	0	0.0002092	0	7.16E-05	0	0.000384	1.07378E-05	2.29657E-05	1.14828E-08
	Presidio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Red River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Robertson	0.00035926	0	0.000406685	3.91005E-07	0.000265328	0	0.000358385	4.60167E-06	0.0015339	0	0.000356	0.000659357	0.000371	0	0.0009089	0	0.093323	0	0.001655	4.62125E-05	0.000710563	3.55281E-07
	Taylor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Titus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tom Green	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upton	3.2238E-05	0	3.25131E-05	3.12596E-08	2.38092E-05	0	5.38302E-05	6.9118E-07	1.409E-05	0	4.65E-06	8.60519E-06	4.59E-05	0	0.0001596	0	5.46E-05	0	0.000293	8.19094E-06	1.75186E-05	8.75929E-09
	Ward	0.01980763	0	0.0199767	1.92065E-05	0.014628815	0	0.033074321	0.000424674	0.0086584	0	0.002854	0.005287197	0.028218	0	0.098068	0	0.033554	0	0.180198	0.005032675	0.010763753	5.38188E-06
	Webb	0.01418005	0	0.000283942	2.72995E-07	0.010472596	0	0.000474359	6.09078E-06	0.0001047	0	0.000101	0.000187782	0.002916	0	0.0004515	0	0.0001	0	0.000516	1.44152E-05	0.000208561	1.04281E-07
	Wharton	0.00015439	0	0.000191235	1.83862E-07	0.000114024	0	6.43902E-05	8.2677E-07	0.0011702	0	0.000266	0.000492473	0.000107	0	6.777E-05	0	8.17E-05	0	0.000112	3.13424E-06	0.000496618	2.48309E-07
	Wichita	0.00021984	0	0.000221719	2.13171E-07	0.000162364	0	0.000367089	4.71342E-06	9.61E-05	0	3.17E-05	5.86821E-05	0.000313	0	0.0010884	0	0.000372	0	0.002	5.58572E-05	0.000119466	5.97329E-08
	Wilbarger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Wise	0.00291847	0	0.002955932	2.84196E-06	0.002155421	0	0.004892446	6.2819E-05	0.0012878	0	0.000424	0.000784947	0.004281	0	0.0149528	0	0.004924	0	0.026441	0.000738446	0.001589054	7.94527E-07
	Young	0.00549666	0	0.005543579	5.32984E-06	0.004059529	0	0.009178198	0.000117848	0.0024027	0	0.000792	0.001467209	0.00783	0	0.0272141	0	0.009311	0	0.050005	0.001396579	0.002986965	1.49348E-06
	Total	1.14303735	0	1.154658244	0.00111014	1.089429227	0	1.180868675	0.015162354	1.5393506	0	1.443965	2.674932267	1.481727	0	1.2697054	0	1.151969	0	1.517783	0.042389477	2.733594237	0.001366797
Energy Savings by PCA (MWh)		0.00		0.00		0.00		0.01		0.00		1.85		0.00		0.00		0.00		0.03			

11 ESTIMATING HOURLY INCOMING SOLAR RADIATION FROM LIMITED METEOROLOGICAL DATA

11.1 Introduction

One of the important tasks performed as part of the Laboratory's Senate Bill 5 effort has been the assembly and use of measured weather data for all Texas NOAA sites that correspond to the TMY2 sites for the years 1999 to 2006. Unfortunately, many of these sites have had discontinuous solar data, which requires the use of synthetic solar radiation to fill-in missing records. This section of the report contains information about the synthesis procedures used to generate the solar radiation data for those sites where data are missing.

To accomplish this, eleven-year (1980-90) continuous records at different locations containing hourly sums of integrated solar radiation were evaluated against coincident hourly cloud observations. To begin, the solar irradiance at a given solar elevation was plotted vs. total cloud amount for each season and for the whole year; in the same way, the ratio of the irradiance under clouded skies compared to that under a cloudless sky is analyzed. One of the important studies in this field is Kasten and Czeplak (1980) who showed that the ratio of global radiation at total cloud amount to global radiation at cloudless sky at the same solar elevation could be parameterized by the relationship Ig/Igcs = 1-C(n/8) D. For Texas, solar radiation data in the relationship is a better fit for the expression of the form Ig/Igcs = 1-Cexp[D(nc/10)], where the nc, is the total cloud amount, as n before, but in tenths. This expression is evaluated further in the section that follows.

11.2 Procedure for Estimating Solar Radiation Components Data

Solar radiation data is a weather parameter that has not been recorded in many locations during the past decade in Texas where there was only one station for 40,000 ha of irrigated farmland. Several studies have evaluated data in Texas, including Henggeler (1996), and Spokas and Forcella (2006). In addition, the relation of the weather stations monitoring solar radiation compared with those that monitored other ambient variables such as Tdb, Twb, Tdp, wind speed, has been determined to be 1:500 by Thornton and Running (1999), as well as Spokas and Forcella (2006).

11.2.1 Estimation of direct-normal solar radiation

In addition to the studies that have evaluated the limited availability of solar radiation data, analyses that are based on DOE-2 simulations not only require one contiguous year of data to be reformatted for use by the simulation program, they also require all components of solar radiation, including global horizontal and Direct-Normal incident solar radiation.

There are a number of different routines available for calculating direct-normal solar radiation from global horizontal solar radiation, including Erbs (1982), which is used in this effort.

Table 11-1 contains the basic equations that are utilized to generate the Direct-Normal solar radiation based on the global horizontal solar radiation. In comparison to measured values of the Direct-Normal solar radiation, from a Normal Incident Pyrheliometer (NIP), the values calculated from the Erbs correlation tend to underestimate large portions of the year. Though this outcome was expected due to the nature of the Erbs' correlation, its use is more advisable than the use of the mixed data sets that contain measured Direct-Normal Solar Radiation for some portions and synthetic Direct Normal for others. Therefore, for this effort all Direct-Normal solar radiation was synthesized for all sites using Erbs routines.

11.2.2 Synthesis of hourly global solar radiation: preliminary procedure

The previous section briefly described the methodology the Laboratory uses to synthesize the solar radiation components when only the global horizontal solar radiation is available. Initially it was thought that if the global horizontal solar radiation was not available, a manual data filling procedure should be used that would utilize several techniques, including using data from previous "similar" years or from nearby stations. However, these procedures were found to be inadequate because missing Solar Radiation data can be found for long or short periods. Short periods can be characterized as gaps with a length of days and hours. Long periods can include gaps for up to one week. In the worst cases, data were unavailable for months or years. Therefore, there was a need to develop a procedure for the synthesis of hourly global horizontal solar radiation that allows for filling the void of data in any place in Texas.

There are many procedures to synthesize hourly global horizontal solar radiation and its components. Unfortunately, most of these procedures are based on data taken from other parts of the world that do not experience the varying hot-dry and hot-humid conditions that exist in Texas. Also, some methodologies are based on parameters that may not be available for the location where the Solar Radiation is needed. In the current case for Texas, available long-term meteorological data are available from the National Oceanic and Atmospheric Administration, which limits the use of certain parameters.

One of the meteorological parameters that is available in almost all of the NOAA stations is the cloud cover. This parameter has been used since the eighties to determine hourly global solar radiation. Kasten and Czeplak (1980) proposed evaluating the global solar radiation, I_G, from the total cloud amount, N, in oktas, through a relationship with the global solar radiation under a cloudless sky, I_{Gcs}, which depends on the elevation angle, and can be obtained via a linear parameterization as follows

$$I_{G_{CS}} = A\sin\alpha - B$$

They found that the ratio of global radiation for a given cloud amount to I_{Gc} is independent of the solar elevation and can be expressed as

$$I_G / I_{G\,cs} = 1 - 0.75(N/8)^{3.4}$$

The diffuse component was also found to be independent of the solar elevation and related to the global irradiance by the following equation

$$I_d / I_G = 0.3 - 0.7(N/8)^2$$

The application of this methodology to data from Abilene, Texas, in the year 2001 is shown in Figure 11-1 and Figure 11-2. Figure 11-1 shows the global solar radiation synthesized for Abilene for the winter-spring season of 2001. There is an important variation, evident in Figure 11-2, which shows that the measured and the predicted global solar are a good fit for the clear days but the cloudy day model had a problem relative to the amount of water vapor in the atmosphere. Therefore, the Kasten and Czeplak procedures need to be modified or adjusted for the variation in global solar radiation that was traceable to atmospheric moisture.

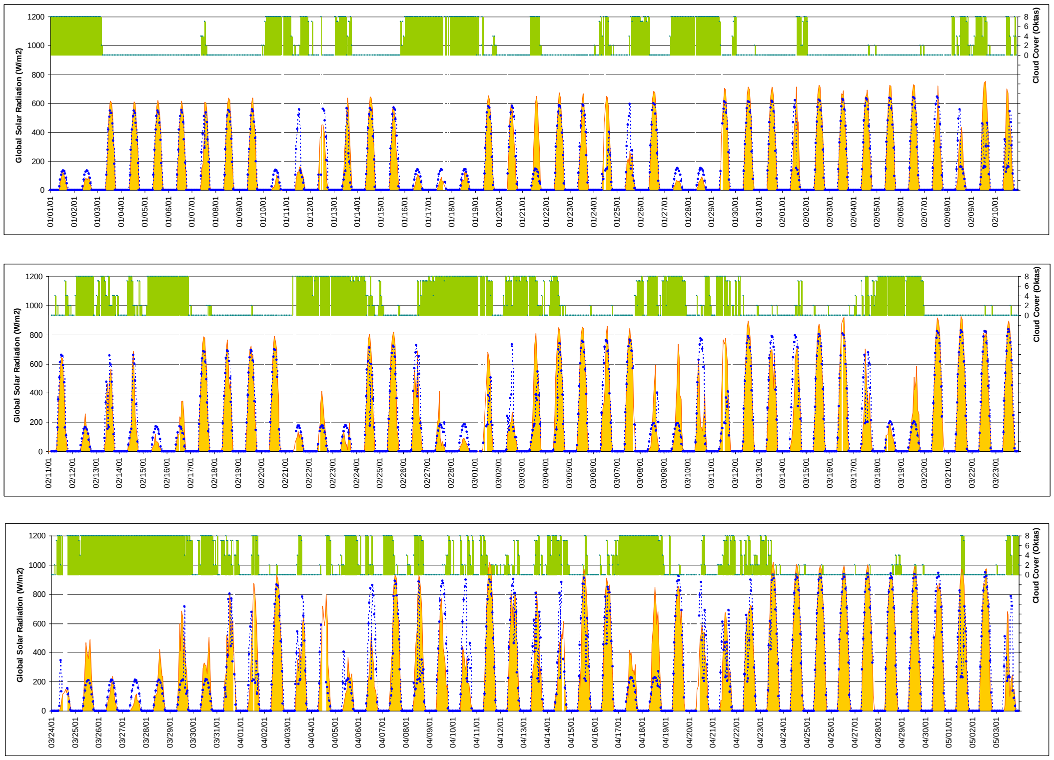


Figure 11-1: Output of the global horizontal solar synthesized for Abilene, Texas, in the 2001 winter-spring season.

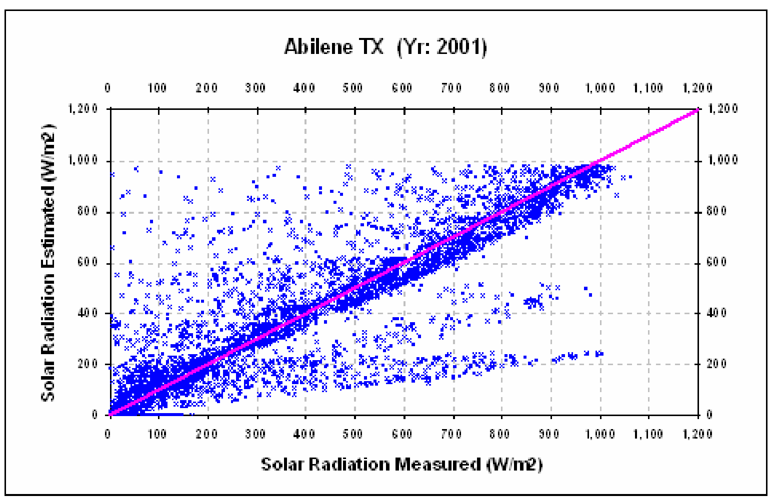


Figure 11-2: Comparison of the estimated versus measured global horizontal solar radiation for Abilene, Texas, in the year 2001.

Table 11-1: Major steps of the simplified numerical procedure for direct-normal solar radiation synthesis through Erbs correlation.

$B = (n-1)360/365$

$E_t = 229.2(0.000075+(0.001868Cos(B))-(0.032077Sin(B))-(0.014615Cos(2B))-(0.04089Sin(2B)))$

$d = 23.45Sin((284+n)360/365)$

$h_{st} = (60t + 4(90 - l_{loc}) + E_t)/60$

$h_w = (h_{st}^* - 12)15$

$I_o = I_{cs}((1+0.033 Cos(n\,360/365))(Cos(f) Cos(d) Cos(h_w) + Sin(f) Sin(d))$

$K_t = I/I_o$

- $K_t <= 0.22$ $I_d/I_o = 1 - 0.09K_t$
- $K_t > 0.80$ $I_d/I_o = 0.165$
- Otherwise $I_d/I_o = 0.9511 - 0.1604K_t + 4.388K_t^2 - 16.638K_t^3 + 12.336K_t^4$

$I_d = (I_d/I)_{ERBS} I$

$I_b = (1 - (I_d/I)_{ERBS})I$

$Cos(q) = Cos(f) Cos(d) Cos(h_w) + Sin(f) Sin(d)$

$I_{DN} = I_b/Cos(q)$

n - Day of the year [1, … , 365]
E_t - Equation of time [min]
d - Solar Declination [23.45°, -23.45°]
t - Local time [hrs]
l_{loc} - Longitude local [Degrees]
h_{st} - Decimal Solar Time
h_w - Hour angle [-180°, 180°]
f - Latitude local [Degrees]
I_{cs} - Solar Constat Irradiation [1367 W/m2]
I_o - Extraterrestrial Radiation [W/m2]
K_t - Clearness Index
$(I_d/I)_{ERBS}$ - Erbs' Correlations
I - Global Radiation [W/m2]
I_b - Bean Radiation Component [W/m2]
I_d - Diffuse Radiation Component [W/m2]
q - Incidence angle [Degrees]
I_{DN} - Direct Normal Radiation [W/m2]

11.2.3 Synthesis of hourly global solar radiation: preliminary results of an adjusted/modified cloud cover model.

Due to the variation of the Kasten and Czeplak model, the solar radiation data equations were revisited and analyzed. In these equations the relationship between the global radiation for clear days as a function of the altitude solar angle has been very well established to be linear and expressed as follows

$$I_{Gcs} = A\sin\alpha - B$$

For the global horizontal solar radiation computation, a function in Kasten and Czeplak representing the cloud cover used an expression that had the ratio of global radiation (I_G) to the global radiation for cloudless sky (I_{Gcs}) at the same solar elevation or altitude solar (α) as independent of α, which was parameterized by the relationship

$$I_G / I_{Gcs} = 1 - C(N/8)^D$$

The diffuse component was independent of the solar elevation and was related to the global irradiance by the following expression

$$I_d / I_G = C_1 - C_2 (N/8)^{C_3}$$

The direct component was calculated as the difference of global and diffuse components. The coefficients A, B, C, and D (besides C_1, C_2, and C_3 for the diffuse component) involved in the modeling have to be fitted against enough measured global solar radiation data to account for all the conditions in the location – i.e. the modeling in reality is site-specific.

Table 11-2 contains the mathematical depiction of the procedure to obtain the coefficients that are required for the solar radiation relationships. As mentioned before, the size of the data sample should be as large as possible to assure the integration of the range of variability of the location solar radiation.

Table 11-2: General mathematical procedure to derive the constants of the global solar radiation model as a function of the cloud cover.

$$I_G / I_{Gc} = 1 - C(N/U)^D$$
$$1 - I_G / I_{Gc} = C(N/U)^D$$
$$\ln(1 - I_G / I_{Gc}) = \ln\left(C(N/U)^D\right)$$
$$\ln(1 - I_G / I_{Gc}) = D\ln(N/U) + \ln(C)$$

which can be represented as a linear equation as follows.

$$y = mx + b$$
$$y = \ln(1 - I_G / I_{Gc}) \quad m = D \quad x = \ln(N/U) \quad b = \ln(C)$$

For the Global Solar Radiation at clear sky conditions

$$I_{G_C} = A\sin\alpha - B$$
$$u = mv + b$$
$$u = I_{G_C} \quad v = \sin\alpha \quad m = A \quad b = -B$$
$$\alpha = f(date, hour, \phi, l)$$

A, B, C, and *D* coefficients involved in the model presented above are to be calibrated with measured data.

$$\sin\alpha = \cos\phi\cos\delta\cos\omega + \sin\phi\sin\delta$$

$$\delta = 23.45\left(\frac{360(284+n)}{365}\right)$$

Solar time – Local standard time = 4(Lst – Lloc)+E

$E = 229.2(0.000075 + 0.001868 \cos B_E - 0.032077 \sin B_E - 0.014615 \cos 2B_E - 0.04089 \sin 2B_E)$

$B_E = (n\text{-}1)360/365$

δ	Solar declination (in degrees).
ω	Hour angle, the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15° per hour, morning negative, afternoon positive (in degrees).
α	Solar altitude angle (or solar elevation), the angle between the horizontal and the line to the sun. The complement of the zenith angle (in degrees).
N	Cloud amount (on oktas or tenths)
I_{Gc}	Solar global radiation (W/m^2)
I_{Gcs}	Solar global radiation under Cloudless sky (W/m^2)
U	is the units of the cloud cover, typically oktas or tenths of sky cover

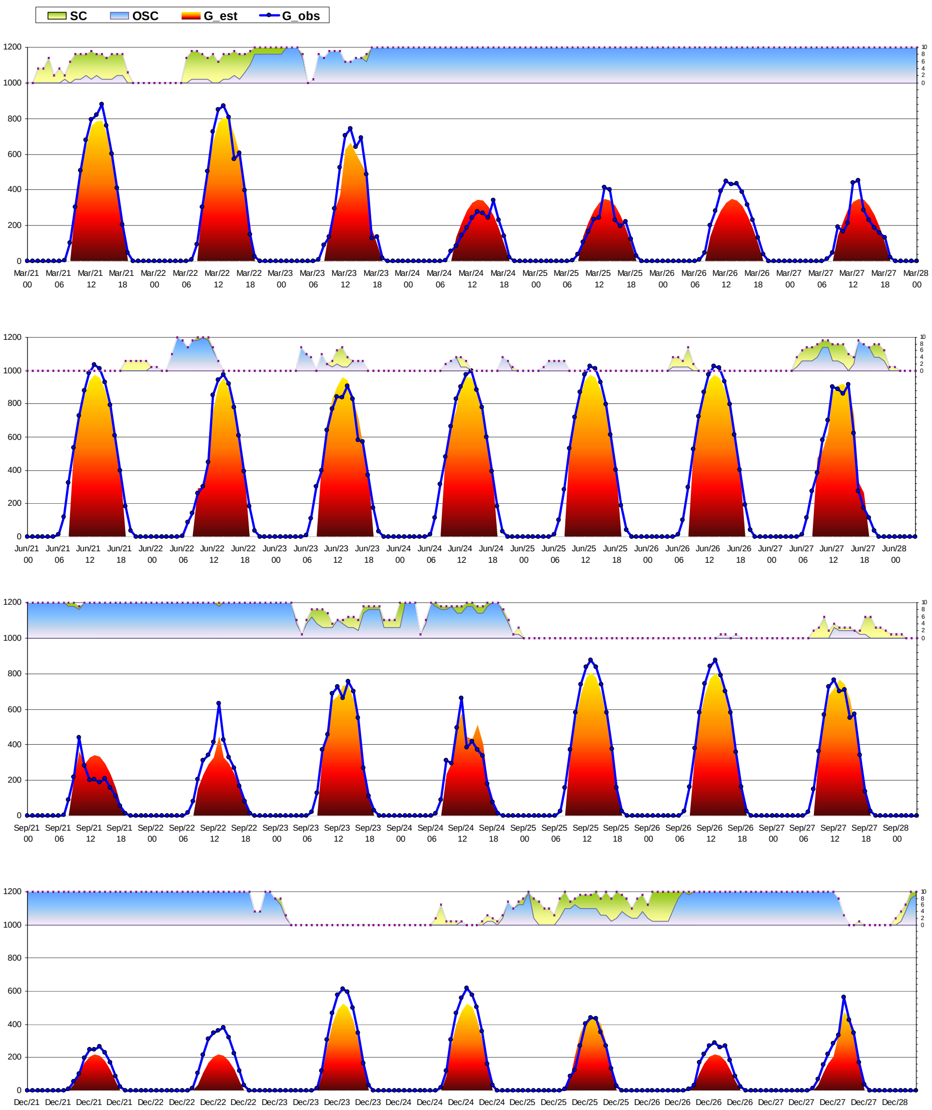


Figure 11-3 Cloud cover adjusted model depiction for a week in each of the season in the year 1990 (Abilene, Texas).

Using the procedure specified in Table 11-2, two more models were created. The results of the application of these models are presented in Figure 11-4 through Figure 11-6. Figure 11-4 shows the comparison of the data for Abilene, Texas, in 1990 using the Kasten and Czeplak model. Figure 11-5 and Figure 11-6 show the comparison for the same year, but use models that have been adjusted specifically for Abilene. In these figures, the reduction of the variability between the predictions and the measured data can clearly be seen when compared with the prediction obtained from the Kasten and Czeplak model. The improvement is due to the use of actual data on the derivation of the cloud-cover model, instead of using the generalized parameters proposed by Kasten and Czeplak. In Figure 11-3, the results from the exponentially adjusted model are presented for the year 1990 for Abilene. The pattern closely follows the measured data in all the seasons. The statistics of the modeling are presented in

Table 11-3.

Table 11-3 Statistics of the application of the exponential adjusted cloud cover model for Abilene, Texas, in the year of 1990.

Predicted					**Spring**	**Summer**	**Fall**	**Winter**	***Whole Year***
n_x =	3,568		Number of Data		920	920	853	875	**3,568**
S_x =	1,694,296		Sum	W/m2	530,253	540,811	323,397	299,834	**1,694,296**
x_avg =	474.86		Mean	W/m2	576.36	587.84	379.13	342.67	**474.86**
x_med =	462.15		Media	W/m2	573.57	598.65	379.61	309.49	**462.15**
s =	244.50		Standard Deviation	W/m2	247.72	222.72	195.52	198.26	**244.50**

Difference Statistical Measures

d =	0.9864	[0, 1]	Index of Agreement		0.9892	0.9849	0.9848	0.9856	**0.9864**
ME =	0.9436	[0, 1]	Modeling Efficiency		0.9539	0.9358	0.9388	0.9427	**0.9436**
MAE =	45.41	[~ 0]	Mean Absolute Error	W/m2	44.38	45.23	45.70	46.39	**45.41**
RMSE =	58.08	[~ 0]	Root Mean Square Error	W/m2	57.45	63.27	53.82	57.04	**58.08**
MBE =	14.40	[~ 0]	Mean Bias Error	W/m2	4.04	-10.85	33.51	33.23	**14.40**
r =	0.9760		Pearson		0.9785	0.9713	0.9827	0.9803	**0.9789**
r^2	0.9525		Squared Pearson		0.9575	0.9435	0.9657	0.9610	**0.9582**

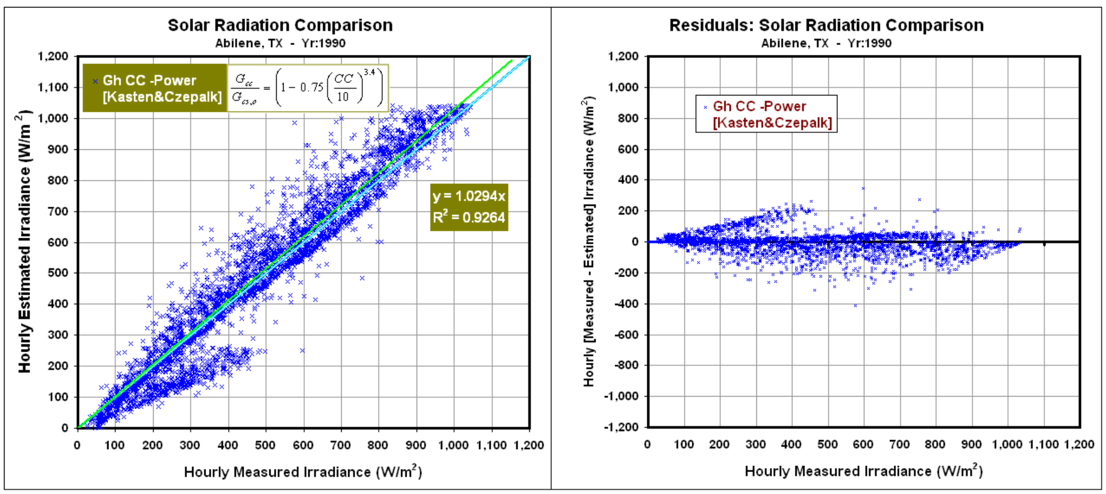


Figure 11-4: Comparison of the Kasten and Czeplak cloud-cover model versus measured global horizontal solar radiation for Abilene, Texas, in 1990.

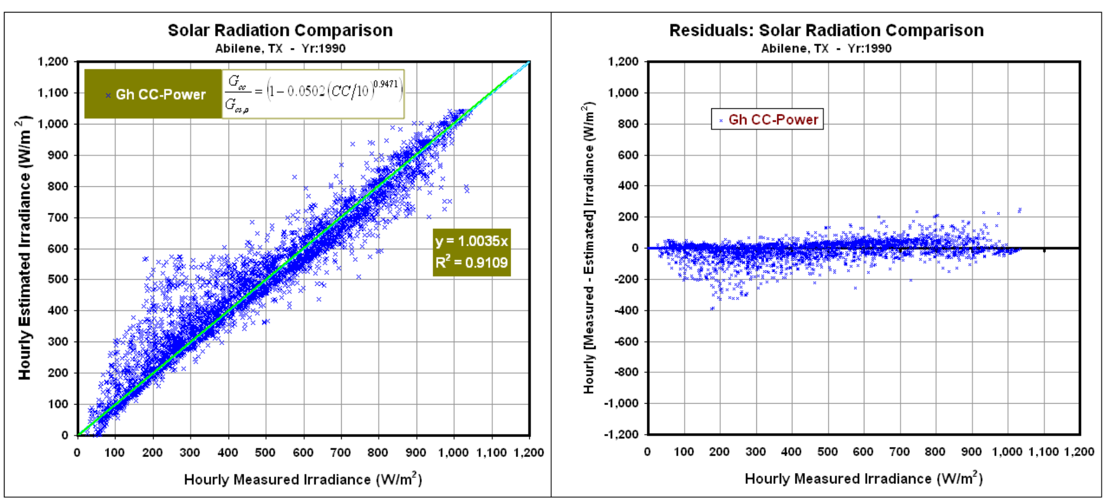


Figure 11-5: Comparison of the adjusted Kasten and Czeplak cloud-cover model versus measured global horizontal solar radiation for Abilene, Texas, in 1990.

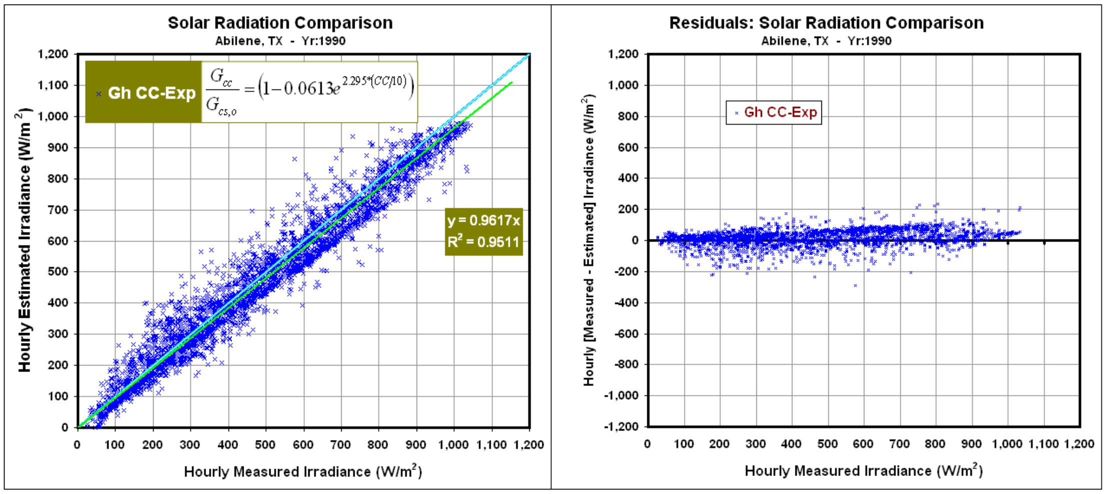


Figure 11-6: Comparison of the exponentially adjusted cloud-cover model versus measured global horizontal solar radiation for Abilene, Texas, in 1990.

12 REFERENCES

Erbs, D. G., Klein, S. A., Duffie, J. A. 1982. “Estimation of the Diffuse Radiation Fraction for Hourly, Daily and Monthly-Average Global Radiation,” *Solar Energy*, Vol. 28, No. 4, 1982, p. 293-302.

Giebel 2001. “On the Benefits of Distributed Generation of Wind Energy in Europe,” PhD thesis from the Carl von Ossietzky Universität Oldenburg. Fortschr.-Ber. VDI Reihe 6 Nr. 444. Düsseldorf, VDI Verlag. ISBN 3-18-344406-2.

Haberl, J., Culp, C., Yazdani, B., Subbarao, K., Verdict, M., Liu, Z., Baltazar-Cervantes, J-C, Gilman, D., Fitzpatrick, T., Turner, D. 2006. “Statewide Air Emissions Calculations From Wind and Other Renewables: Summary Report,” *Energy Systems Laboratory Report No. ESL-TR-06-08-01*, 114 pages (August).

Haberl, J., Culp, C., Yazdani, B., Gilman, D., Fitzpatrick, T., Muns, S., Verdict, M.; Ahmed, M., Liu, Z., Baltazar-Cervantes, J. C., Degelman, L., Turner, D. 2006. “Energy Efficiency/Renewable Energy Impact in the Texas Emissions Reduction Plan (TERP) September 2004-December 2005, Vol. II-Summary Report, Annual Report to the Texas Commission on Environmental Quality,” *Energy Systems Laboratory Report No. ESL-TR-06-06-08.*

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

Kasten, F. and Czeplak, G. 1980. “Solar and Terrestrial Radiation Dependent on the Amount and Type of Clouds,” *Solar Energy*, Vol. 24, pp. 177–189.

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, Pt. 2, pp. 425-434.

Spokas, K. and Forcella, F. 2006. “Estimating Hourly Incoming Solar Radiation from Limited Meteorological Data,” *Weed Science*, Vol. 54, pp 182-187, January-February.

13 APPENDIX A

In this section, the linear regression models developed based on 2005 wind power generation data are presented for each wind farm. The estimated 1999 annual and OSP power production using 2005 daily models and the resulting emissions reduction are also shown in details for each wind farm. A listing of the wind farms analyzed in this year's report is contained in Table 13-1.

Brazos Wind Ranch
Callahan Divide Wind Energy Center
Horse Hollow 1
Desert Sky
King Mountain Wind Ranch (KING_NE)
King Mountain Wind Ranch (KING_NW)
King Mountain Wind Ranch (KING_SE)
King Mountain Wind Ranch (KING_SW)
Sweetwater Wind 2
Trent Mesa
Delaware Mountain Wind Farm
Indian Mesa I
Texas Wind Power Project
Big Spring Wind Power
Southwest Mesa Wind Project
Woodward Mountain Ranch (WOODWRD1)
Woodward Mountain Ranch (WOODWRD2)

Table 13-1: Listing of Wind Farms Analyzed for Base-year Calculations.

13.1 Brazos Wind Ranch

Table 13-2: Site Information for Brazos Wind Ranch.

GENSITECODE_ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Interconnection	Weather Station
BRAZ_WIND	WIND	Fluvana	SCURRY	Dec-03	160	Cielo/Orion/Green Mountain	Brazos Wind Ranch	Mitsubishi 1000 (160)	ERCOT	AEP-West	ONCOR	ABI

SUBGENCODE_ERCOT	GENSITECODE_ERCOT	Capacity (MW)
BRAZ_WND_WND1	BRAZ_WIND	99
BRAZ_WND_WND2	BRAZ_WIND	61

13.1.1 Brazos Wind Ranch - BRAZ_WND_WND1.

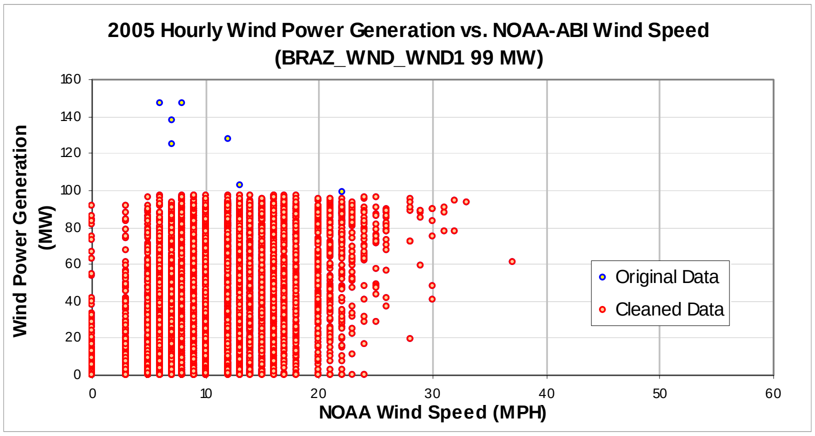


Figure 13-1: BRAZ_WND_WND1 - Hourly Wind Power vs. NOAA Wind Speed (2005).

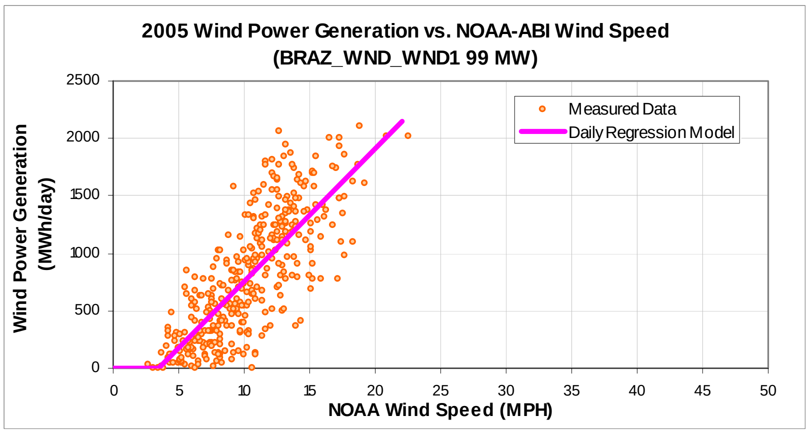


Figure 13-2: BRAZ_WND_WND1 - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-3: BRAZ_WND_WND1 - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-404.8196
Left Slope (MWh/mph-day)	116.2699
RMSE (MWh/day)	334.5641
R2	0.6163
CV-RMSE	42.1%

Table 13-4: BRAZ_WND_WND1 – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	10.34	23,402	24,731	-5.68%	32%	34%
Feb-05	28	8.92	14,839	17,803	-19.97%	22%	27%
Mar-05	31	11.54	27,635	29,036	-5.07%	38%	39%
Apr-05	30	12.97	29,212	33,089	-13.27%	41%	46%
May-05	30	11.03	22,626	26,336	-16.40%	32%	37%
Jun-05	30	11.86	30,165	29,218	3.14%	42%	41%
Jul-05	31	9.94	19,033	23,286	-22.34%	26%	32%
Aug-05	31	8.26	16,625	17,230	-3.64%	23%	23%
Sep-05	30	9.29	23,730	20,248	14.67%	33%	28%
Oct-05	31	9.26	23,981	20,896	12.86%	33%	28%
Nov-05	30	10.33	29,345	23,898	18.56%	41%	34%
Dec-05	31	10.02	28,608	23,577	17.59%	39%	32%
Total	364	10.32	289,202	289,348	-0.05%	33%	33%
Total in OSP (07/15-09/15)	63	8.98	40,405	40,266	0.34%	27%	27%

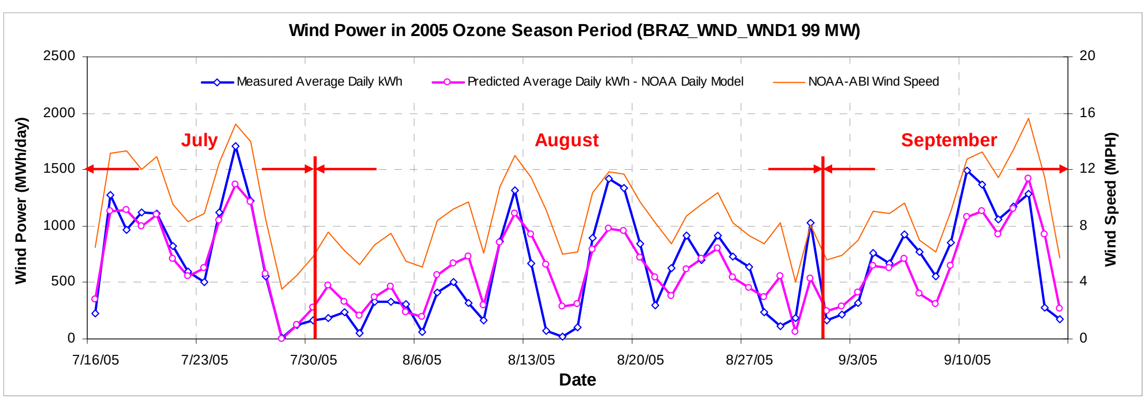


Figure 13-3: BRAZ_WND_WND1 - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

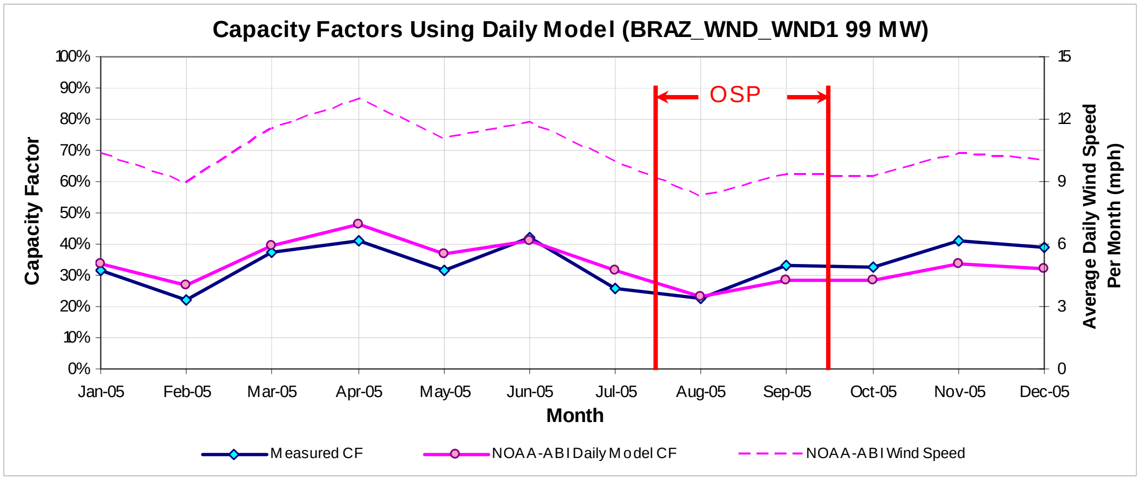


Figure 13-4: BRAZ_WND_WND1 - Predicted Capacity Factors Using Daily Models (2005).

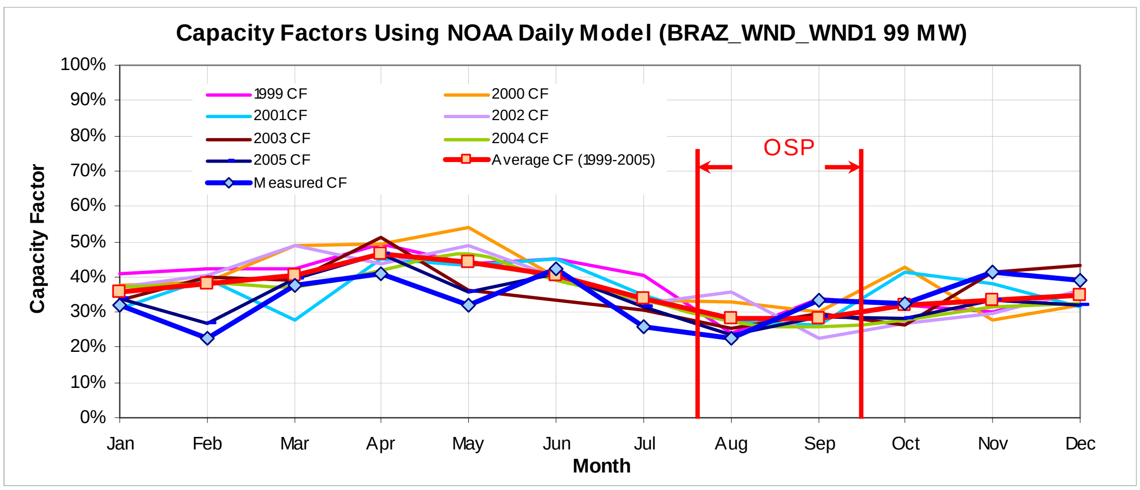


Figure 13-5: BRAZ_WND_WND1 - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-5: BRAZ_WND_WND1 - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
331,570	290,411
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
724	641

13.1.2 Brazos Wind Ranch - BRAZ_WND_WND2

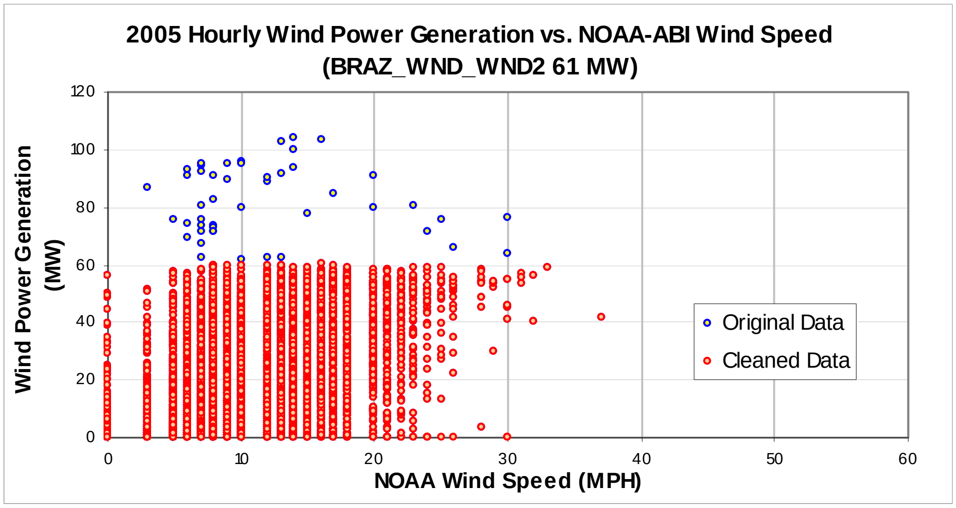


Figure 13-6: BRAZ_WND_WND2 - Hourly Wind Power vs. NOAA Wind Speed (2005).

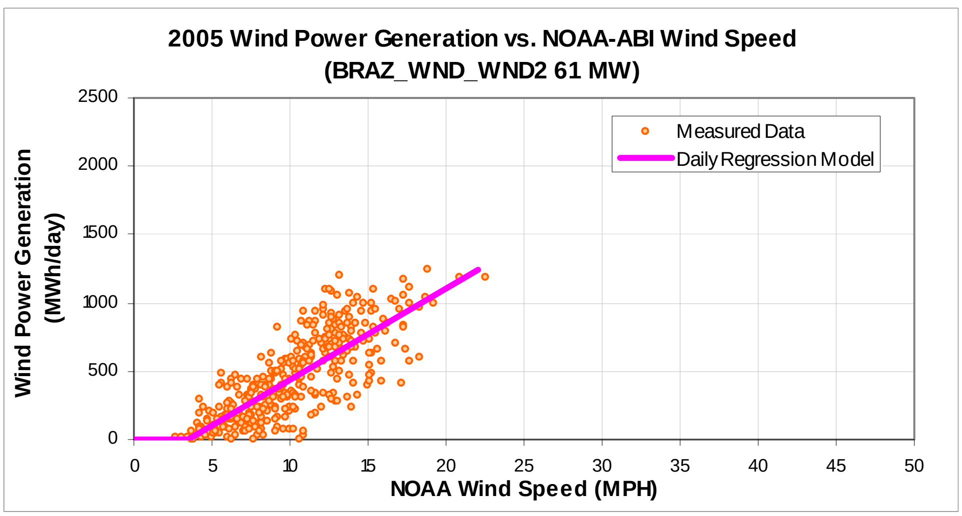


Figure 13-7: BRAZ_WND_WND2 - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-6: BRAZ_WND_WND2 - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-228.0380
Left Slope (MWh/mph-day)	66.7414
RMSE (MWh/day)	190.5690
R2	0.6179
CV-RMSE	41.5%

Table 13-7: BRAZ_WND_WND2 – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	10.34	13,603	14,331	-5.35%	30%	32%
Feb-05	28	8.92	8,693	10,336	-18.91%	21%	25%
Mar-05	31	11.54	15,485	16,802	-8.50%	34%	37%
Apr-05	30	12.97	17,350	19,124	-10.23%	40%	44%
May-05	31	11.03	13,184	15,247	-15.65%	29%	34%
Jun-05	30	11.86	17,825	16,902	5.18%	41%	38%
Jul-05	31	9.94	11,866	13,501	-13.78%	26%	30%
Aug-05	31	8.27	8,682	9,714	-11.88%	19%	21%
Sep-05	30	9.29	13,662	11,753	13.98%	31%	27%
Oct-05	31	9.26	13,833	12,125	12.35%	30%	27%
Nov-05	30	10.05	15,436	12,391	19.73%	35%	28%
Dec-05	31	10.02	16,198	13,668	15.62%	36%	30%
Total	365	10.30	165,818	165,893	-0.05%	31%	31%
Total in OSP (07/15-09/15)	62	8.99	22,838	23,076	-1.04%	25%	25%

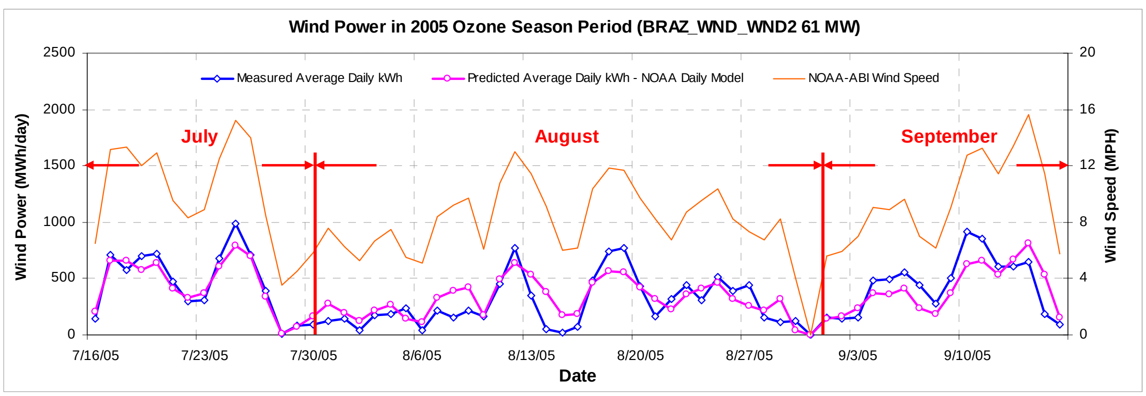


Figure 13-8: BRAZ_WND_WND2 - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

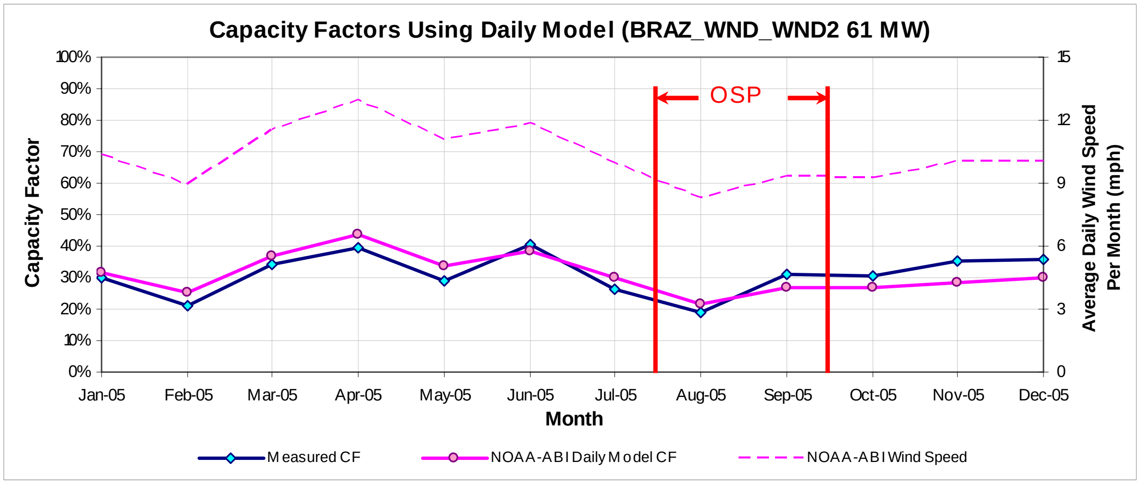


Figure 13-9: BRAZ_WND_WND2 - Predicted Capacity Factors Using Daily Models (2005).

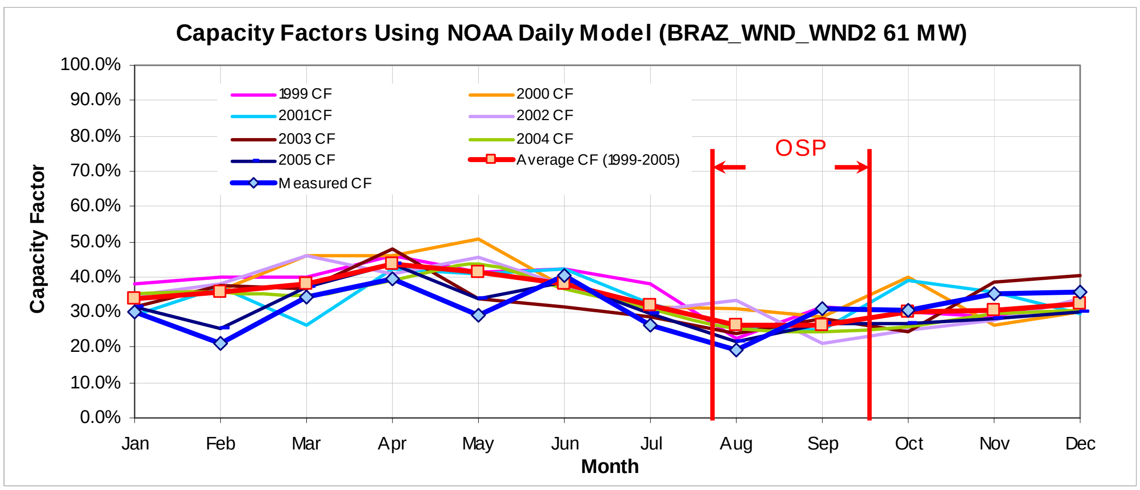


Figure 13-10: BRAZ_WND_WND2 - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-8: BRAZ_WND_WND2 - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
191,907	170,608
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
420	368

13.2 Callahan Divide Wind Energy Center

Table 13-9: Site Information for Callahan Divide Wind Energy Center.

GENSITECODE_ ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Interconnection	Weather Station
CALLAHAN	WIND	Abilene	TAYLOR	Feb-07	114	FPL Energy	Callahan Divide Wind Energy Center	GE Wind 1500 (76)	ERCOT	AEP-West	AEP-TNC	ABI

SUBGENCODE_ ERCOT	GENSITECODE_ ERCOT	Capacity (MW)
CALLAHAN_WN D1	CALLAHAN	114

13.2.1 Callahan Divide - CALLAHAN_WND1

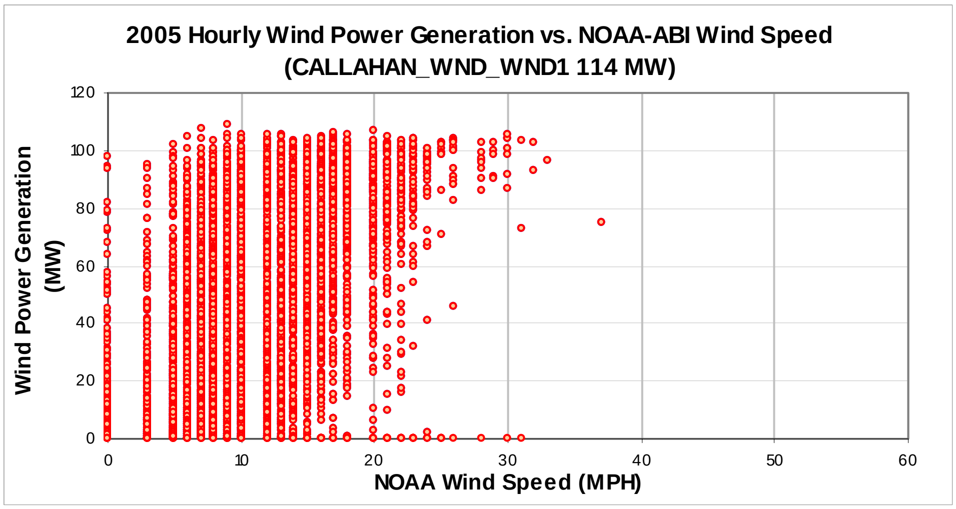


Figure 13-11: CALLAHAN_WND1- Hourly Wind Power vs. NOAA Wind Speed (2005).

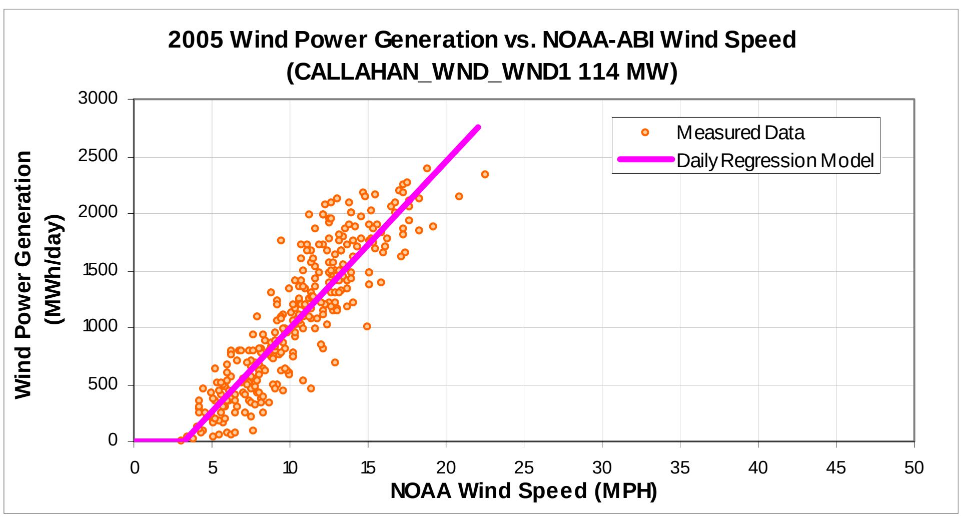


Figure 13-12: CALLAHAN_WND1- - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-10: CALLAHAN_WND1- Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-473.0277
Left Slope (MWh/mph-day)	147.0913
RMSE (MWh/day)	276.2406
R2	0.7948
CV-RMSE	26.0%

Table 13-11: CALLAHAN_WND1– Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	0						
Feb-05	0						
Mar-05	31	11.54	32,856	37,946	-15.49%	39%	45%
Apr-05	30	12.97	40,715	43,034	-5.70%	50%	52%
May-05	30	11.03	31,705	34,490	-8.78%	39%	42%
Jun-05	30	11.86	39,718	38,137	3.98%	48%	46%
Jul-05	31	9.94	25,935	30,671	-18.26%	31%	36%
Aug-05	31	8.26	22,867	23,010	-0.62%	27%	27%
Sep-05	30	9.29	27,714	26,788	3.34%	34%	33%
Oct-05	31	9.26	32,309	27,608	14.55%	38%	33%
Nov-05	30	10.33	34,846	31,406	9.87%	42%	38%
Dec-05	31	10.02	35,438	31,039	12.41%	42%	37%
Total	305	10.44	324,102	324,128	-0.01%	39%	39%
(07/15-09/15)	63	8.98	52,361	53,404	-1.99%	30%	31%

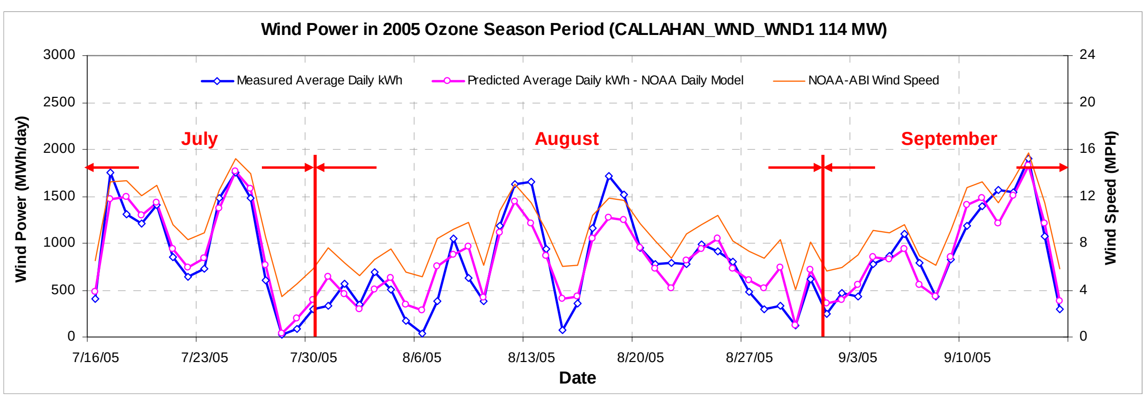


Figure 13-13: CALLAHAN_WND1- Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

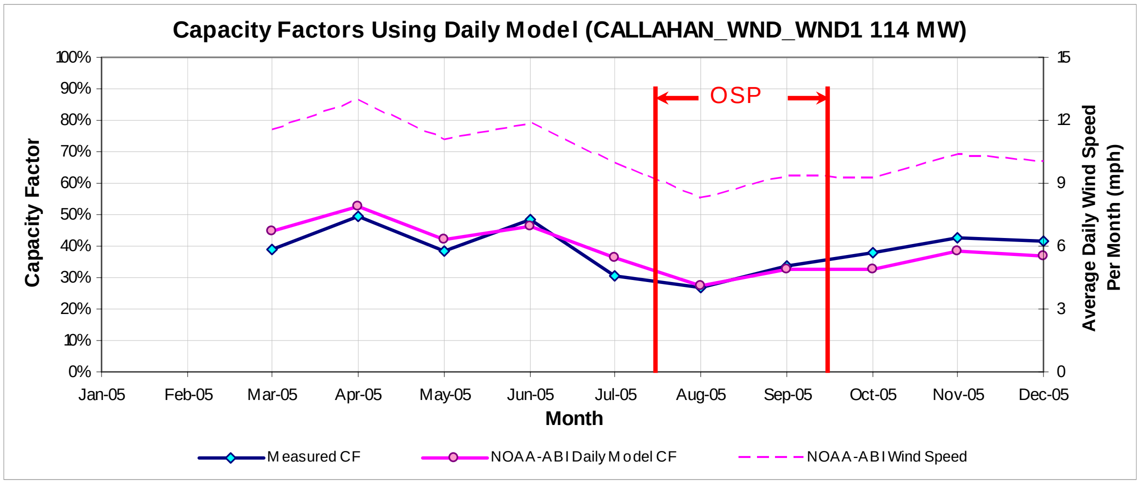


Figure 13-14: CALLAHAN_WND1- Predicted Capacity Factors Using Daily Models (2005).

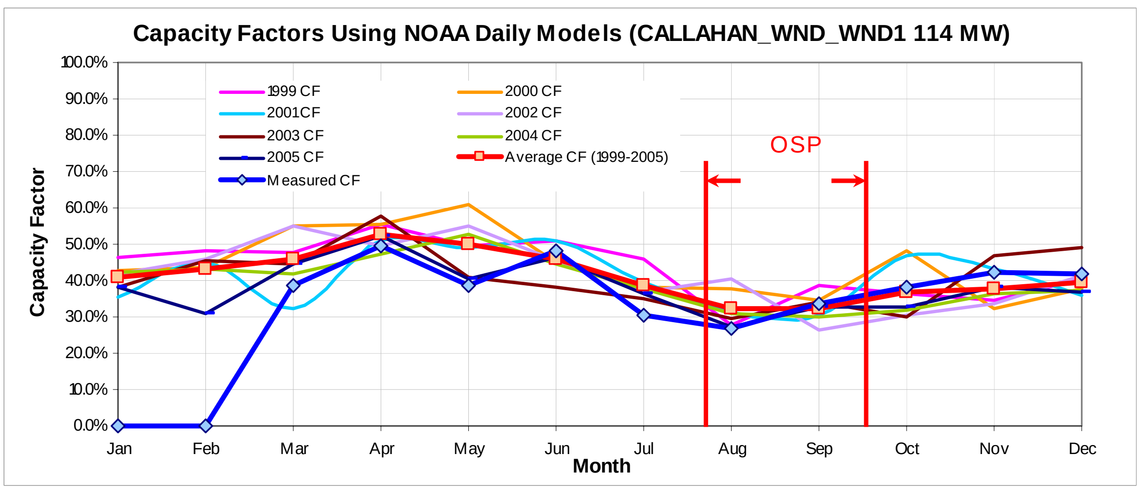


Figure 13-15: CALLAHAN_WND1- Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-12: CALLAHAN_WND1- Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
433,697	332,572
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
955	831

13.3 Horse Hollow 1

Table 13-13: Site Information for Horse Hollow 1.

GENSITECODE_ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Interconnection	Weather Station	Remarks
H_HOLLOW	WIND	Abilene	TAYLOR	Oct-05	213	FPL Energy	Horse Hollow 1	GE Energy 1.5 MW (142)	ERCOT	AEP-West	AEP-TNC	ABI	

SUBGENCODE_ERCOT	GENSITECODE_ERCOT	Capacity (MW)
H_HOLLOW_WND1	H_HOLLOW	213

13.3.1 Horse Hollow 1- H_HOLLOW_WND1.

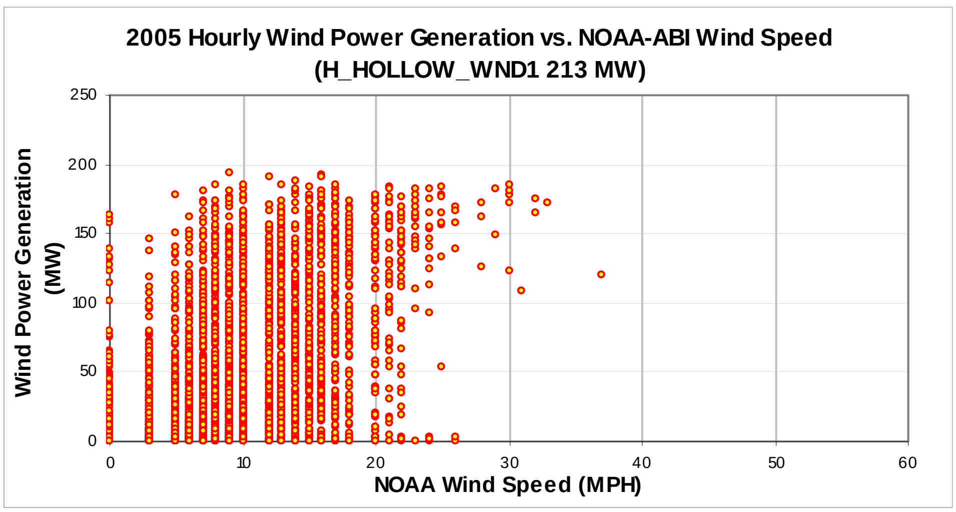


Figure 13-16: H_HOLLOW_WND1 - Hourly Wind Power vs. NOAA Wind Speed (2005).

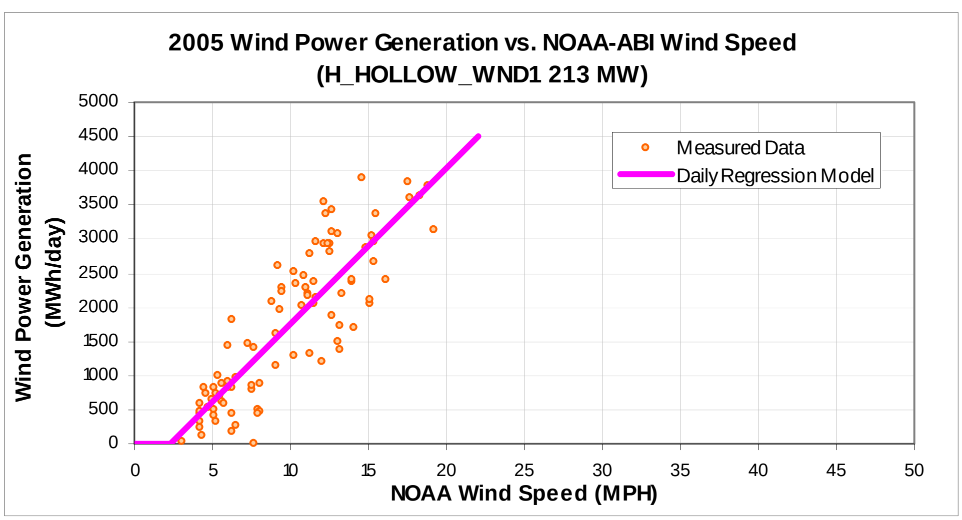


Figure 13-17: H_HOLLOW_WND1 - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-14: H_HOLLOW_WND1 - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-531.0397
Left Slope (MWh/mph-day)	228.2557
RMSE (MWh/day)	564.8930
R2	0.7351
CV-RMSE	32.8%

Table 13-15: H_HOLLOW_WND1 – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	0						
Feb-05	0						
Mar-05	0						
Apr-05	0						
May-05	0						
Jun-05	0						
Jul-05	0						
Aug-05	0						
Sep-05	0						
Oct-05	31	9.26	39,019	49,095	-25.82%	25%	31%
Nov-05	30	10.33	58,390	54,825	6.11%	38%	36%
Dec-05	31	10.02	60,970	54,459	10.68%	38%	34%
Total	92	9.87	158,379	158,379	0.00%	34%	34%
Total in OSP (07/15-09/15)							

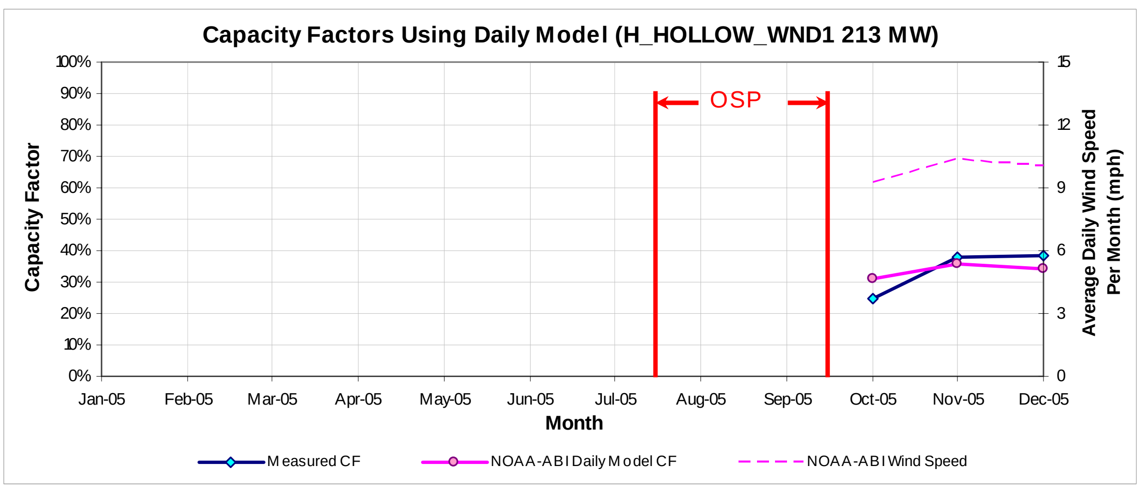


Figure 13-18: H_HOLLOW_WND1 - Predicted Capacity Factors Using Daily Models (2005).

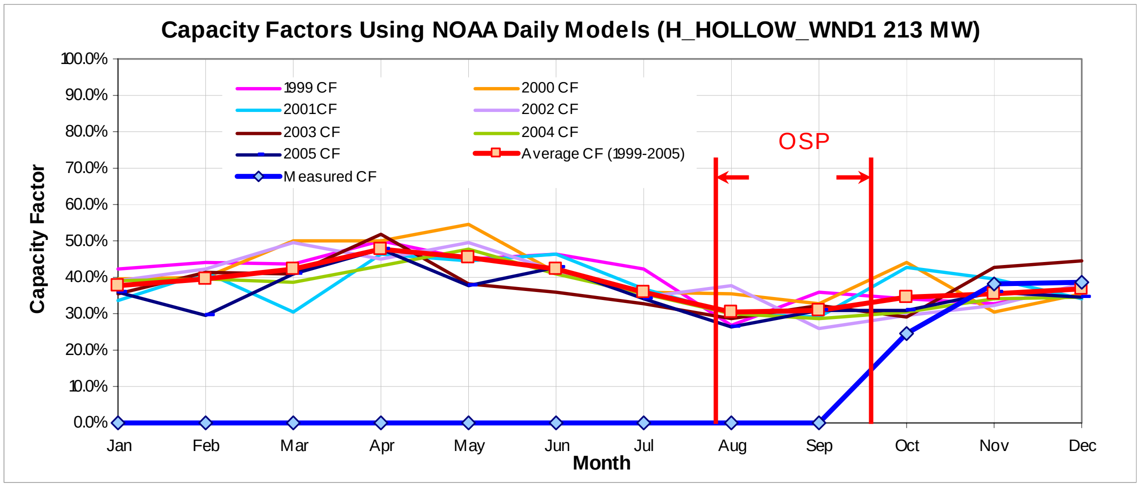


Figure 13-19: H_HOLLOW_WND1 - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-16: H_HOLLOW_WND1 - Predicted Power Production in 1999.

1999 (Aug. – Dec.) Estimated MWh/yr (2005 Daily Model)	2005 (Aug. – Dec.) Measured MWh/yr
328,264	203,681
1999 OSP Estimated MWh/day (2005 Daily Model)	**2005 OSP Measured MWh/day**
1,685	N/A

13.4 Desert Sky

Table 13-17: Site Information for Desert Sky.

GENSITECODE _ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
INDNENR	WIND	Iraan	PECOS	Dec-01	160.5	AEP	Desert Sky (Indian Mesa II)	Enron 1500 (107)	ERCOT	TXU	WTU	FST

SUBGENCODE _ERCOT	GENSITECOD E_ERCOT	Capacity (MW)
INDNENR_IND NENR	INDNENR	
INDNENR_IND NENR_2	INDNENR	

13.4.1 Desert Sky - INDNENR_INDNENR

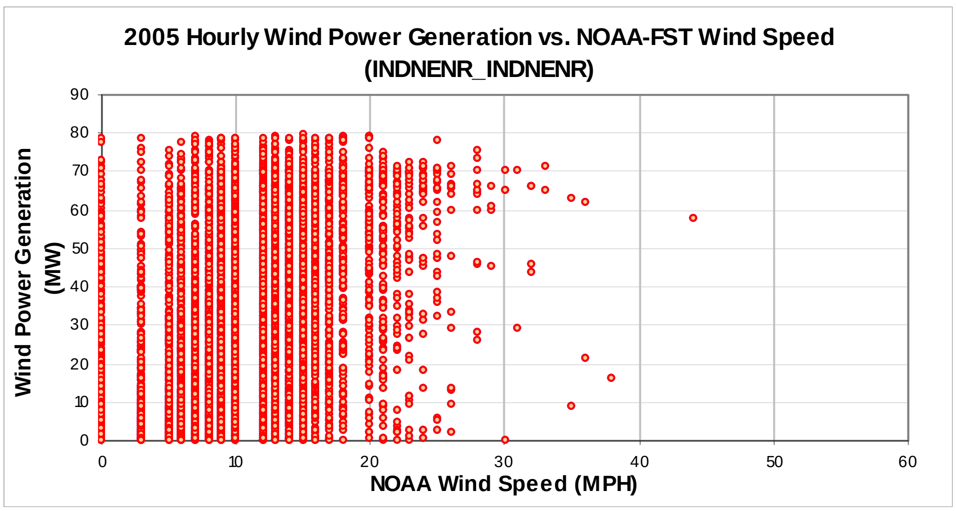


Figure 13-20: INDNENR_INDNENR - Hourly Wind Power vs. NOAA Wind Speed (2005).

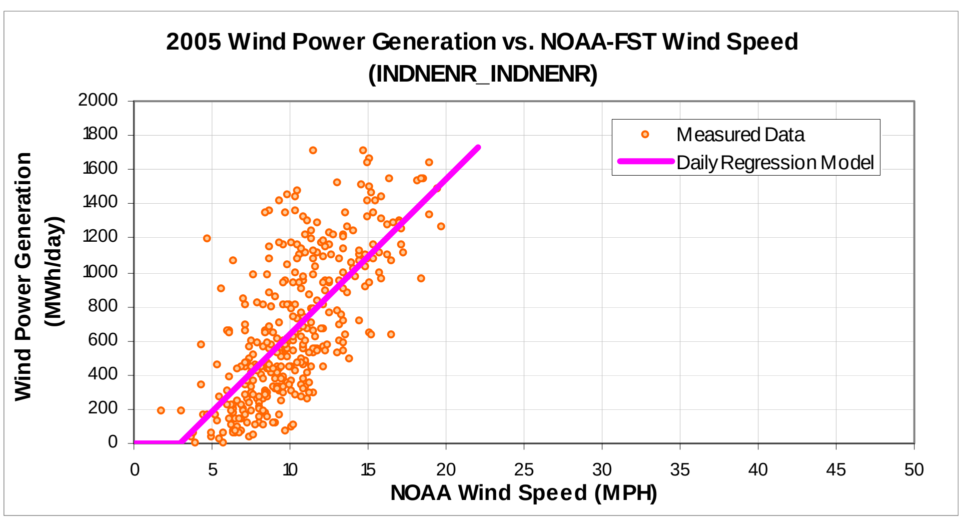


Figure 13-21: INDNENR_INDNENR - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-18: INDNENR_INDNENR - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-265.7163
Left Slope (MWh/mph-day)	90.8413
RMSE (MWh/day)	298.2063
R2	0.4879
CV-RMSE	44.3%

Table 13-19: INDNENR_INDNENR – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	10.20	21,596	20,498	5.09%	36%	34%
Feb-05	28	9.24	12,089	16,050	-32.76%	22%	30%
Mar-05	31	11.08	17,862	22,974	-28.62%	30%	39%
Apr-05	30	12.46	24,698	25,988	-5.22%	43%	45%
May-05	30	11.73	23,249	24,004	-3.25%	40%	42%
Jun-05	30	12.45	27,332	25,949	5.06%	47%	45%
Jul-05	31	10.61	21,779	21,644	0.62%	37%	36%
Aug-05	31	8.49	17,303	15,673	9.42%	29%	26%
Sep-05	30	9.17	18,721	17,009	9.14%	33%	30%
Oct-05	31	9.68	21,540	19,015	11.72%	36%	32%
Nov-05	30	10.26	20,031	19,981	0.25%	35%	35%
Dec-05	31	8.62	18,634	16,153	13.31%	31%	27%
Total	364	10.33	244,836	244,938	-0.04%	35%	35%
Total in OSP (07/15-09/15)	63	9.29	39,348	36,429	7.42%	33%	30%

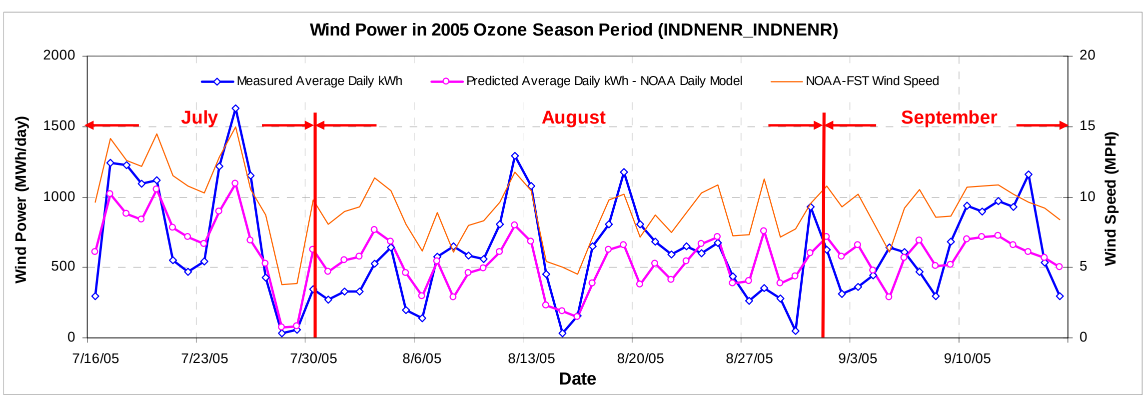


Figure 13-22: INDNENR_INDNENR - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

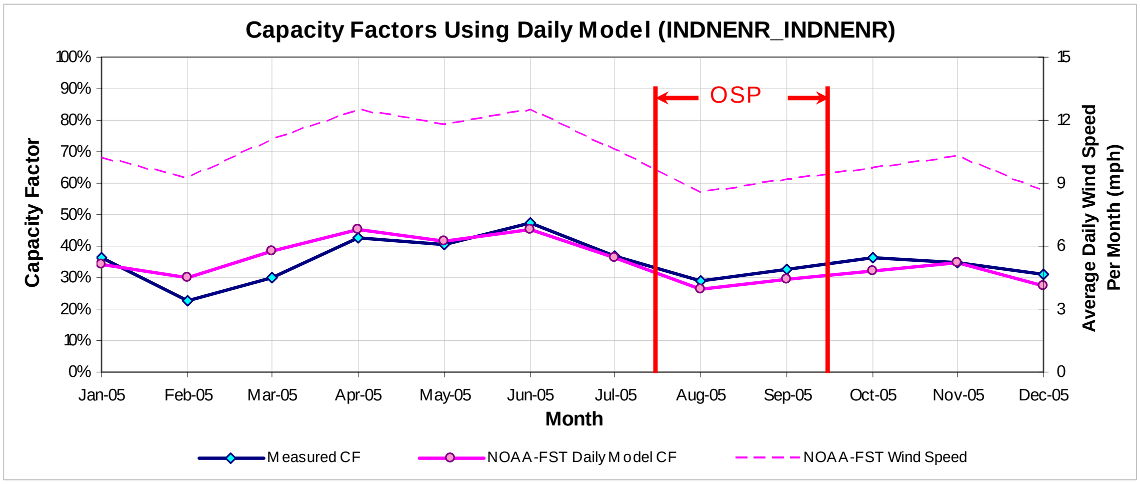


Figure 13-23: INDNENR_INDNENR - Predicted Capacity Factors Using Daily Models (2005).

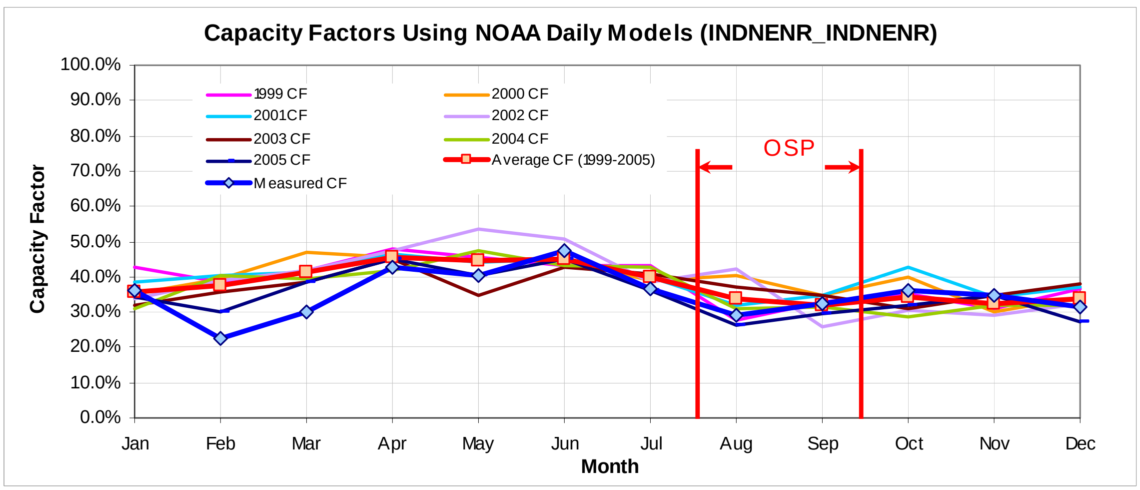


Figure 13-24: INDNENR_INDNENR - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-20: INDNENR_INDNENR - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
273,888	246,131
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
639	625

13.4.2 Desert Sky - INDNENR_INDNENR_2

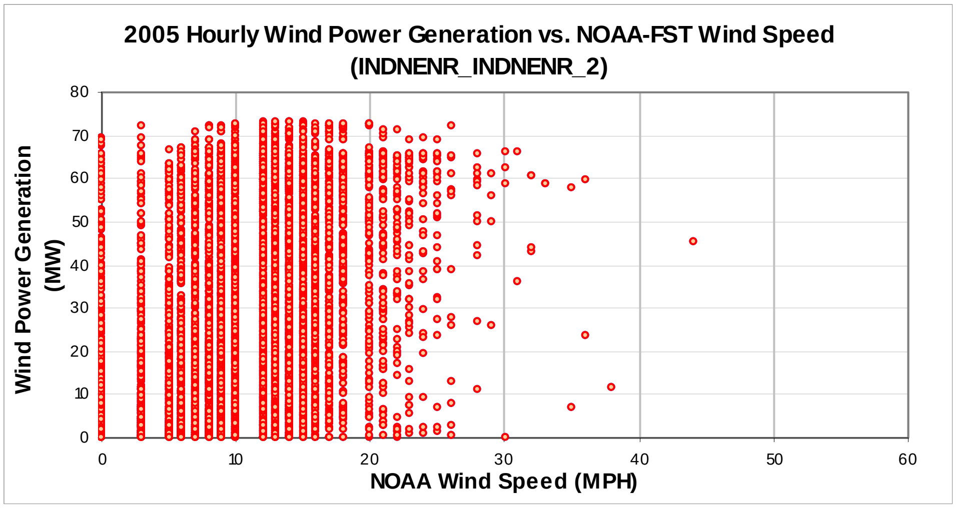


Figure 13-25: INDNENR_INDNENR_2 - Hourly Wind Power vs. NOAA Wind Speed (2005).

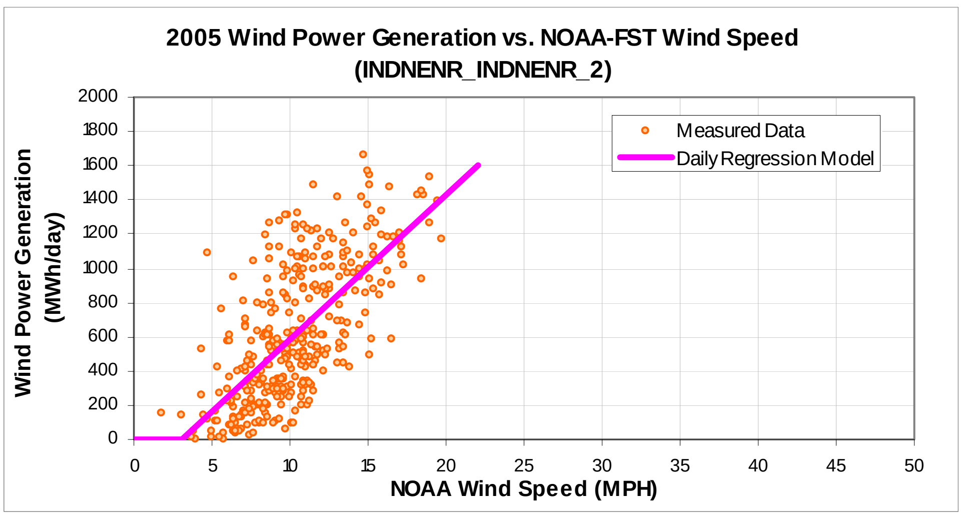


Figure 13-26: INDNENR_INDNENR_2 - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-21: INDNENR_INDNENR_2 - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-259.8180
Left Slope (MWh/mph-day)	84.6349
RMSE (MWh/day)	290.6969
R2	0.4653
CV-RMSE	47.3%

Table 13-22: INDNENR_INDNENR_2 – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	10.20	19,960	18,718	6.22%	34%	31%
Feb-05	28	9.24	10,673	14,610	-36.89%	20%	27%
Mar-05	31	11.08	15,381	21,025	-36.69%	26%	35%
Apr-05	30	12.46	21,948	23,845	-8.64%	38%	41%
May-05	30	11.73	21,649	21,996	-1.61%	38%	38%
Jun-05	30	12.45	25,807	23,808	7.75%	45%	41%
Jul-05	31	10.61	19,836	19,785	0.26%	33%	33%
Aug-05	31	8.49	16,111	14,222	11.72%	27%	24%
Sep-05	30	9.17	17,300	15,479	10.52%	30%	27%
Oct-05	31	9.68	19,710	17,336	12.04%	33%	29%
Nov-05	30	10.26	18,331	18,248	0.45%	32%	32%
Dec-05	31	8.62	16,941	14,682	13.34%	28%	25%
Total	364	10.33	223,647	223,755	-0.05%	32%	32%
Total in OSP (07/15-09/15)	63	9.29	36,829	33,168	9.94%	30%	27%

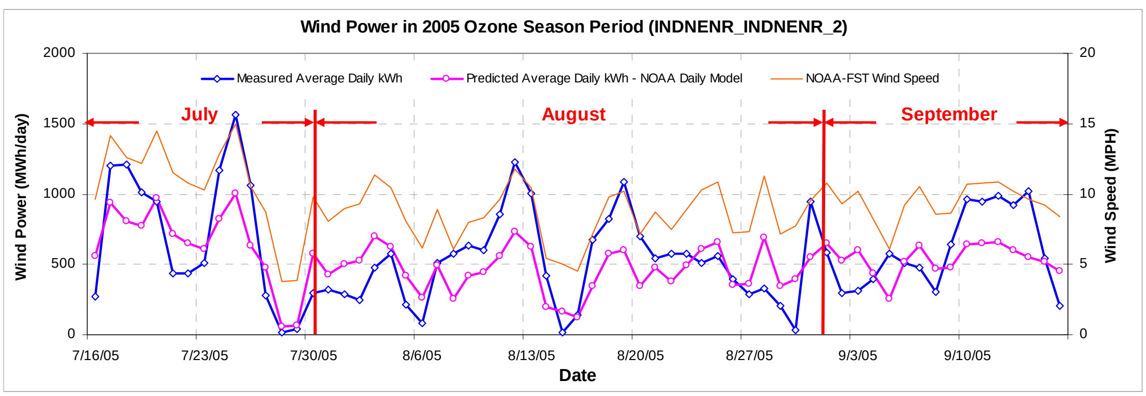


Figure 13-27: INDNENR_INDNENR_2 - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

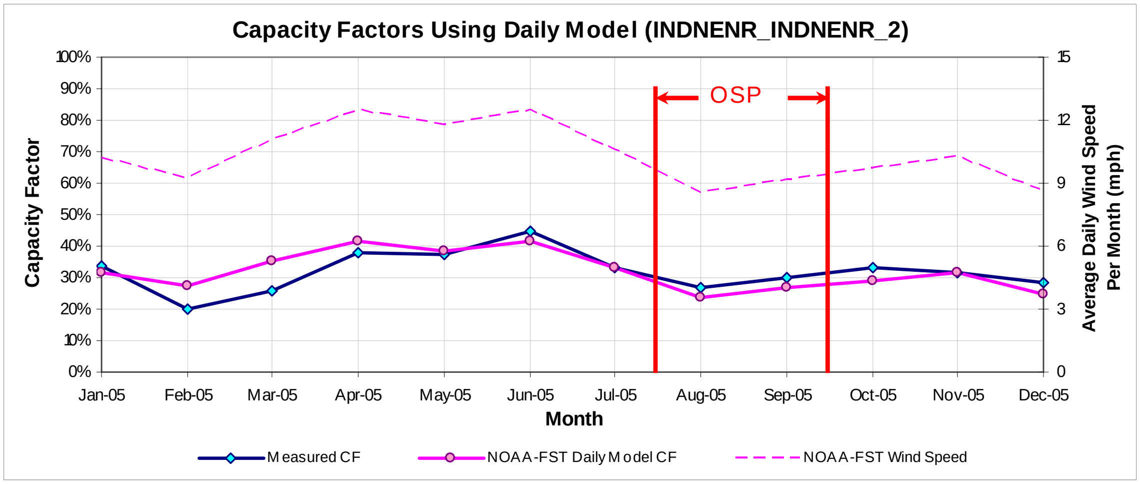


Figure 13-28: INDNENR_INDNENR_2 - Predicted Capacity Factors Using Daily Models (2005).

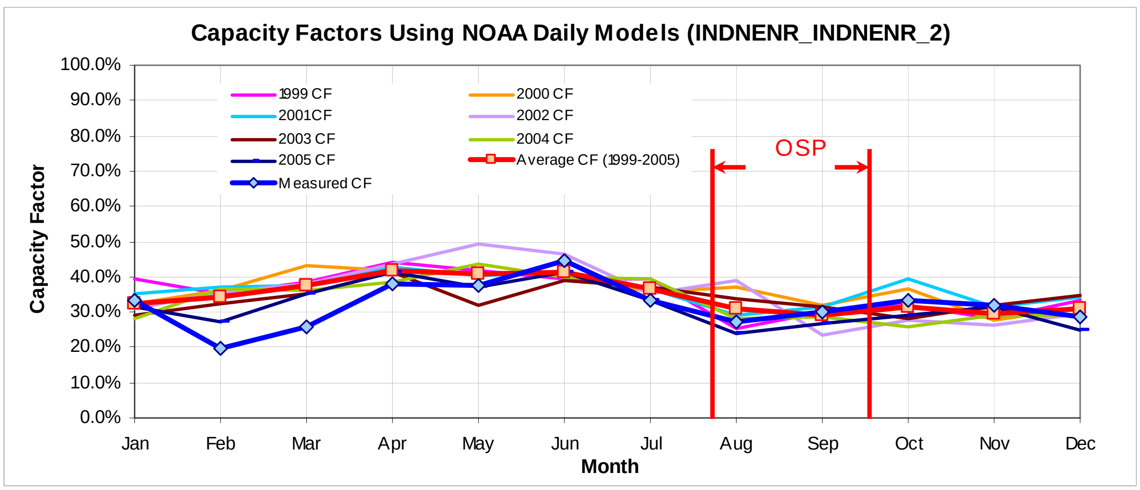


Figure 13-29: INDNENR_INDNENR_2 - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-23: INDNENR_INDNENR_2 - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
250,714	224,842
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
583	585

13.5 King Mountain Wind Ranch (KING_NE)

Table 13-24: Site Information for King Mountain Wind Ranch (KING_NE).

GENSITECODE_ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Interconnection	Weather Station
KING_NE	WIND	McCamey	UPTON	Dec-01	79.3	FPL/Cielo	King Mountain Wind Ranch	Bonus 1300 (61)	ERCOT	AEP-West	WTU	MAF

SUBGENCODE_ERCOT	GENSITECODE_ERCOT	Capacity (MW)
KING_NE_KINGNE	KING_NE	79.3

13.5.1 King Mountain – KING_NE_KINGNE

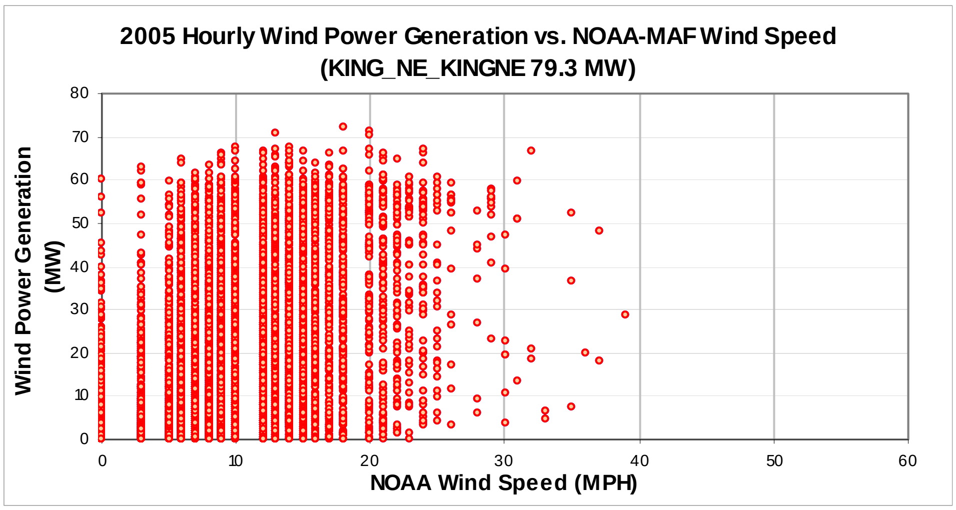


Figure 13-30: KING_NE_KINGNE - Hourly Wind Power vs. NOAA Wind Speed (2005).

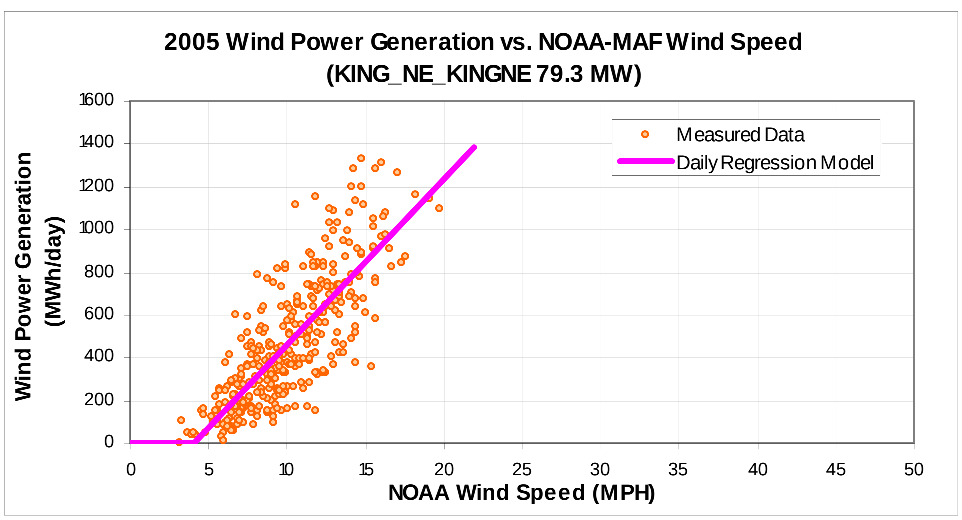


Figure 13-31: KING_NE_KINGNE - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-25: KING_NE_KINGNE - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-313.2377
Left Slope (MWh/mph-day)	77.0860
RMSE (MWh/day)	179.1313
R2	0.6384
CV-RMSE	38.0%

Table 13-26: KING_NE_KINGNE – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	9.71	14,949	13,485	9.79%	25%	23%
Feb-05	28	8.90	8,944	10,524	-17.67%	17%	20%
Mar-05	31	11.14	15,701	16,922	-7.78%	27%	29%
Apr-05	30	12.12	19,494	18,636	4.40%	34%	33%
May-05	31	10.75	17,156	15,988	6.81%	29%	27%
Jun-05	30	12.10	18,455	18,585	-0.70%	32%	33%
Jul-05	31	10.41	12,858	15,166	-17.95%	22%	26%
Aug-05	31	9.18	10,432	12,218	-17.12%	18%	21%
Sep-05	30	9.66	12,580	12,946	-2.91%	22%	23%
Oct-05	31	9.28	14,381	12,479	13.23%	24%	21%
Nov-05	30	9.38	13,863	12,356	10.87%	24%	22%
Dec-05	31	9.52	13,383	13,045	2.53%	23%	22%
Total	365	10.18	172,197	172,351	-0.09%	25%	25%
Total in OSP (07/15-09/15)	63	9.65	23,791	27,148	-14.11%	20%	23%

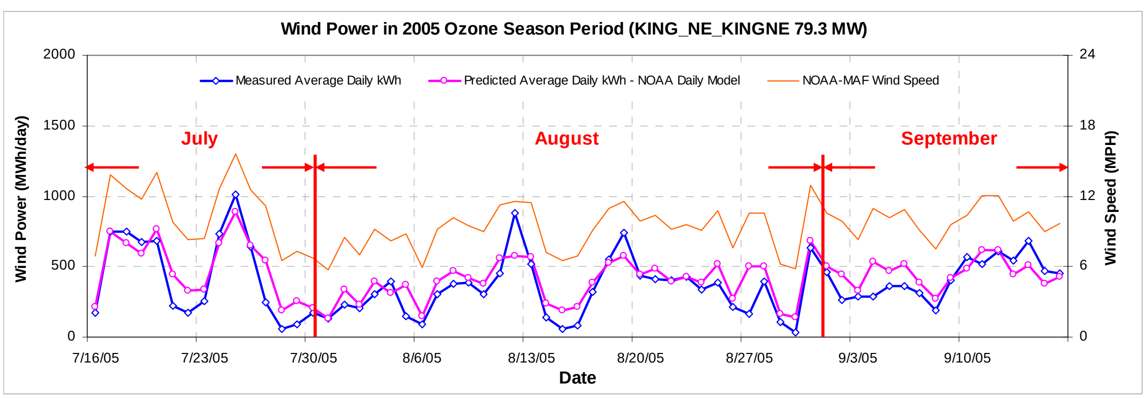


Figure 13-32: KING_NE_KINGNE - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

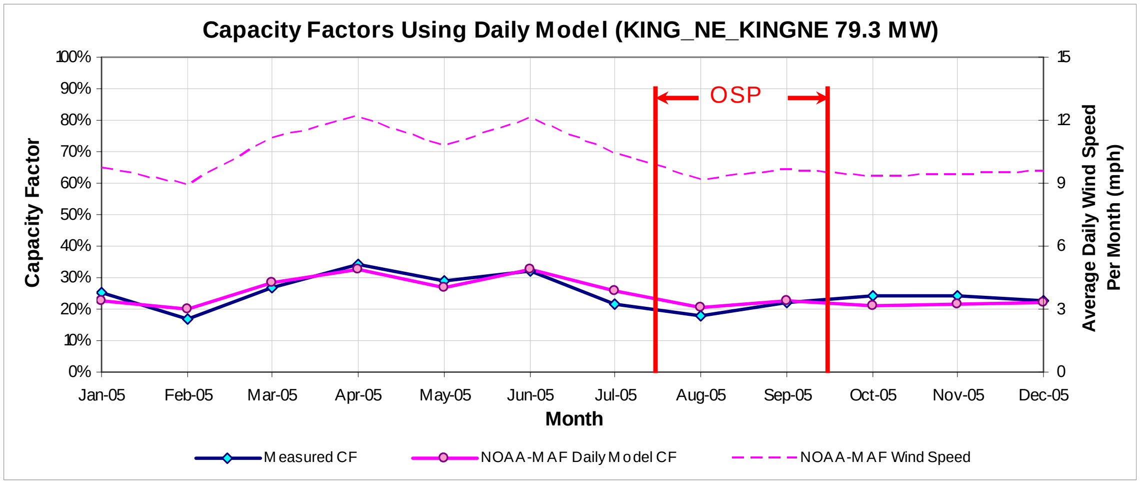


Figure 13-33: KING_NE_KINGNE - Predicted Capacity Factors Using Daily Models (2005).

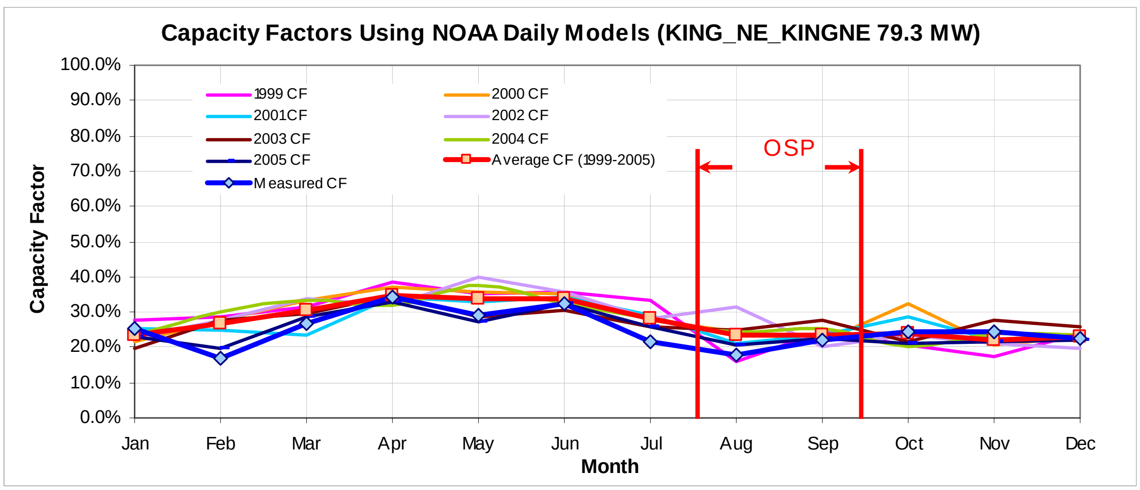


Figure 13-34: KING_NE_KINGNE - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-27: KING_NE_KINGNE - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
192,701	172,198
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
417	378

13.6 King Mountain Wind Ranch (KING_NW)

Table 13-28: Site Information for King Mountain Wind Ranch (KING_NW).

GENSITECODE_ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Interconne-ction	Weather Station
KING_NW	WIND	McCamey	UPTON	Dec-01	79.3	FPL/Cielo	King Mountain Wind Ranch	Bonus 1300 (61)	ERCOT	AEP-West	WTU	MAF

SUBGENCODE_ERCOT	GENSITECODE_ERCOT	Capacity (MW)
KING_NW_KING NW	KING_NW	79.3

13.6.1 King Mountain – KING_NW_KINGNW

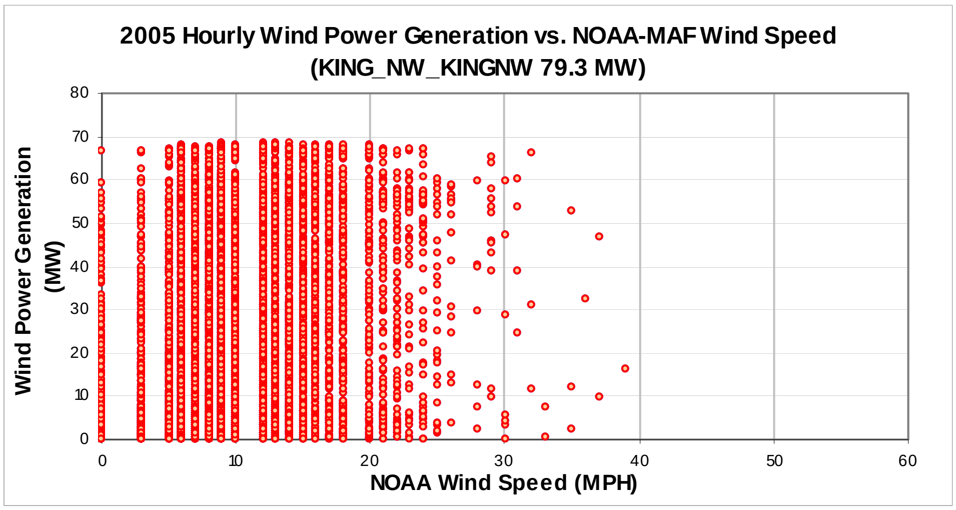


Figure 13-35: KING_NW_KINGNW - Hourly Wind Power vs. NOAA Wind Speed (2005).

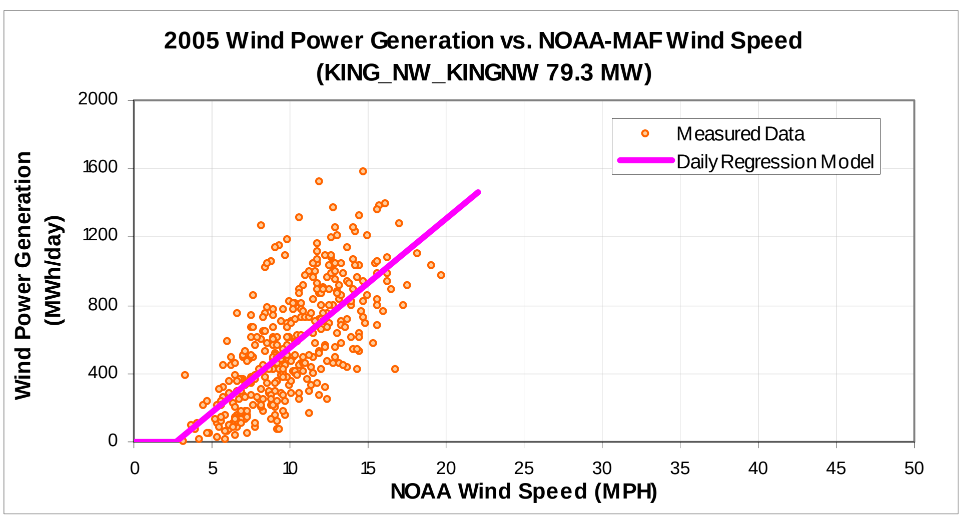


Figure 13-36: KING_NW_KINGNW - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-29: KING_NW_KINGNW - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-200.2764
Left Slope (MWh/mph-day)	75.5253
RMSE (MWh/day)	242.8377
R2	0.4798
CV-RMSE	42.7%

Table 13-30: KING_NW_KINGNW – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	9.71	18,419	16,517	10.33%	31%	28%
Feb-05	28	8.90	10,568	13,211	-25.02%	20%	25%
Mar-05	31	11.14	15,408	19,885	-29.05%	26%	34%
Apr-05	30	12.12	20,265	21,458	-5.89%	35%	38%
May-05	31	10.75	20,689	18,970	8.31%	35%	32%
Jun-05	30	12.10	23,562	21,407	9.15%	41%	37%
Jul-05	31	10.41	17,239	18,164	-5.37%	29%	31%
Aug-05	31	9.18	15,107	15,276	-1.12%	26%	26%
Sep-05	30	9.66	17,386	15,883	8.65%	30%	28%
Oct-05	31	9.28	19,454	15,521	20.22%	33%	26%
Nov-05	30	9.38	16,130	15,249	5.46%	28%	27%
Dec-05	31	9.52	13,399	16,086	-20.05%	23%	27%
Total	365	10.18	207,627	207,627	0.00%	30%	30%
Total in OSP (07/15-09/15)	63	9.65	33,655	33,315	1.01%	28%	28%

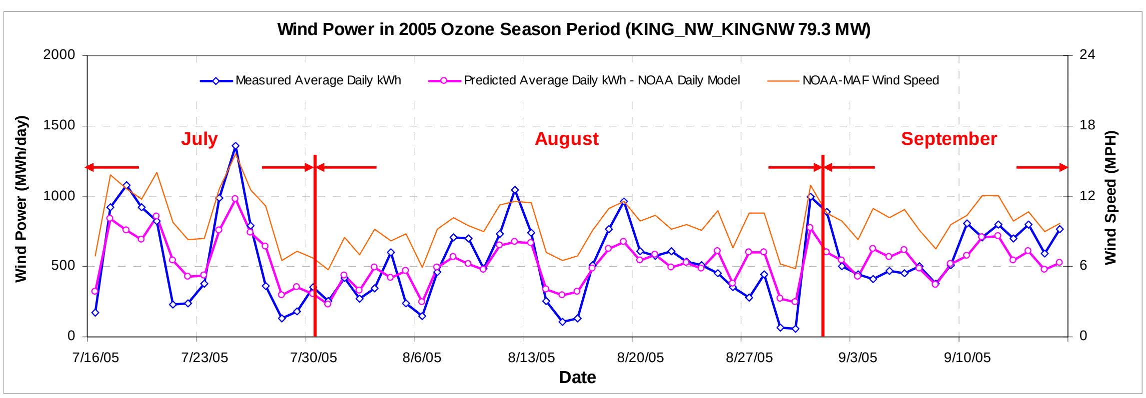


Figure 13-37: KING_NW_KINGNW - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

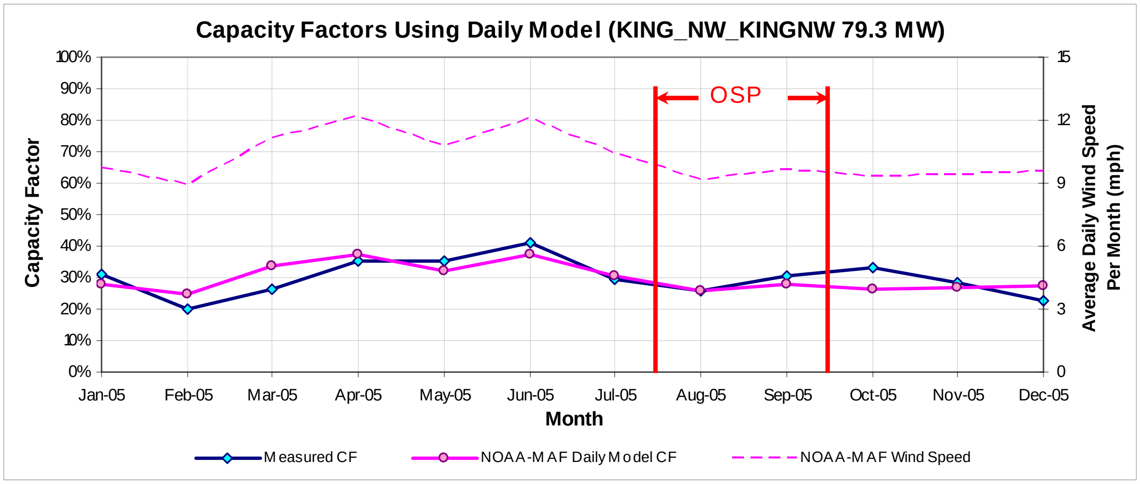


Figure 13-38: KING_NW_KINGNW - Predicted Capacity Factors Using Daily Models (2005).

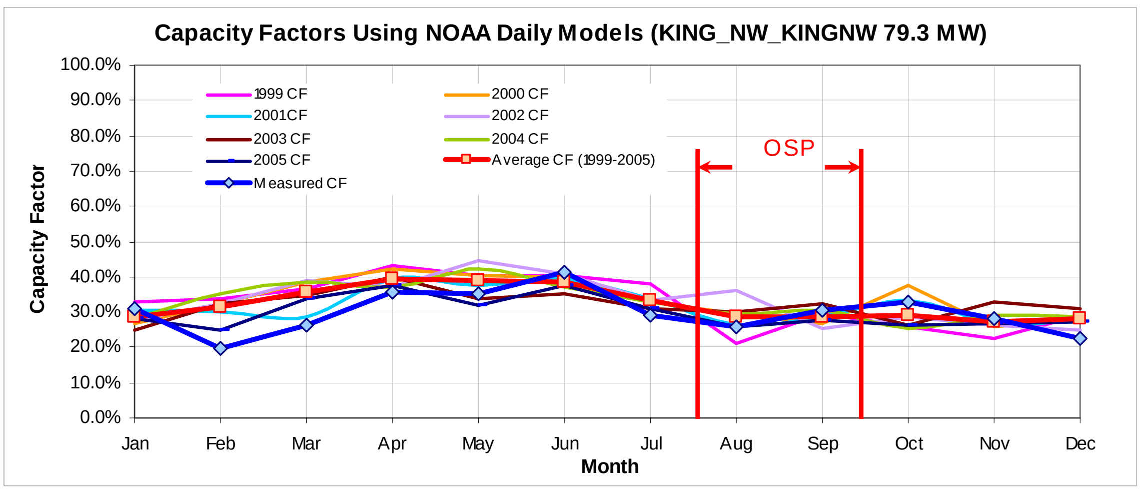


Figure 13-39: KING_NW_KINGNW - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-31: KING_NW_KINGNW - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
227,493	207,634
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
515	534

13.7 King Mountain Wind Ranch (KING_SE)

Table 13-32: Site Information for King Mountain Wind Ranch (KING_SE).

GENSITECODE_ ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
KING_SE	WIND	McCamey	UPTON	Dec-01	40.3	FPL/Cielo	King Mountain Wind Ranch	Bonus 1300 (61)	ERCOT	AEP-West	WTU	MAF

SUBGENCODE_ ERCOT	GENSITECODE_ERCOT	Capacity (MW)
KING_SE_KINGSE	KING_SE	40.3

13.7.1 King Mountain – KING_SE_KINGSE.

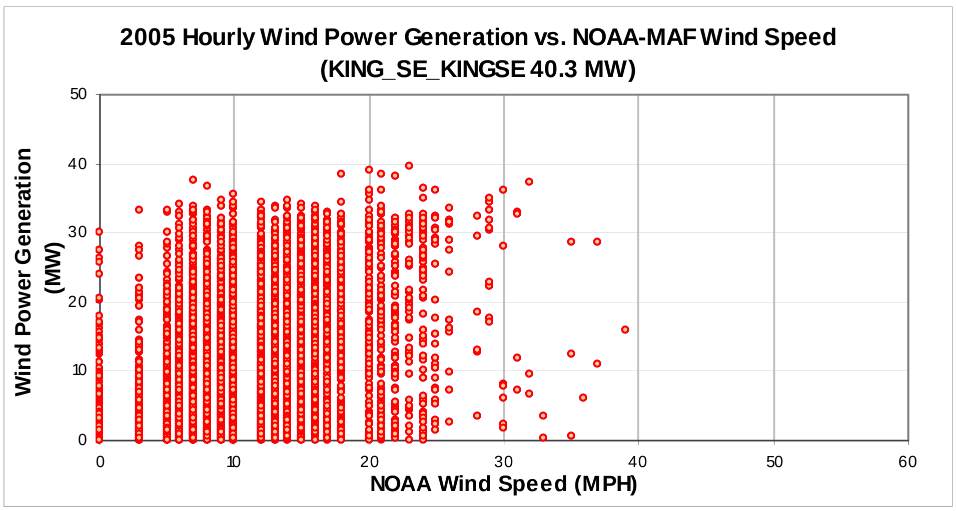


Figure 13-40: KING_SE_KINGSE - Hourly Wind Power vs. NOAA Wind Speed (2005).

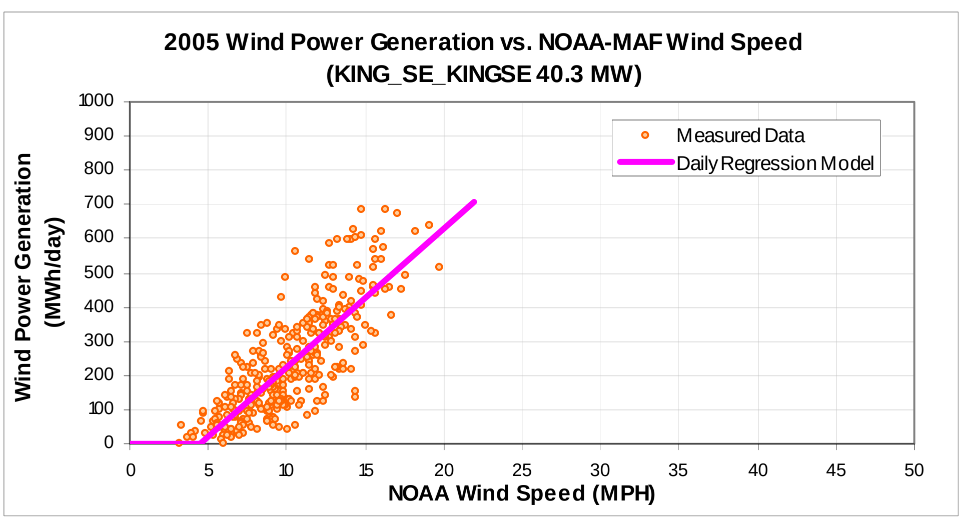


Figure 13-41: KING_SE_KINGSE - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-33: KING_SE_KINGSE - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-178.0938
Left Slope (MWh/mph-day)	40.3829
RMSE (MWh/day)	93.0687
R2	0.6422
CV-RMSE	39.9%

Table 13-34: King Mountain – KING_ SE – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	9.71	7,050	6,631	5.96%	24%	22%
Feb-05	28	8.90	4,770	5,158	-8.11%	18%	19%
Mar-05	31	11.14	7,920	8,431	-6.46%	26%	28%
Apr-05	30	12.12	10,177	9,343	8.20%	35%	32%
May-05	31	10.75	8,612	7,942	7.78%	29%	26%
Jun-05	30	12.10	9,134	9,316	-2.00%	31%	32%
Jul-05	31	10.41	6,431	7,511	-16.80%	21%	25%
Aug-05	31	9.18	4,856	5,967	-22.88%	16%	20%
Sep-05	30	9.66	5,371	6,362	-18.46%	19%	22%
Oct-05	31	9.28	6,975	6,131	12.10%	23%	20%
Nov-05	30	9.38	6,970	6,067	12.95%	24%	21%
Dec-05	31	9.52	6,834	6,400	6.35%	23%	21%
Total	365	10.18	85,099	85,257	-0.19%	24%	24%
Total in OSP (07/15-09/15)	63	9.65	11,453	13,340	-16.48%	19%	22%

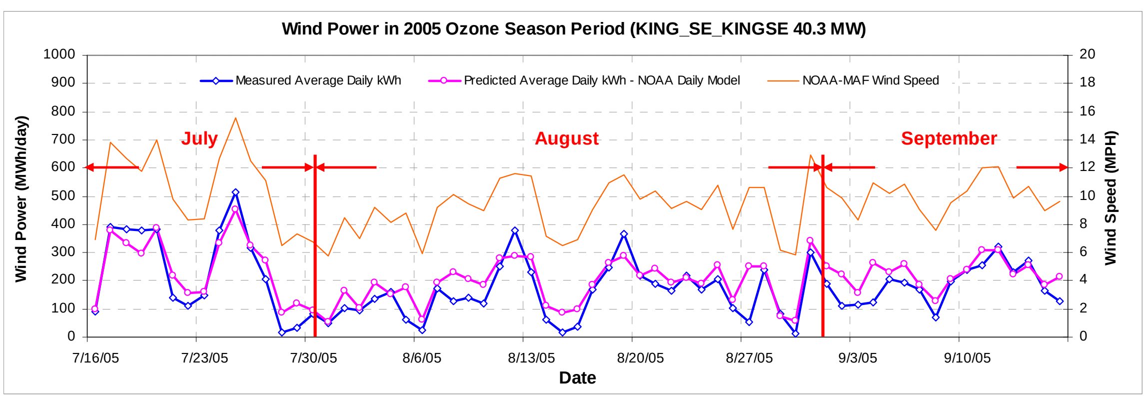


Figure 13-42: KING_SE_KINGSE - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

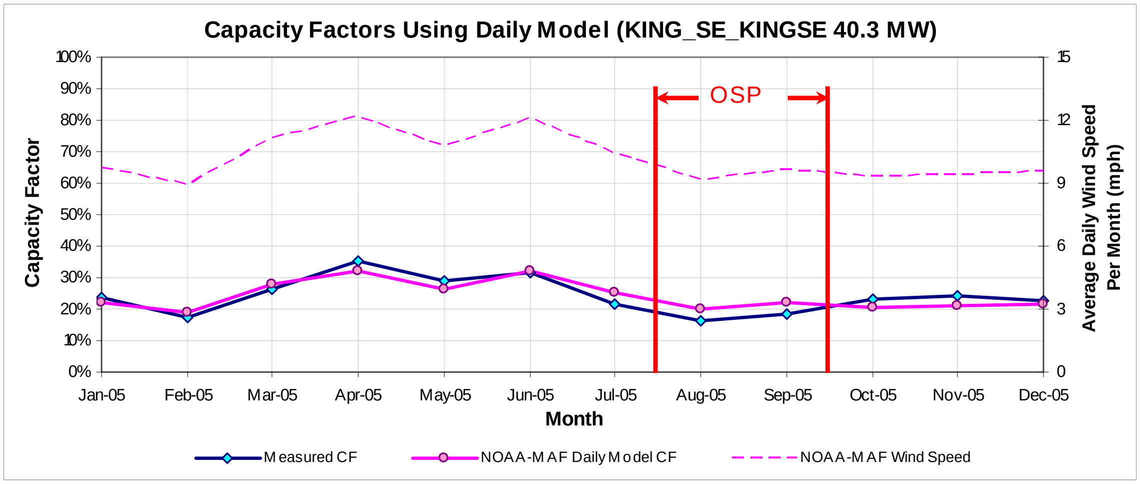


Figure 13-43: KING_SE_KINGSE - Predicted Capacity Factors Using Daily Models (2005).

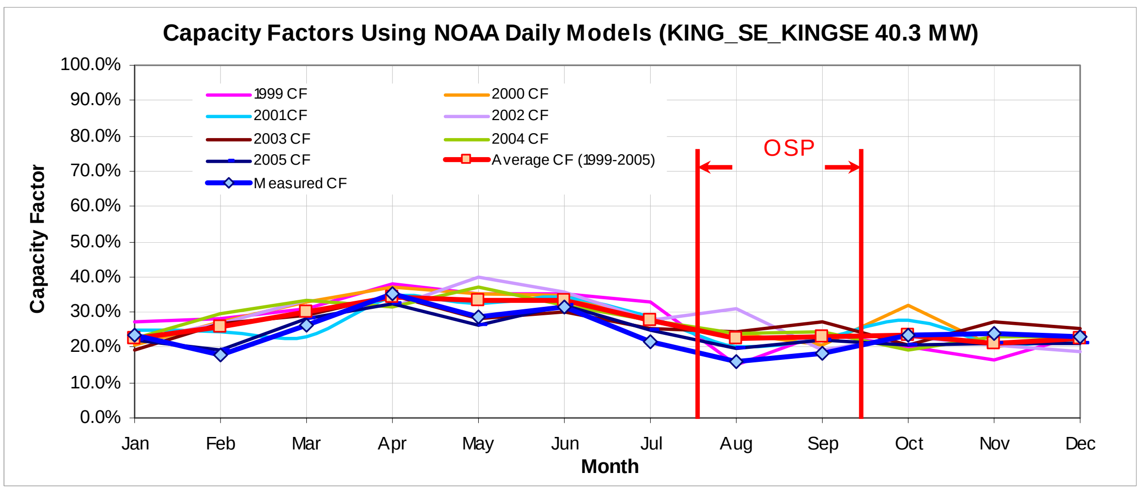


Figure 13-44: KING_SE_KINGSE - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-35: KING_SE_KINGSE - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
95,931	85,097
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
204	182

13.8 King Mountain Wind Ranch (KING_SW)

Table 13-36: Site Information for King Mountain Wind Ranch (KING_SW).

GENSITECODE_ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Interconnection	Weather Station
KING_SW	WIND	McCamey	UPTON	Dec-01	79.3	FPL/Cielo	King Mountain Wind Ranch	Bonus 1300 (61)	ERCOT	AEP-West	WTU	MAF

SUBGENCODE_ERCOT	GENSITECODE_ERCOT	Capacity (MW)
KING_SW_KINGSW	KING_SW	79.3

13.8.1 King Mountain – KING_SW_KINGSW

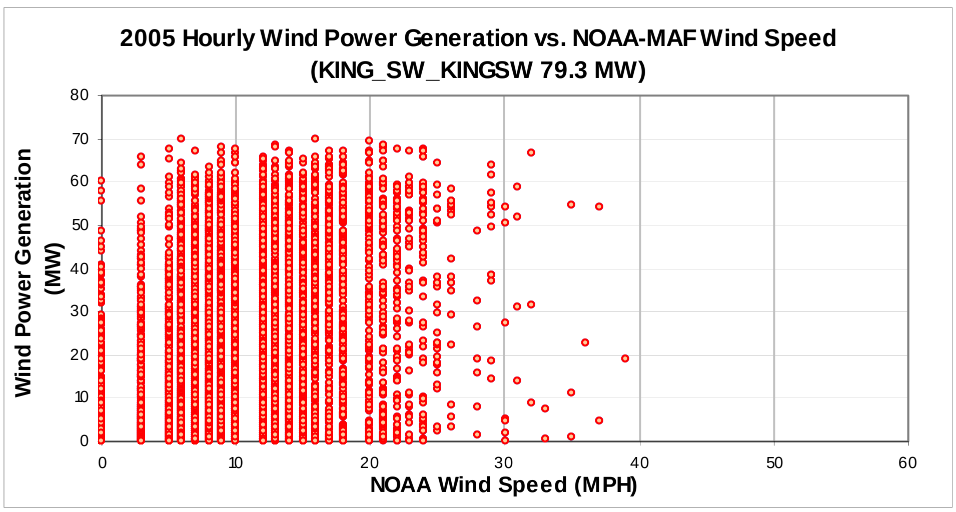


Figure 13-45: KING_SW_KINGSW - Hourly Wind Power vs. NOAA Wind Speed (2005).

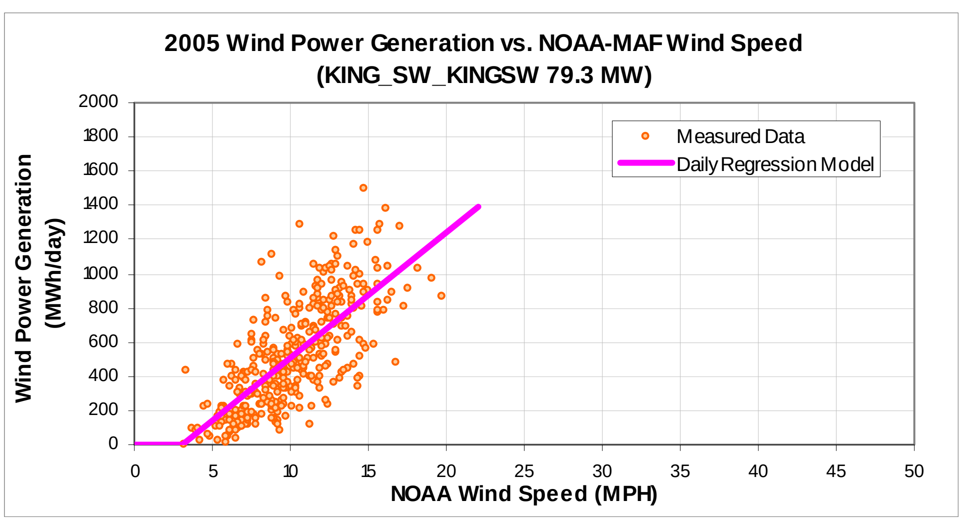


Figure 13-46: KING_SW_KINGSW - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-37: KING_SW_KINGSW - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-230.3848
Left Slope (MWh/mph-day)	73.7931
RMSE (MWh/day)	210.6922
R2	0.5391
CV-RMSE	40.4%

Table 13-38: KING_SW_KINGSW – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	9.71	16,765	15,063	10.15%	28%	26%
Feb-05	28	8.90	10,469	11,937	-14.02%	20%	22%
Mar-05	31	11.14	14,863	18,353	-23.48%	25%	31%
Apr-05	30	12.12	19,472	19,925	-2.32%	34%	35%
May-05	31	10.75	19,058	17,459	8.39%	32%	30%
Jun-05	30	12.10	21,368	19,875	6.98%	37%	35%
Jul-05	31	10.41	16,071	16,672	-3.74%	27%	28%
Aug-05	31	9.18	12,873	13,850	-7.59%	22%	23%
Sep-05	30	9.66	15,167	14,477	4.55%	27%	25%
Oct-05	31	9.28	17,650	14,089	20.18%	30%	24%
Nov-05	30	9.38	13,373	13,858	-3.63%	23%	24%
Dec-05	31	9.52	13,070	14,641	-12.02%	22%	25%
Total	365	10.18	190,199	190,199	0.00%	27%	27%
Total in OSP (07/15-09/15)	63	9.65	29,860	30,365	-1.69%	25%	25%

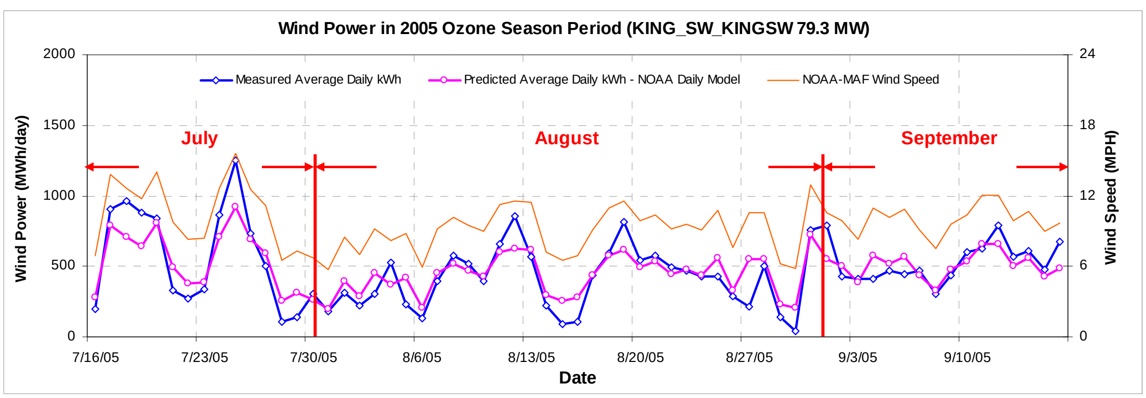


Figure 13-47: KING_SW_KINGSW - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

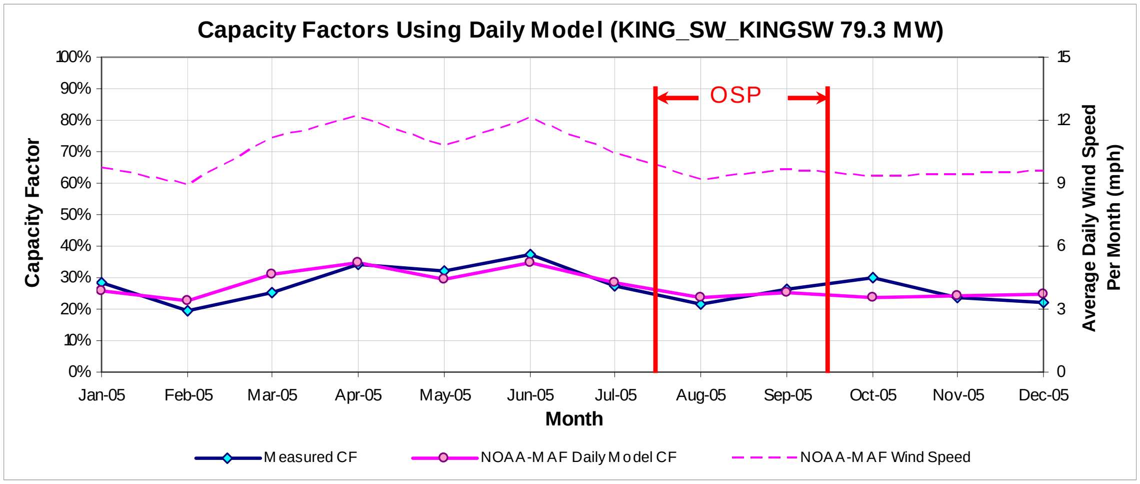


Figure 13-48: KING_SW_KINGSW - Predicted Capacity Factors Using Daily Models (2005).

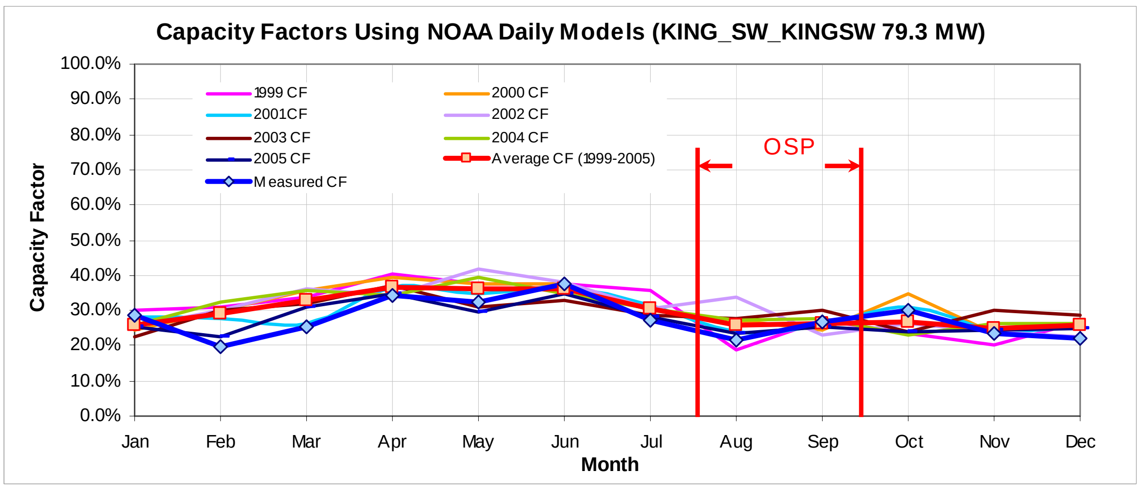


Figure 13-49: KING_SW_KINGSW - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-39: KING_SW_KINGSW - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
209,671	190,202
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
469	474

13.9 Sweetwater Wind 2

Table 13-40: Site Information for Sweetwater Wind 2.

GENSITECODE_ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
SWEETWN2	WIND	Sweetwater	NOLAN	Feb-05	91.5	DKRW Development	Sweetwater Wind 2	GE Wind 1500 (61)	ERCOT	TXU	TXU	ABI

SUBGENCODE_ERCOT	GENSITECODE_ERCOT	Capacity (MW)
SWEETWN2_WND2	SWEETWN2	91.5

13.9.1 Sweetwater Wind 2 - SWEETWN2_WND2

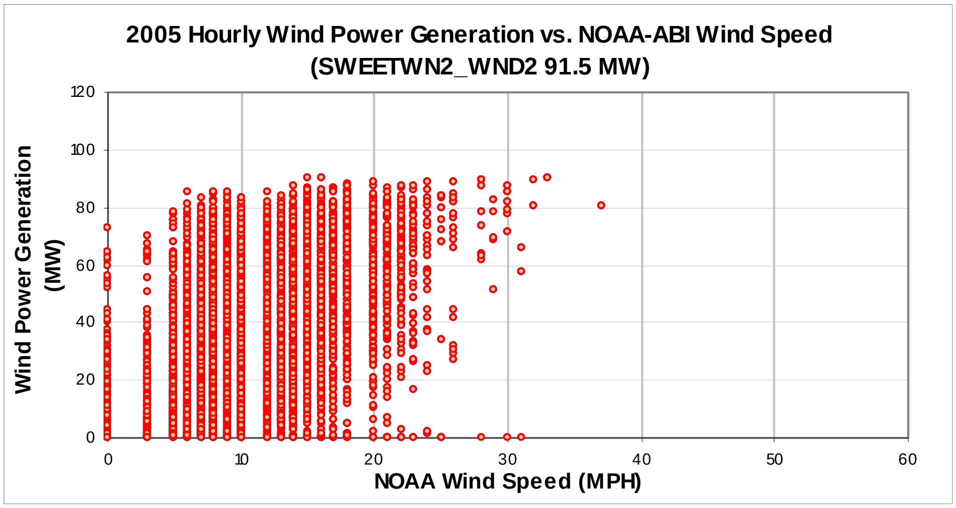


Figure 13-50: SWEETWN2_WND2 - Hourly Wind Power vs. NOAA Wind Speed (2005).

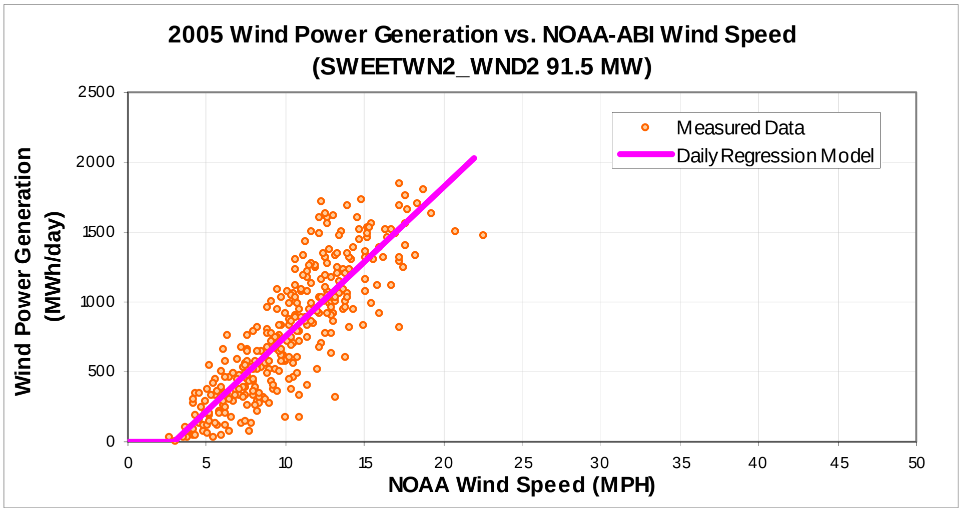


Figure 13-51: SWEETWN2_WND2 - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-41: SWEETWN2_WND2 - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-316.3912
Left Slope (MWh/mph-day)	106.4280
RMSE (MWh/day)	237.1122
R2	0.7322
CV-RMSE	30.4%

Table 13-42: SWEETWN2_WND2 – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	0						
Feb-05	28	8.92	12,056	17,758	-47.30%	20%	29%
Mar-05	31	11.54	27,431	28,258	-3.01%	40%	42%
Apr-05	30	12.97	31,008	31,913	-2.92%	47%	48%
May-05	30	11.03	25,278	25,731	-1.80%	38%	39%
Jun-05	30	11.86	27,467	28,370	-3.29%	42%	43%
Jul-05	31	9.94	20,644	22,994	-11.38%	30%	34%
Aug-05	31	8.26	16,113	17,451	-8.30%	24%	26%
Sep-05	30	9.29	20,361	20,158	0.99%	31%	31%
Oct-05	31	9.26	24,114	20,759	13.91%	35%	30%
Nov-05	30	10.33	27,581	23,500	14.80%	42%	36%
Dec-05	31	10.02	28,067	23,260	17.13%	41%	34%
Total	333	10.31	260,120	260,152	-0.01%	36%	36%
Total in OSP (07/15-09/15)	63	8.98	39,233	40,270	-2.64%	28%	29%

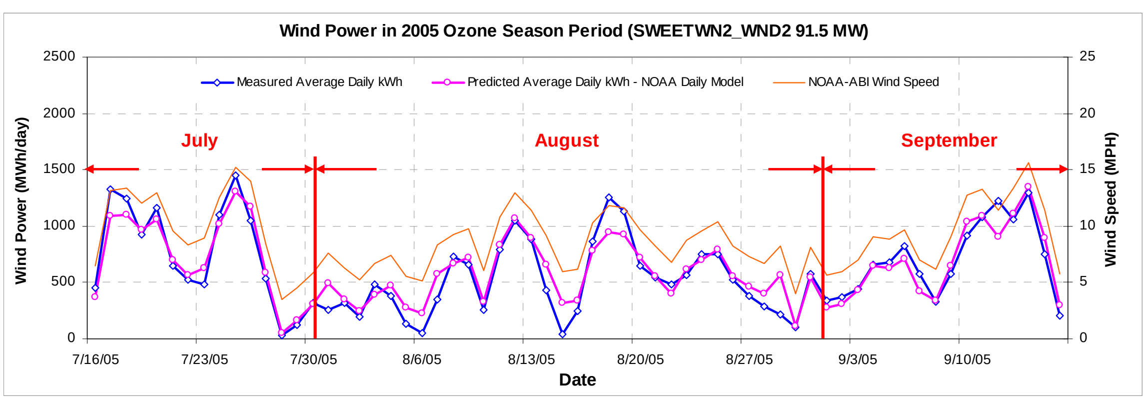


Figure 13-52: SWEETWN2_WND2 - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

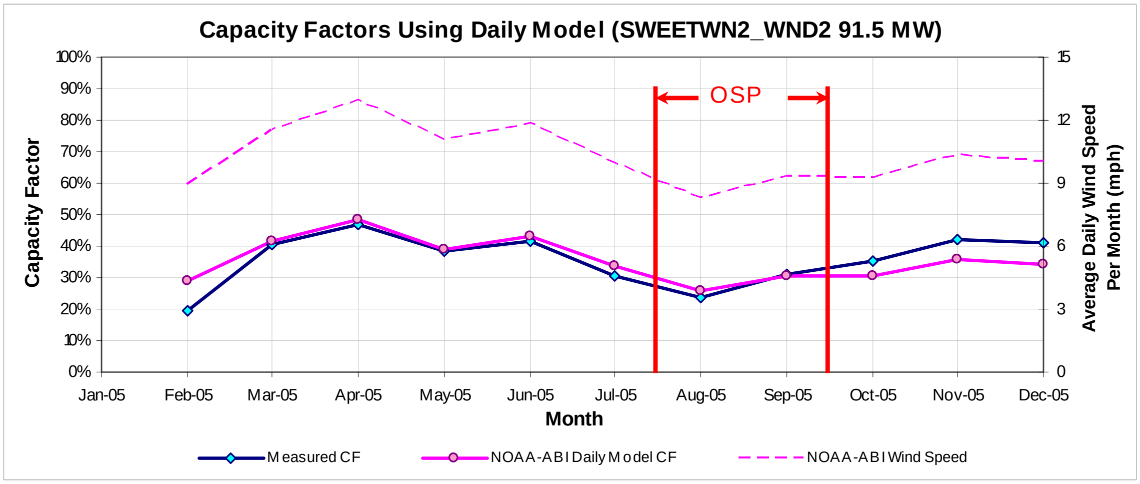


Figure 13-53: SWEETWN2_WND2 - Predicted Capacity Factors Using Daily Models (2005).

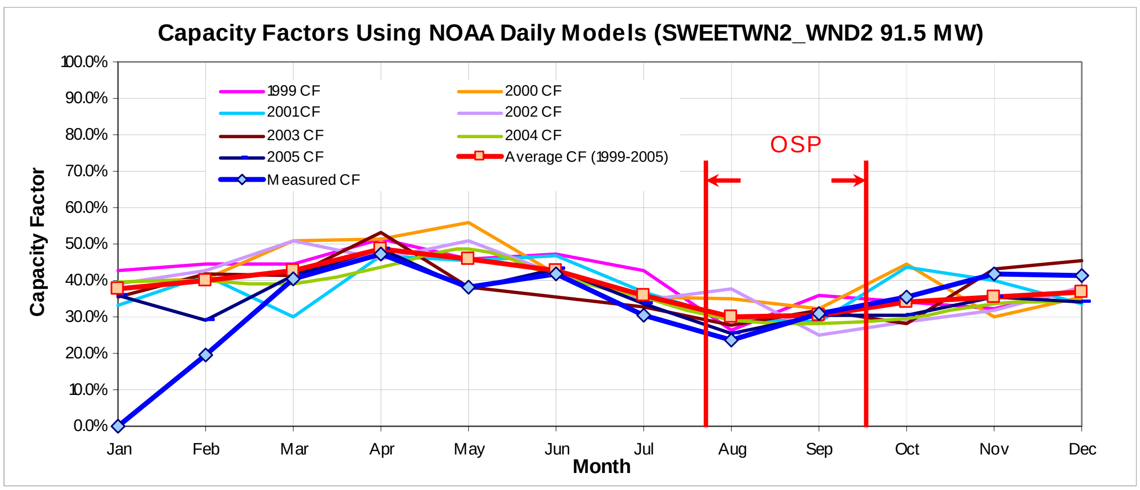


Figure 13-54: SWEETWN2_WND2 - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-43: SWEETWN2_WND2 - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
323,218	262,537
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
717	623

13.10 Trent Mesa

Table 13-44: Site Information for Trent Mesa.

GENSITECODE_ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
TRENT	WIND	Trent Mesa	NOLAN	Nov-01	150	AEP	Trent Mesa	Enron 1500 (100)	ERCOT	TXU	TXU	ABI

SUBGENCODE_ERCOT	GENSITECODE_ERCOT	Capacity (MW)
TRENT_TRENT	TRENT	150

13.10.1 Trent Mesa – TRENT_TRENT

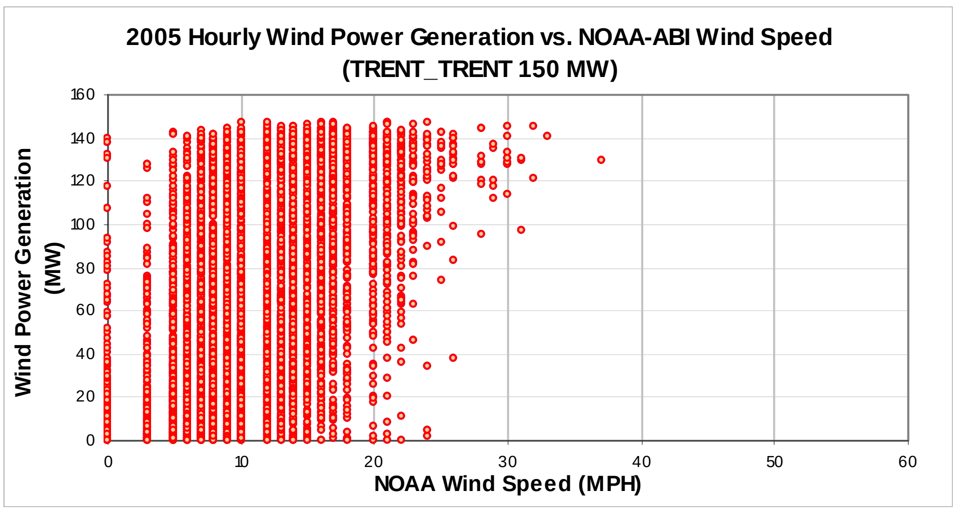


Figure 13-55: TRENT_TRENT - Hourly Wind Power vs. NOAA Wind Speed (2005).

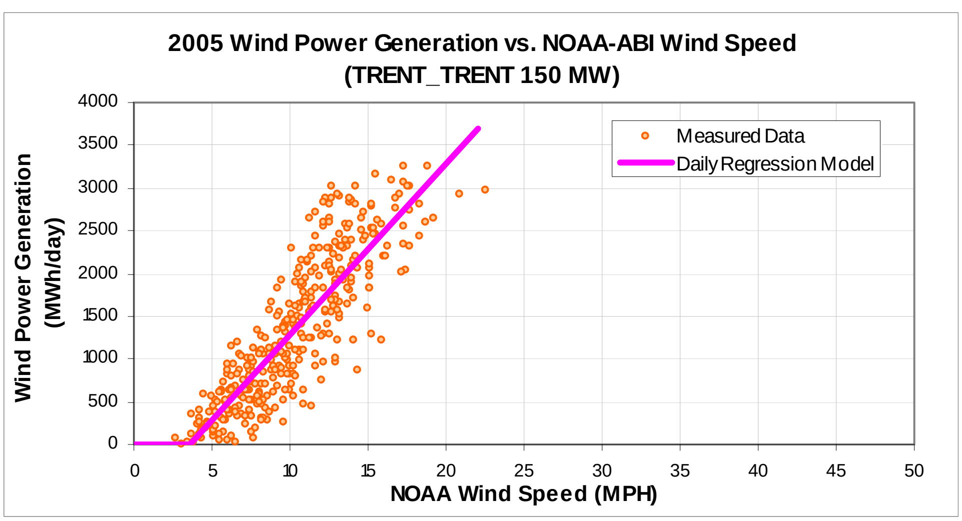


Figure 13-56: TRENT_TRENT - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-45: TRENT_TRENT - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-718.2117
Left Slope (MWh/mph-day)	200.3226
RMSE (MWh/day)	439.5447
R2	0.7342
CV-RMSE	32.6%

Table 13-46: TRENT_TRENT – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	10.34	40,971	41,966	-2.43%	37%	38%
Feb-05	28	8.92	27,216	30,113	-10.65%	27%	30%
Mar-05	31	11.54	45,824	49,384	-7.77%	41%	44%
Apr-05	30	12.97	53,405	56,387	-5.58%	49%	52%
May-05	30	11.03	42,773	44,752	-4.63%	40%	41%
Jun-05	30	11.86	52,723	49,718	5.70%	49%	46%
Jul-05	31	9.94	30,865	39,494	-27.96%	28%	35%
Aug-05	31	8.26	30,771	29,043	5.61%	28%	26%
Sep-05	30	9.29	36,200	34,262	5.35%	34%	32%
Oct-05	31	9.26	37,576	35,379	5.85%	34%	32%
Nov-05	30	10.33	47,236	40,551	14.15%	44%	38%
Dec-05	31	10.02	45,160	39,977	11.48%	40%	36%
Total	364	10.32	490,718	491,028	-0.06%	37%	37%
Total in OSP (07/15-09/15)	63	8.98	68,976	68,086	1.29%	30%	30%

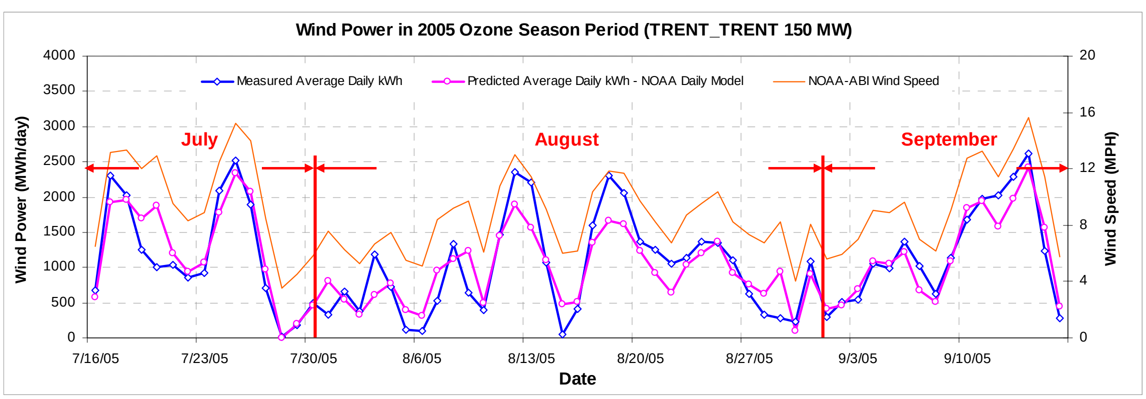


Figure 13-57: TRENT_TRENT - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

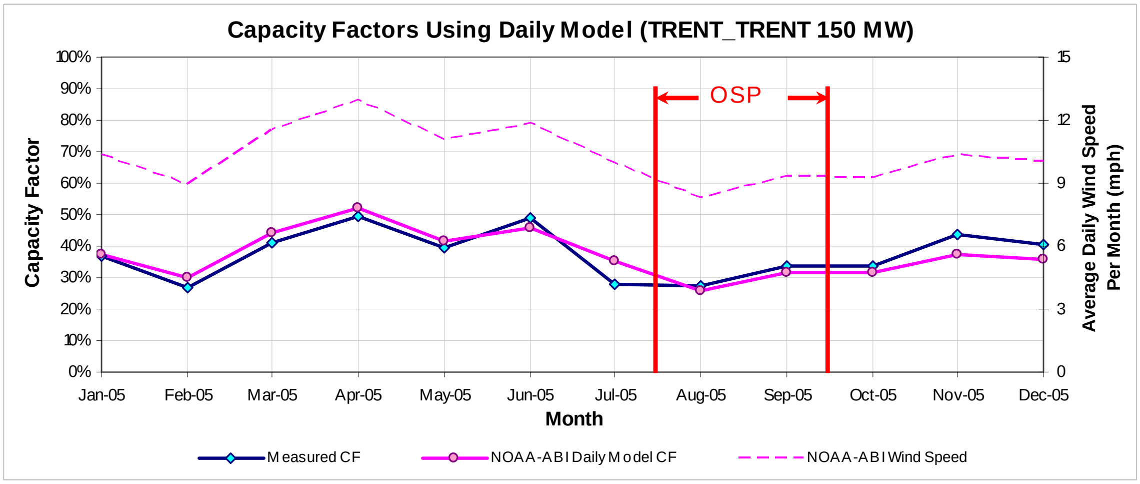


Figure 13-58: TRENT_TRENT - Predicted Capacity Factors Using Daily Models (2005).

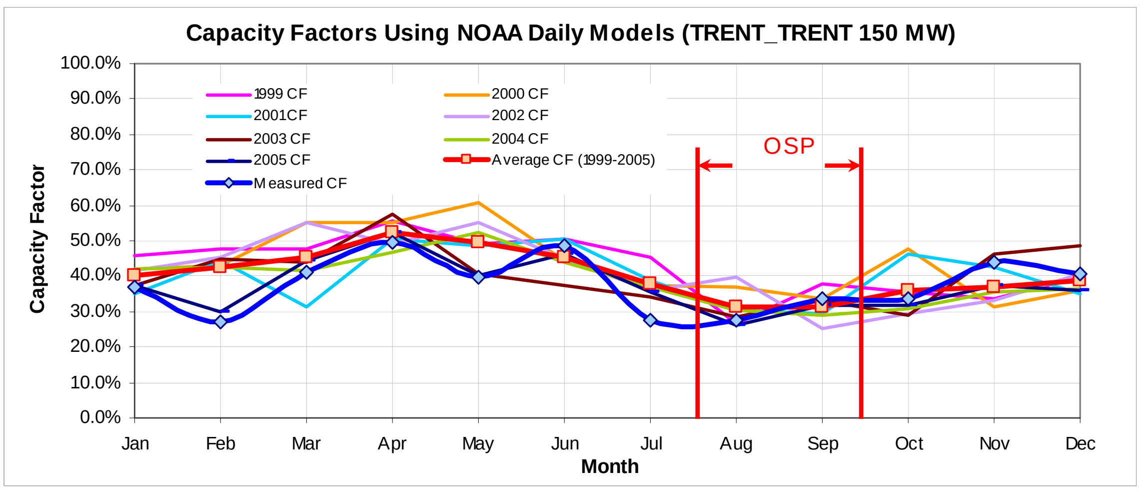


Figure 13-59: TRENT_TRENT - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-47: TRENT_TRENT - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
563,714	492,444
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
1227	1095

13.11 Delaware Mountain Wind Farm

Table 13-48: Site Information for Delaware Mountain Wind Farm.

GENSITECODE _ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
DELAWARE	WIND		CULBERSON	Jun-99	30	American National Wind Power	Delaware Mountain Wind Farm	Zond (40)	ERCOT	TXU	TXU	GDP

SUBGENCODE _ERCOT	GENSITECODE _ERCOT	Capacity (MW)
DELAWARE_WIND_NWP	DELAWARE	30

13.11.1 Delaware Mountain – DELAWARE_WIND_NWP

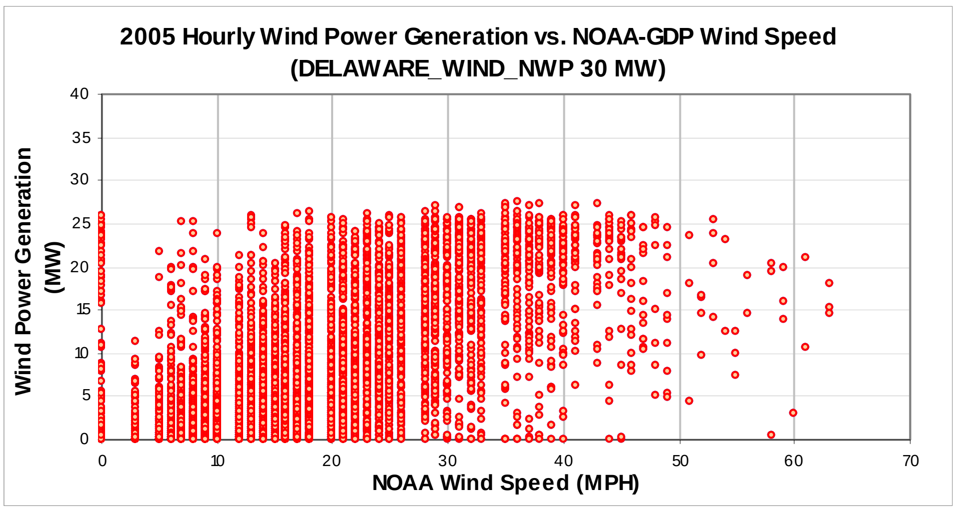


Figure 13-60: DELAWARE_WIND_NWP - Hourly Wind Power vs. NOAA Wind Speed (2005).

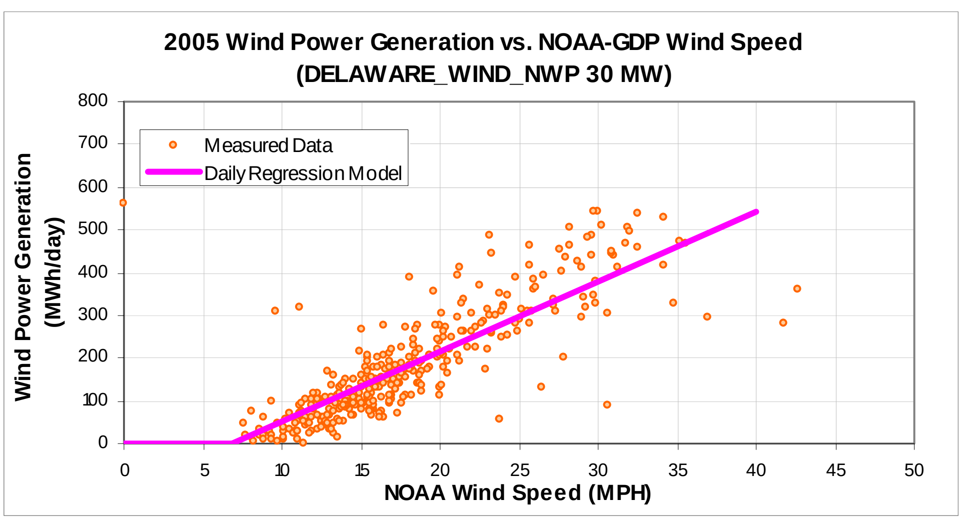


Figure 13-61: DELAWARE_WIND_NWP - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-49: DELAWARE_WIND_NWP - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-112.6147
Left Slope (MWh/mph-day)	16.3490
RMSE (MWh/day)	76.3676
R2	0.6599
CV-RMSE	42.0%

Table 13-50: DELAWARE_WIND_NWP – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	30	19.10	5,458	5,988	-9.71%	25%	28%
Feb-05	28	21.55	6,474	6,711	-3.66%	32%	33%
Mar-05	30	22.29	8,158	7,552	7.43%	38%	35%
Apr-05	29	19.94	7,904	6,300	20.30%	38%	30%
May-05	28	17.34	5,137	4,784	6.87%	25%	24%
Jun-05	30	15.71	4,039	4,326	-7.11%	19%	20%
Jul-05	30	15.97	4,160	4,454	-7.06%	19%	21%
Aug-05	24	12.86	1,456	2,343	-60.95%	8%	14%
Sep-05	29	14.50	3,247	3,609	-11.15%	16%	17%
Oct-05	31	16.83	4,562	5,040	-10.47%	20%	23%
Nov-05	30	19.78	6,281	6,322	-0.64%	29%	29%
Dec-05	30	19.51	6,629	6,189	6.63%	31%	29%
Total	349	18.02	63,507	63,620	-0.18%	25%	25%
Total in OSP (07/15-09/15)	56	1.86	5,773	6,934	-20.11%	14%	17%

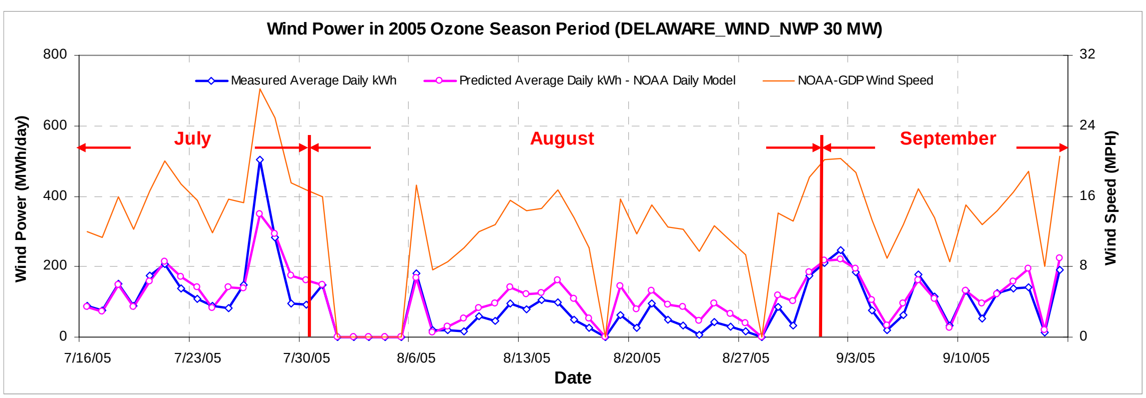


Figure 13-62: DELAWARE_WIND_NWP - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

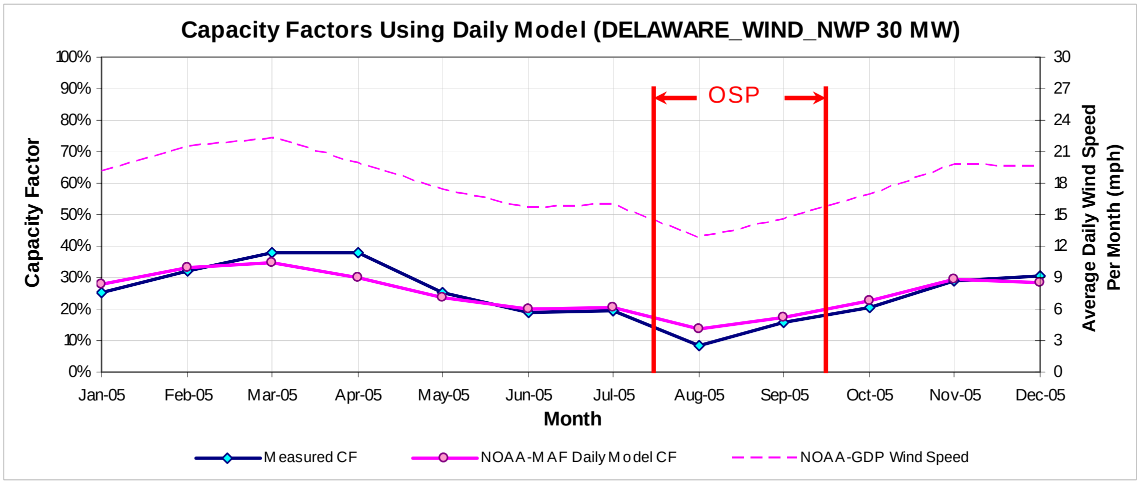


Figure 13-63: DELAWARE_WIND_NWP - Predicted Capacity Factors Using Daily Models (2005).

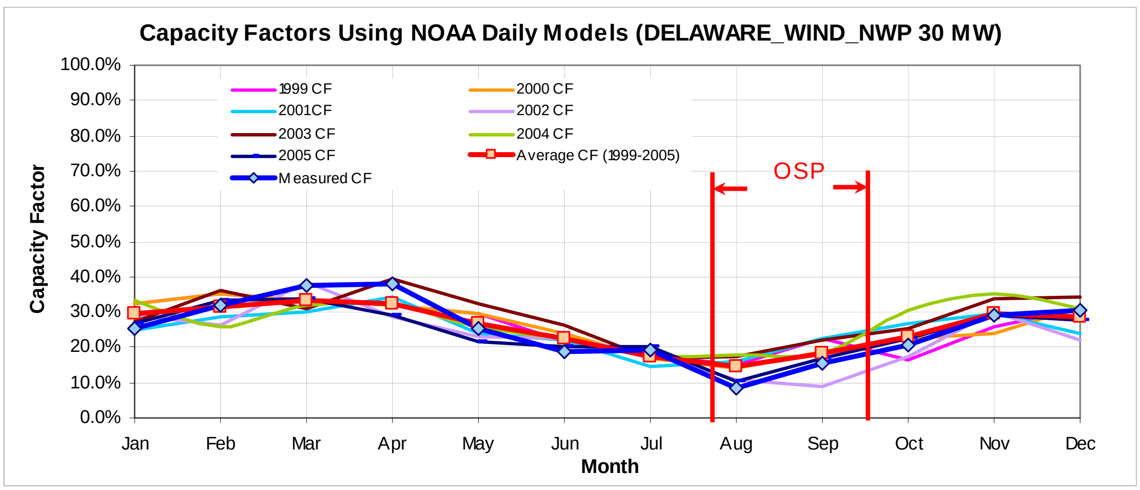


Figure 13-64: DELAWARE_WIND_NWP - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-51: DELAWARE_WIND_NWP - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
68,298	66,267
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
114	103

13.12 Indian Mesa I

Table 13-52: Site Information for Indian Mesa I.

GENSITECODE _ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
INDNNWP	WIND	Iraan	PECOS	Jun-01	82.5	Orion Energy/American National Wind Power	Indian Mesa I	Vestas V-47 (125)	ERCOT	AEP-West	WTU	FST

SUBGENCODE _ERCOT	GENSITECODE_ERCOT	Capacity (MW)
INDNNWP_INDNNWP_J01	INDNNWP	50.3
INDNNWP_INDNNWP_J02	INDNNWP	32.2

13.12.1 Indian Mesa I – INDNNWP_INDNNWP_J01.

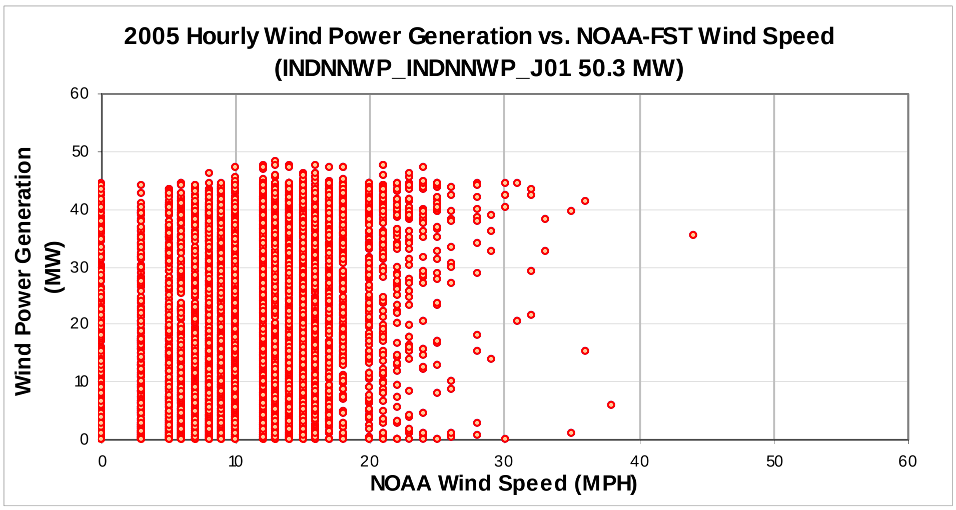


Figure 13-65: INDNNWP_INDNNWP_J01- Hourly Wind Power vs. NOAA Wind Speed (2005).

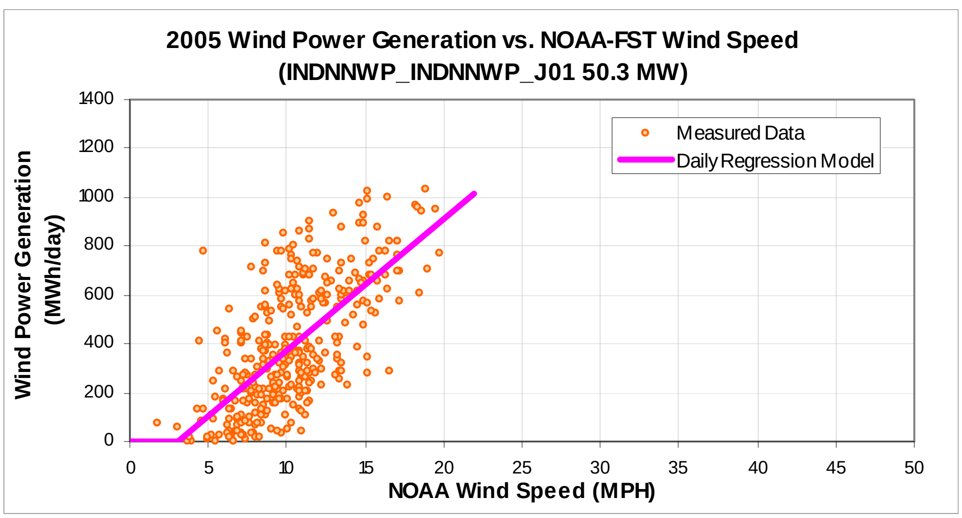


Figure 13-66: INDNNWP_INDNNWP_J01- Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-53: INDNNWP_INDNNWP_J01- Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-163.6291
Left Slope (MWh/mph-day)	53.4693
RMSE (MWh/day)	192.0180
R2	0.4433
CV-RMSE	49.4%

Table 13-54: INDNNWP_INDNNWP_J01 – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	10.20	12,680	11,841	6.62%	34%	32%
Feb-05	28	9.24	6,472	9,245	-42.85%	19%	27%
Mar-05	31	11.08	9,463	13,299	-40.53%	25%	36%
Apr-05	30	12.46	14,148	15,080	-6.59%	39%	42%
May-05	30	11.73	14,418	13,912	3.51%	40%	38%
Jun-05	30	12.45	16,594	15,056	9.27%	46%	42%
Jul-05	31	10.61	12,045	12,516	-3.91%	32%	33%
Aug-05	31	8.49	10,576	9,001	14.89%	28%	24%
Sep-05	30	9.17	11,271	9,795	13.10%	31%	27%
Oct-05	31	9.68	12,702	10,968	13.65%	34%	29%
Nov-05	30	10.26	10,818	11,544	-6.71%	30%	32%
Dec-05	31	8.62	10,293	9,291	9.73%	28%	25%
Total	364	10.33	141,479	141,547	-0.05%	32%	32%
Total in OSP (07/15-09/15)	63	9.29	23,427	20,987	10.42%	31%	28%

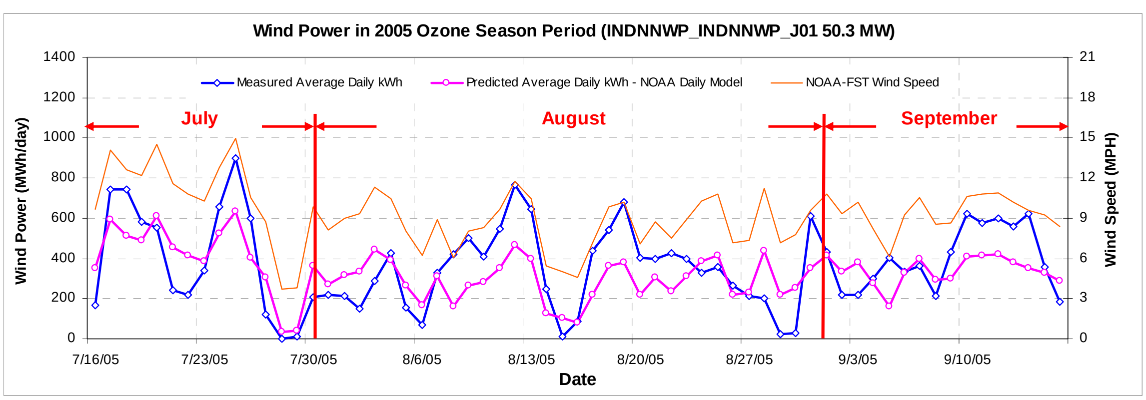


Figure 13-67: INDNNWP_INDNNWP_J01- Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

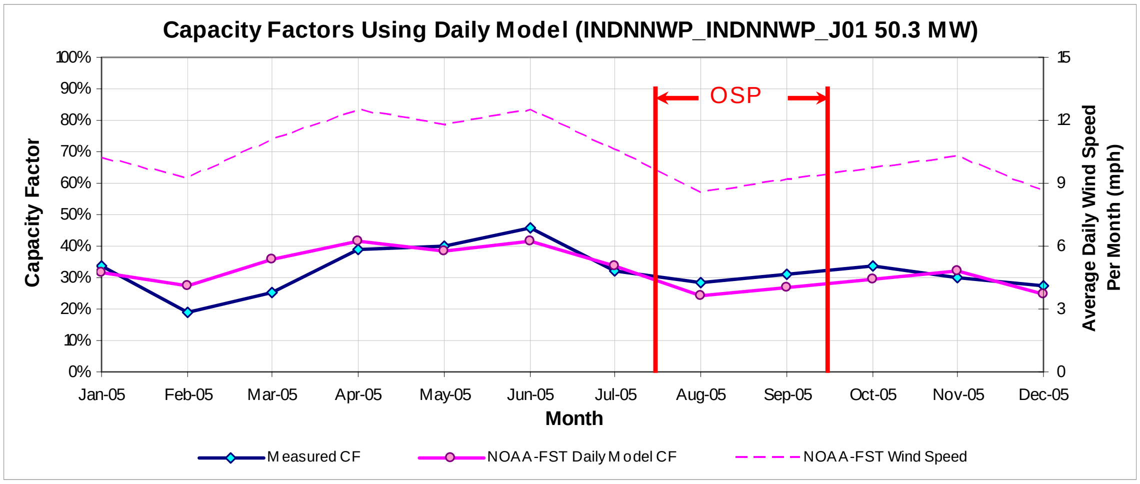


Figure 13-68: INDNNWP_INDNNWP_J01- Predicted Capacity Factors Using Daily Models (2005).

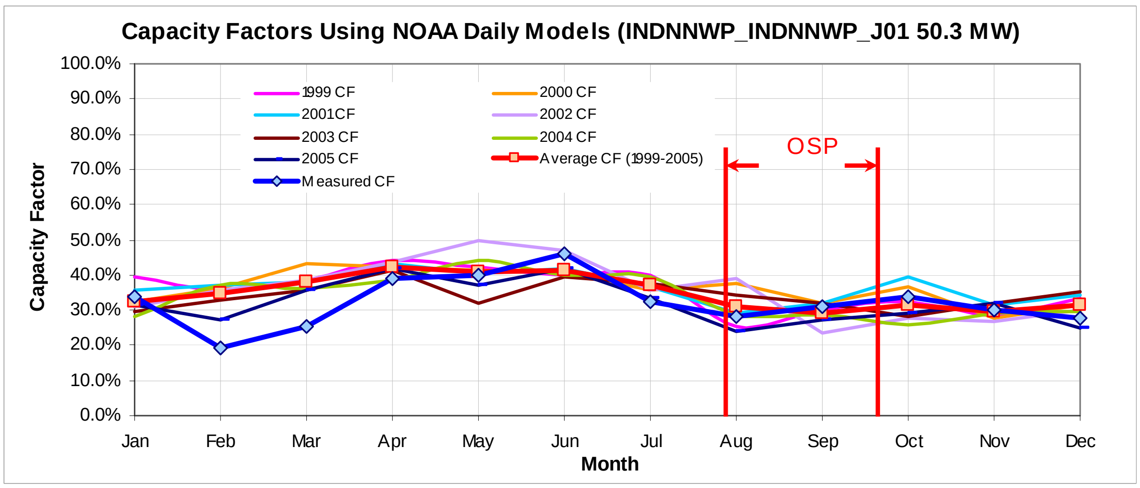


Figure 13-69: INDNNWP_INDNNWP_J01- Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-55: INDNNWP_INDNNWP_J01- Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
158,580	142,264
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
369	372

13.12.2 Indian Mesa I – INDNNWP_INDNNWP_J02

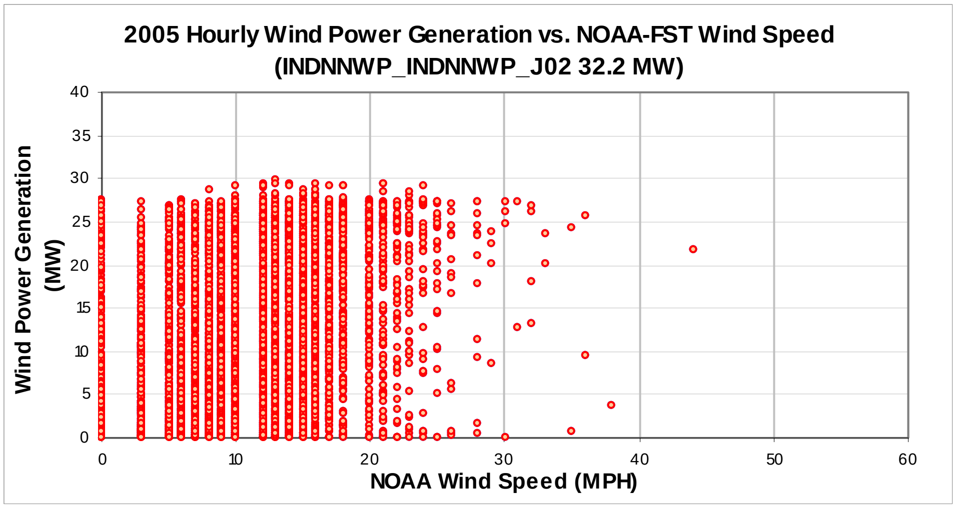


Figure 13-70: INDNNWP_INDNNWP_J02- Hourly Wind Power vs. NOAA Wind Speed (2005).

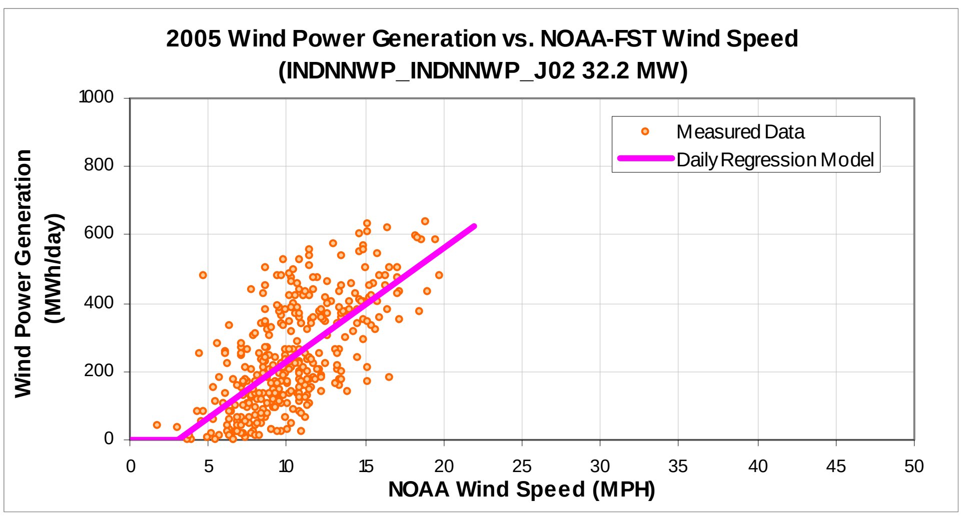


Figure 13-71: INDNNWP_INDNNWP_J02- Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-56: INDNNWP_INDNNWP_J02- Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-101.5533
Left Slope (MWh/mph-day)	33.0748
RMSE (MWh/day)	118.5768
R2	0.4441
CV-RMSE	49.4%

Table 13-57: INDNNWP_INDNNWP_J02 – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	10.20	7,831	7,314	6.60%	33%	31%
Feb-05	28	9.24	3,997	5,709	-42.85%	18%	26%
Mar-05	31	11.08	5,844	8,216	-40.58%	24%	34%
Apr-05	30	12.46	8,737	9,318	-6.65%	38%	40%
May-05	30	11.73	8,904	8,595	3.46%	38%	37%
Jun-05	30	12.45	10,281	9,303	9.51%	44%	40%
Jul-05	31	10.61	7,438	7,731	-3.94%	31%	32%
Aug-05	31	8.49	6,532	5,557	14.91%	27%	23%
Sep-05	30	9.17	6,960	6,049	13.10%	30%	26%
Oct-05	31	9.68	7,840	6,774	13.60%	33%	28%
Nov-05	30	10.26	6,677	7,131	-6.80%	29%	31%
Dec-05	31	8.62	6,352	5,737	9.68%	27%	24%
Total	364	10.33	87,393	87,435	-0.05%	31%	31%
Total in OSP (07/15-09/15)	63	9.29	14,468	12,961	10.42%	30%	27%

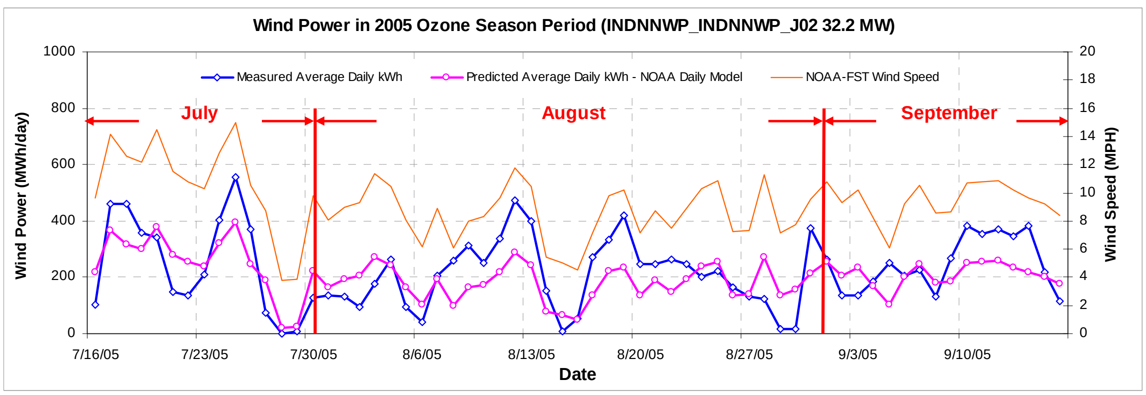


Figure 13-72: INDNNWP_INDNNWP_J02- Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

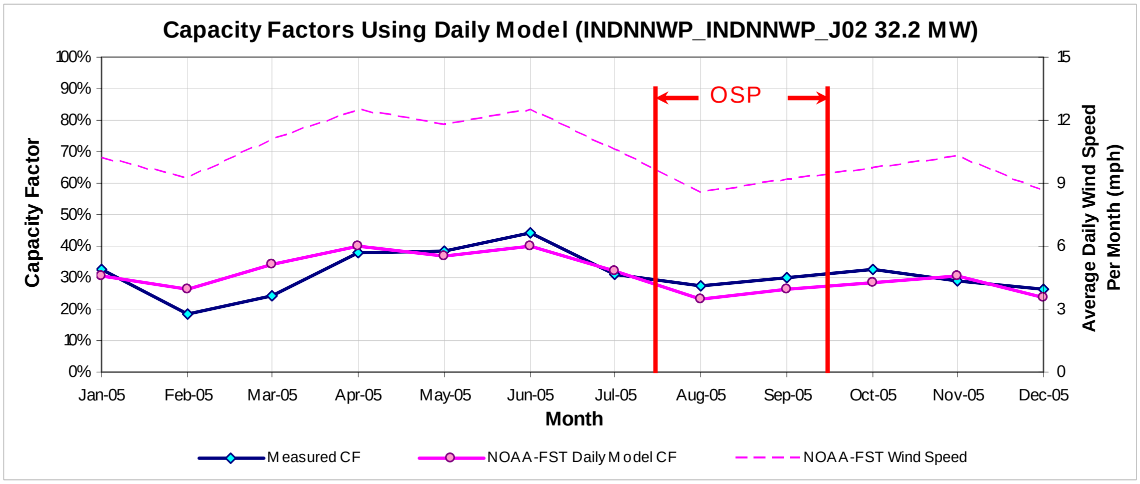


Figure 13-73: INDNNWP_INDNNWP_J02- Predicted Capacity Factors Using Daily Models (2005).

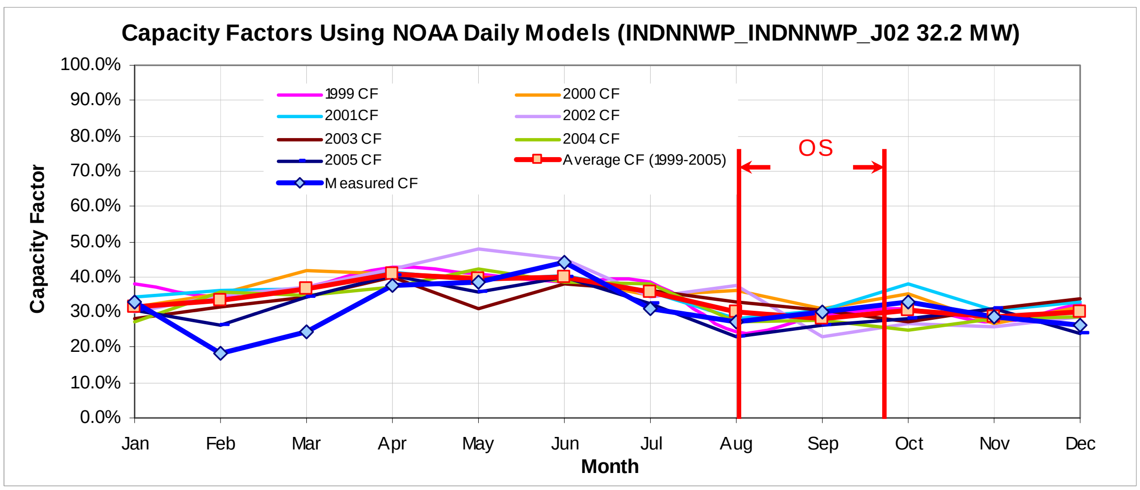


Figure 13-74: INDNNWP_INDNNWP_J02- Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-58: INDNNWP_INDNNWP_J02- Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
97,971	87,914
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
228	230

13.13 Texas Wind Power Project

Table 13-59: Site Information for Texas Wind Power Project.

GENSITECODE _ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
KUNITZ	WIND		CULBERSON	Jan-95	35	LG&E	Texas Wind Power Project	Kenetech (112)	ERCOT	Colorado River Authority		GDP

SUBGENCODE_ ERCOT	GENSITECOD E_ERCOT	Capacity (MW)
KUNITZ_WIND_ LGE_J01	KUNITZ	24.9
KUNITZ_WIND_ LGE_J02	KUNITZ	10.1

13.13.1 Texas Wind Power Project – KUNITZ_WIND_LGE_J01

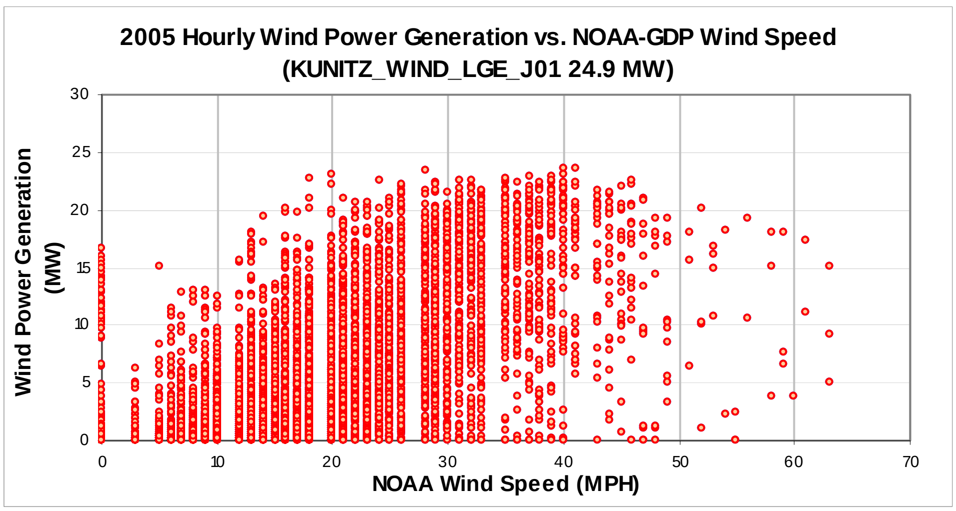


Figure 13-75: KUNITZ_WIND_LGE_J01- Hourly Wind Power vs. NOAA Wind Speed (2005).

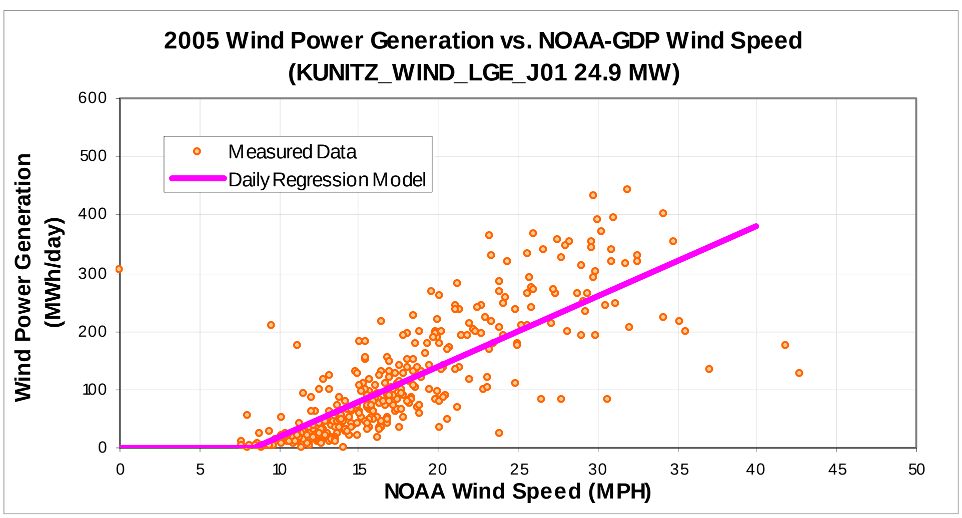


Figure 13-76: KUNITZ_WIND_LGE_J01- Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-60: KUNITZ_WIND_LGE_J01- Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-101.9651
Left Slope (MWh/mph-day)	12.1035
RMSE (MWh/day)	63.8088
R2	0.6037
CV-RMSE	54.9%

Table 13-61: KUNITZ_WIND_LGE_J01– Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	30	19.10	4,186	3,885	7.18%	23%	22%
Feb-05	28	21.55	4,648	4,448	4.30%	28%	27%
Mar-05	30	22.29	5,912	5,033	14.86%	33%	28%
Apr-05	29	19.94	4,721	4,143	12.23%	27%	24%
May-05	28	17.34	3,118	3,021	3.11%	19%	18%
Jun-05	30	15.71	1,751	2,645	-51.06%	10%	15%
Jul-05	30	15.97	1,611	2,739	-70.04%	9%	15%
Aug-05	24	12.86	636	1,297	-103.98%	4%	9%
Sep-05	29	14.50	1,238	2,137	-72.64%	7%	12%
Oct-05	31	16.83	3,298	3,158	4.24%	18%	17%
Nov-05	30	19.78	4,559	4,126	9.49%	25%	23%
Dec-05	30	19.51	4,849	4,024	17.01%	27%	22%
Total	349	18.02	40,527	40,659	-0.33%	19%	19%
Total in OSP (07/15-09/15)	56	1.86	2,258	4,105	-81.79%	7%	12%

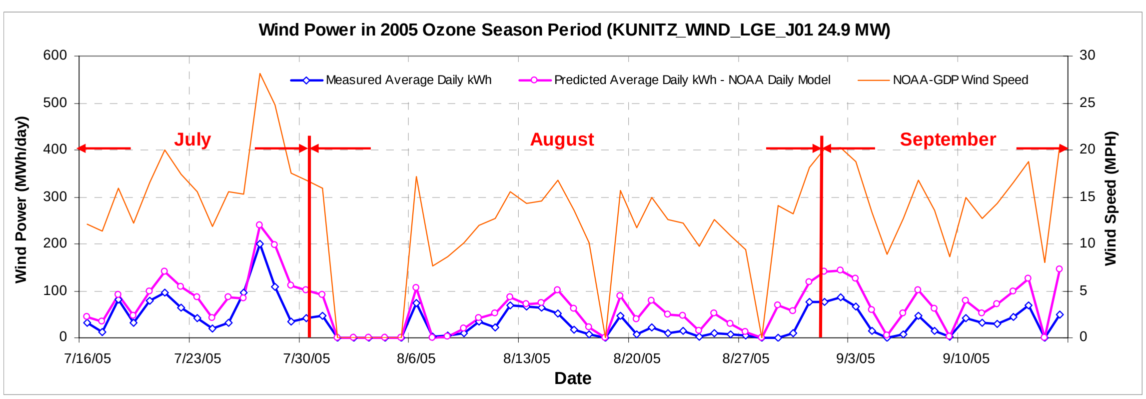


Figure 13-77: KUNITZ_WIND_LGE_J01- Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

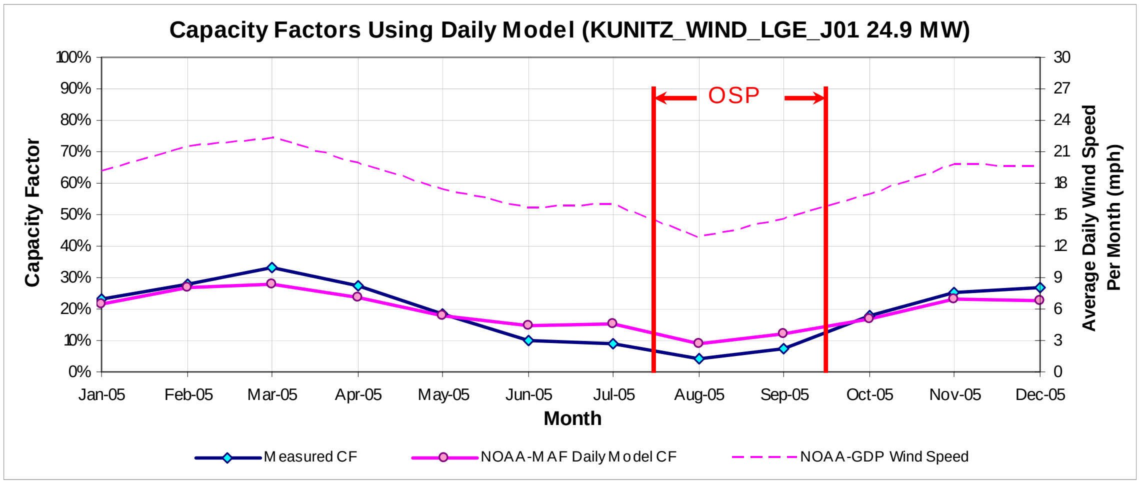


Figure 13-78: KUNITZ_WIND_LGE_J01- Predicted Capacity Factors Using Daily Models (2005).

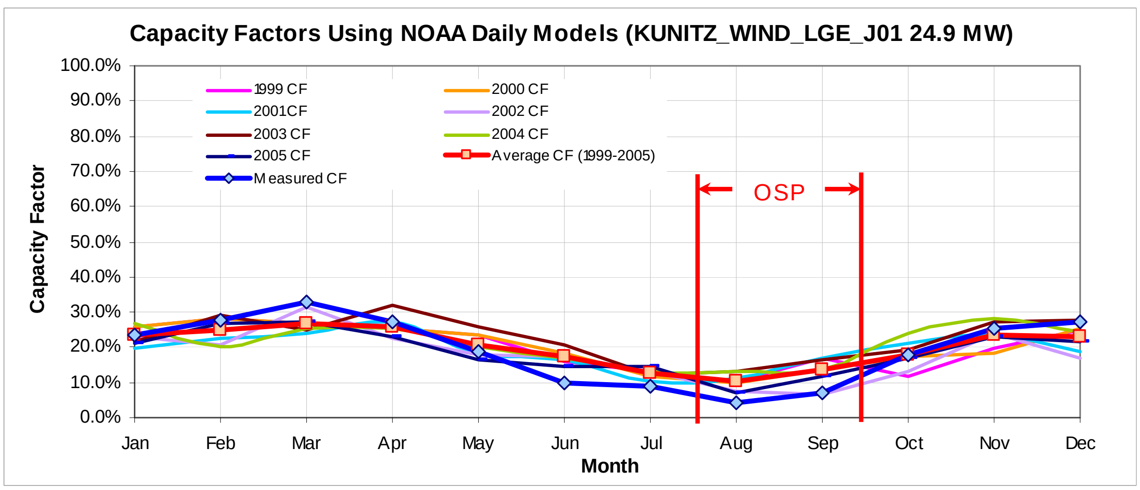


Figure 13-79: KUNITZ_WIND_LGE_J01- Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-62: KUNITZ_WIND_LGE_J01- Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
43,855	42,119
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
67	40

13.13.2 Texas Wind Power Project – KUNITZ_WIND_LGE_J02

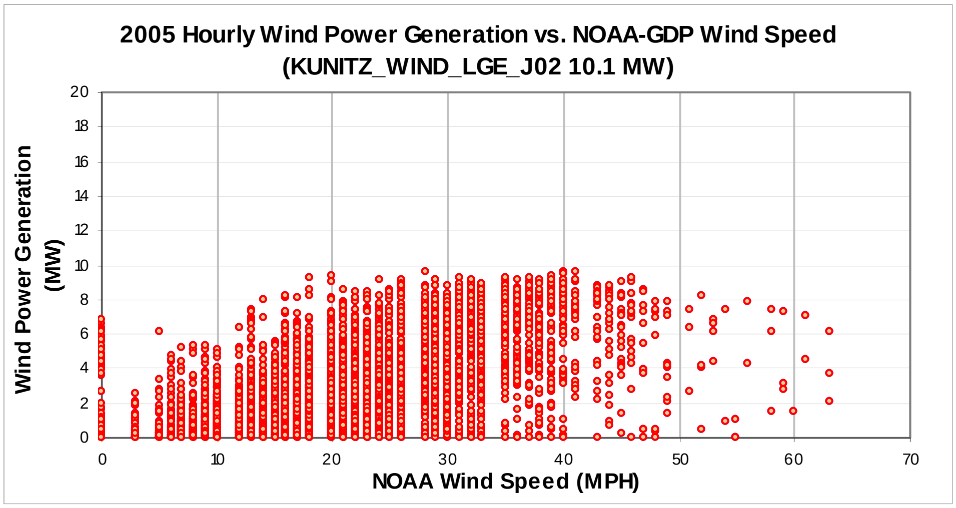


Figure 13-80: KUNITZ_WIND_LGE_J02- Hourly Wind Power vs. NOAA Wind Speed (2005).

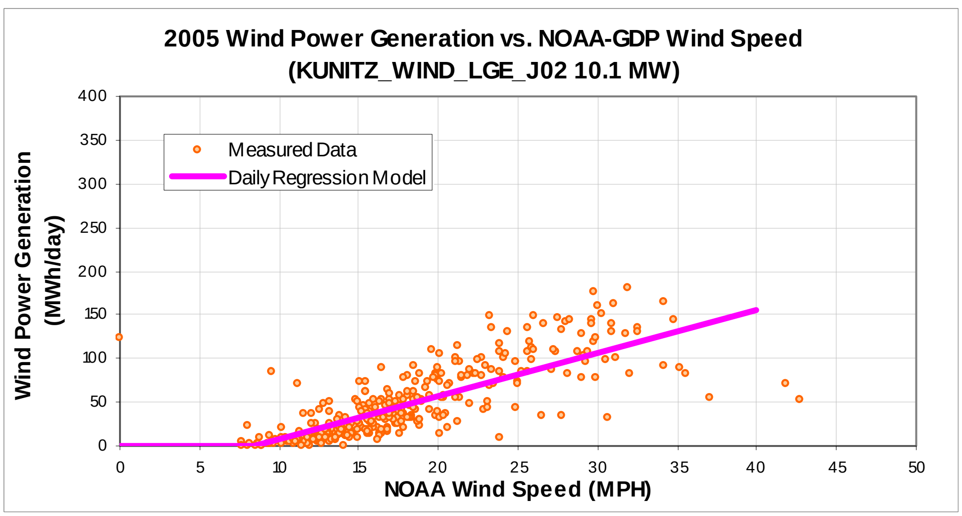


Figure 13-81: KUNITZ_WIND_LGE_J02- Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-63: KUNITZ_WIND_LGE_J02- Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-41.5455
Left Slope (MWh/mph-day)	4.9383
RMSE (MWh/day)	26.0118
R2	0.6041
CV-RMSE	54.8%

Table 13-64: KUNITZ_WIND_LGE_J02– Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh/Mo) NOAA	Predicted Power Generation Using Daily Model (MWh/mo) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	30	19.10	1,714	1,587	7.40%	24%	22%
Feb-05	28	21.55	1,898	1,816	4.28%	28%	27%
Mar-05	30	22.29	2,414	2,055	14.85%	33%	28%
Apr-05	29	19.94	1,926	1,692	12.13%	27%	24%
May-05	28	17.34	1,278	1,234	3.41%	19%	18%
Jun-05	30	15.71	714	1,081	-51.30%	10%	15%
Jul-05	30	15.97	658	1,119	-70.25%	9%	15%
Aug-05	24	12.86	260	531	-103.81%	4%	9%
Sep-05	29	14.50	505	874	-72.86%	7%	12%
Oct-05	31	16.83	1,340	1,290	3.72%	18%	17%
Nov-05	30	19.78	1,854	1,685	9.12%	26%	23%
Dec-05	30	19.51	1,994	1,644	17.58%	27%	23%
Total	349	18.02	16,555	16,608	-0.32%	20%	20%
Total in OSP (07/15-09/15)	56	1.86	923	1,678	-81.88%	7%	12%

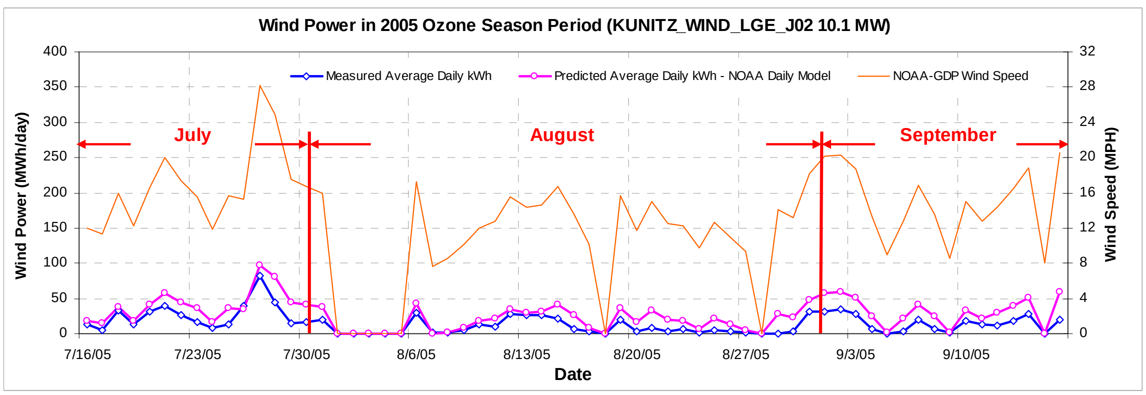


Figure 13-82: KUNITZ_WIND_LGE_J02- Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

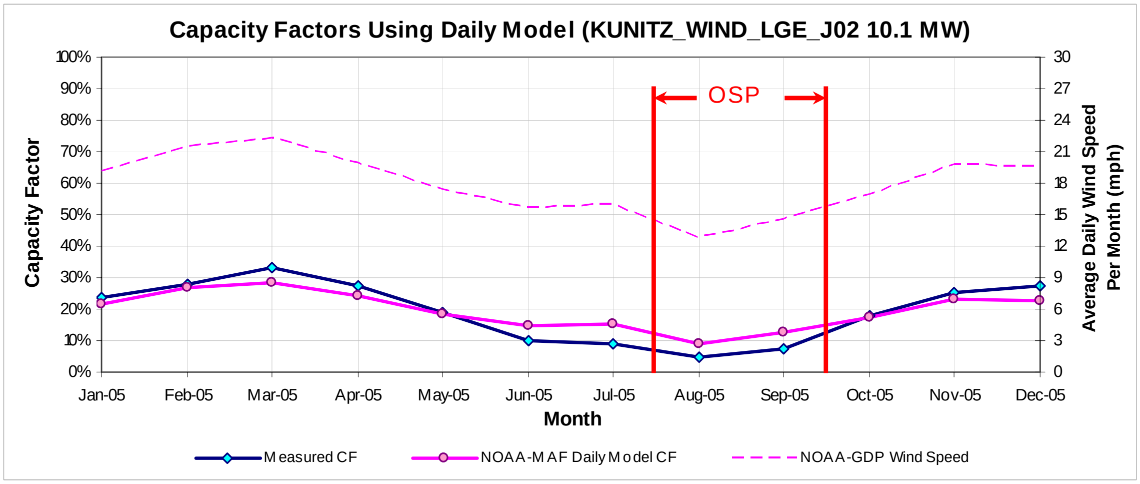


Figure 13-83: KUNITZ_WIND_LGE_J02- Predicted Capacity Factors Using Daily Models (2005).

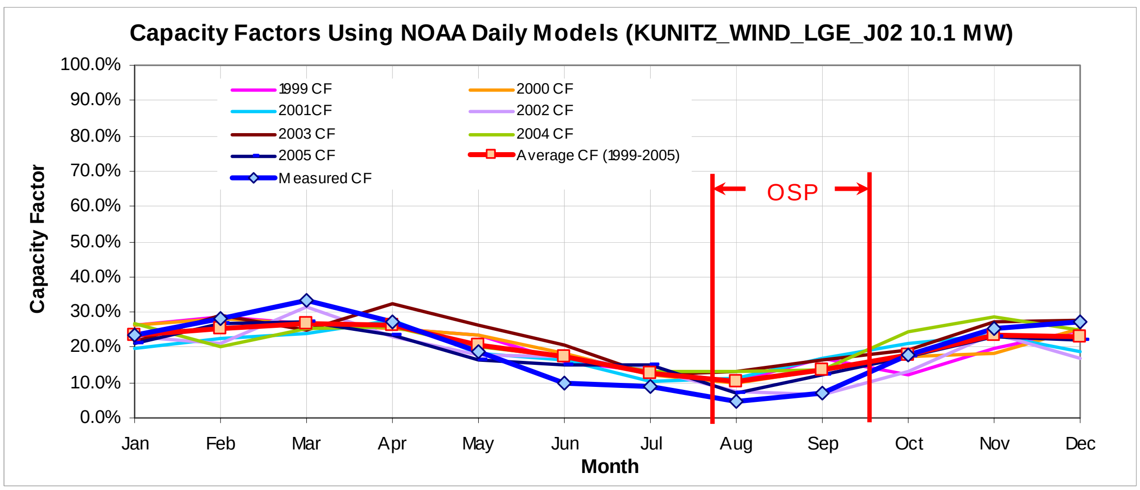


Figure 13-84: KUNITZ_WIND_LGE_J02- Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-65: KUNITZ_WIND_LGE_J02- Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
17,913	17,210
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
27	16

13.14 Big Spring Wind Power

Table 13-66: Site Information for Big Spring Wind Power.

GENSITECODE_ ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
SGMTN	WIND	Big Spring	HOWARD	Feb-99	41	York Research	Big Spring Wind Power	Vestas V-47 (42) Vestas (4)	ERCOT	TXU	TXU	MAF

SUBGENCODE_ ERCOT	GENSITECODE_ ERCOT	Capacity (MW)
SGMTN_SIGNALMT	SGMTN	41

13.14.1 Big Spring Wind Power – SGMTN_SIGNALMT

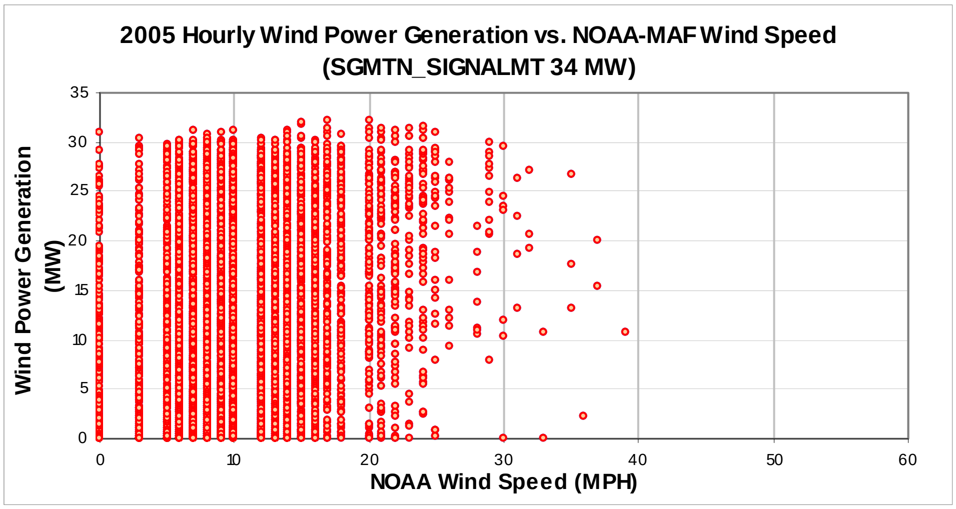


Figure 13-85: SGMTN_SIGNALMT - Hourly Wind Power vs. NOAA Wind Speed (2005).

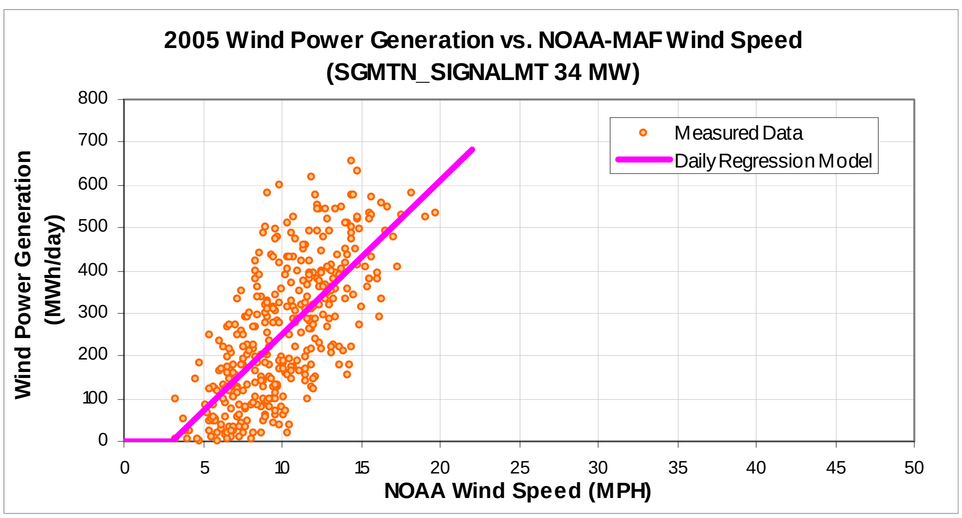


Figure 13-86: SGMTN_SIGNALMT - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-67: SGMTN_SIGNALMT - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-109.0550
Left Slope (MWh/mph-day)	35.9828
RMSE (MWh/day)	116.2169
R2	0.4776
CV-RMSE	45.2%

Table 13-68: SGMTN_SIGNALMT – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	9.71	7,841	7,447	5.03%	31%	29%
Feb-05	28	8.90	4,844	5,913	-22.07%	21%	26%
Mar-05	31	11.14	9,122	9,051	0.78%	36%	36%
Apr-05	30	12.12	9,976	9,814	1.63%	41%	40%
May-05	31	10.75	7,438	8,615	-15.83%	29%	34%
Jun-05	30	12.10	9,447	9,790	-3.63%	39%	40%
Jul-05	31	10.41	5,947	8,231	-38.41%	24%	33%
Aug-05	31	9.18	5,968	6,855	-14.86%	24%	27%
Sep-05	30	9.66	8,014	7,158	10.68%	33%	29%
Oct-05	31	9.28	7,080	6,972	1.53%	28%	28%
Nov-05	30	9.38	9,546	6,856	28.18%	39%	28%
Dec-05	31	9.52	8,719	7,241	16.95%	34%	29%
Total	365	10.18	93,943	93,943	0.00%	32%	32%
Total in OSP (07/15-09/15)	63	9.65	13,680	15,013	-9.74%	27%	29%

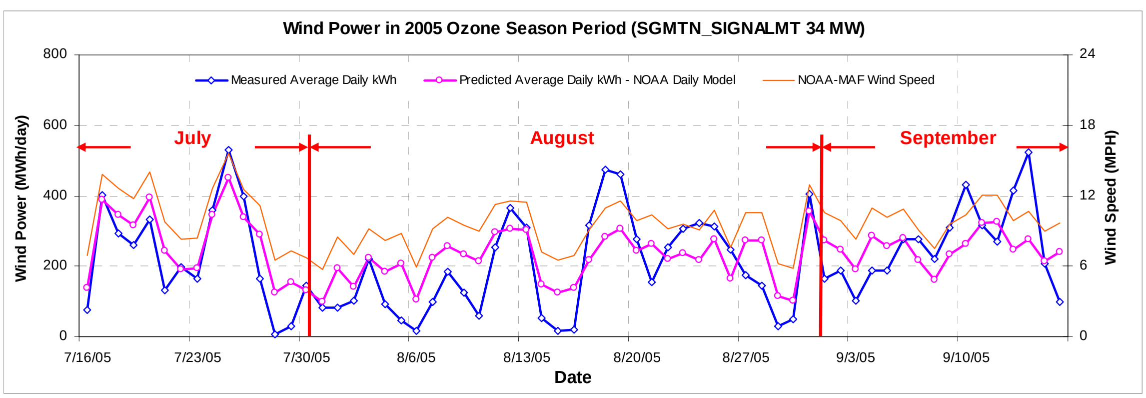


Figure 13-87: SGMTN_SIGNALMT - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

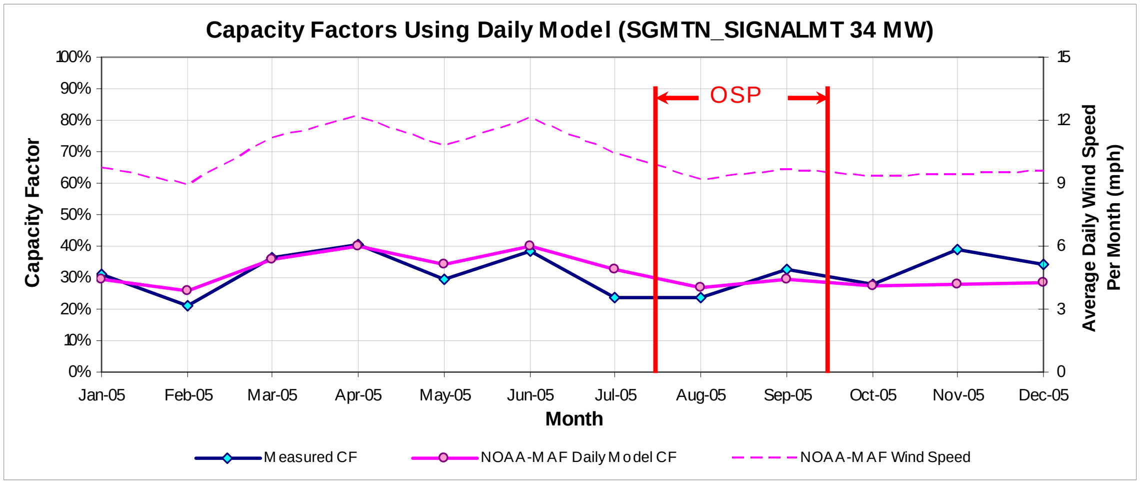


Figure 13-88: SGMTN_SIGNALMT - Predicted Capacity Factors Using Daily Models (2005).

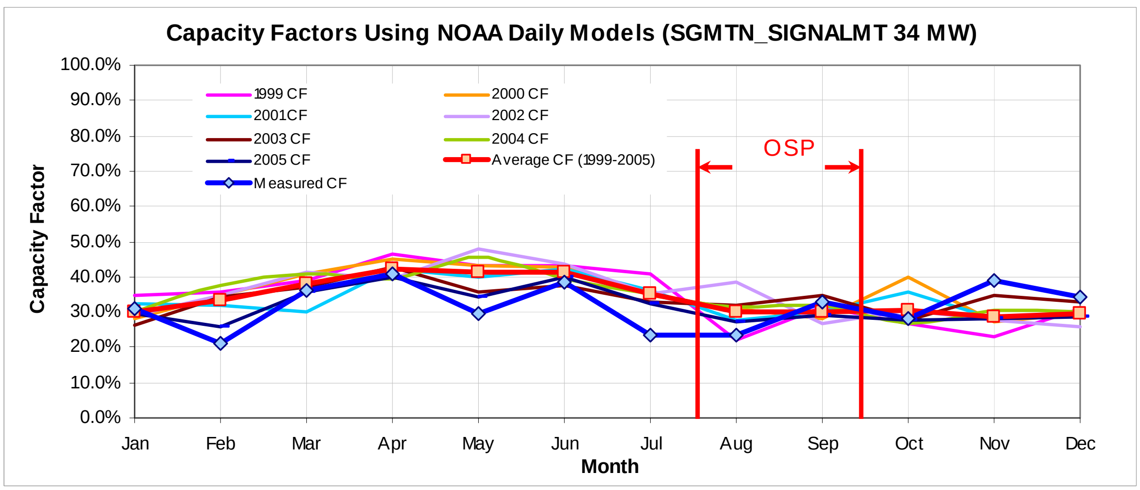


Figure 13-89: SGMTN_SIGNALMT - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-69: SGMTN_SIGNALMT - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
103,431	93,939
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
232	217

13.15 Southwest Mesa Wind Project

Table 13-70: Site Information for Southwest Mesa.

GENSITECODE _ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
SW_MESA	WIND	McCamey	UPTON	Jun-99	75	FPL Energy	Southwest Mesa Wind Project	NEG Micon (107)	ERCOT	AEP-West	WTU	MAF

SUBGENCODE_ERCOT	GENSITECODE_ERCOT	Capacity (MW)
SW_MESA_SW_MESA	SW_MESA	75

13.15.1 Southwest Mesa Wind Project – SW_MESA_SW_MESA

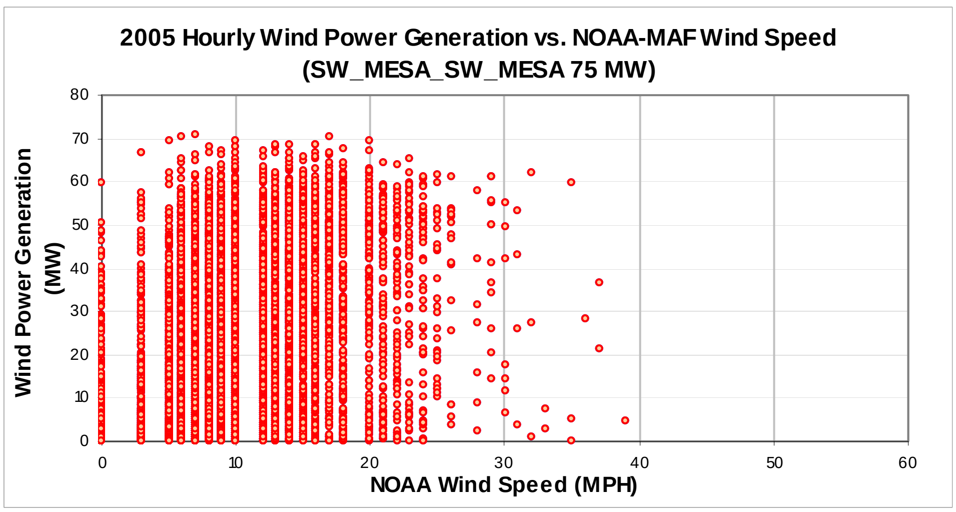


Figure 13-90: SW_MESA_SW_MESA - Hourly Wind Power vs. NOAA Wind Speed (2005).

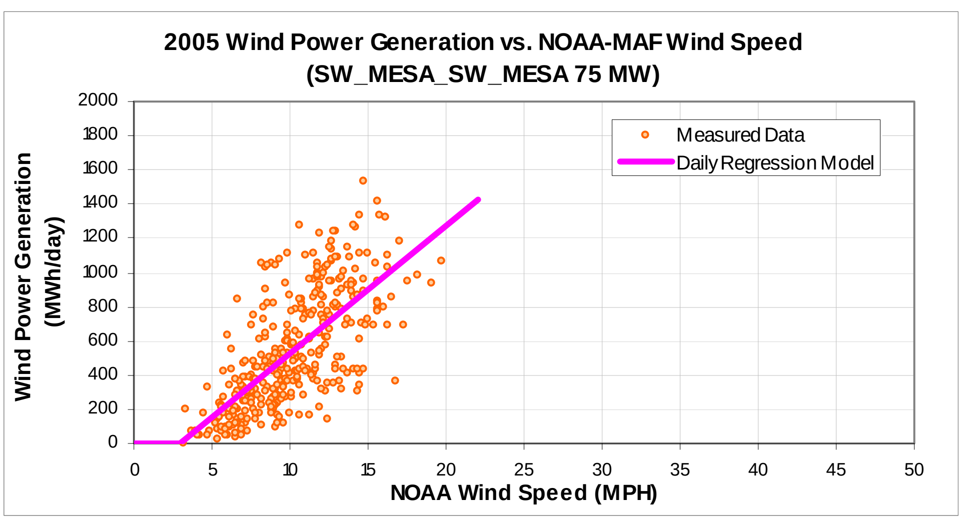


Figure 13-91: SW_MESA_SW_MESA - Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-71: SW_MESA_SW_MESA - Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-220.8549
Left Slope (MWh/mph-day)	74.8714
RMSE (MWh/day)	242.6908
R2	0.4758
CV-RMSE	44.8%

Table 13-72: SW_MESA_SW_MESA – Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	9.71	16,728	15,683	6.25%	30%	28%
Feb-05	28	8.90	10,226	12,472	-21.96%	20%	25%
Mar-05	31	11.14	13,958	19,021	-36.27%	25%	34%
Apr-05	30	12.12	19,536	20,603	-5.46%	36%	38%
May-05	31	10.75	19,728	18,114	8.18%	35%	32%
Jun-05	30	12.10	23,089	20,553	10.98%	43%	38%
Jul-05	31	10.41	18,022	17,315	3.92%	32%	31%
Aug-05	31	9.18	13,860	14,452	-4.27%	25%	26%
Sep-05	30	9.66	15,149	15,076	0.48%	28%	28%
Oct-05	31	9.28	18,657	14,695	21.24%	33%	26%
Nov-05	30	9.38	15,036	14,448	3.91%	28%	27%
Dec-05	31	9.52	13,696	15,255	-11.38%	25%	27%
Total	365	10.18	197,685	197,685	0.00%	30%	30%
Total in OSP (07/15-09/15)	63	9.65	32,892	31,621	3.86%	29%	28%

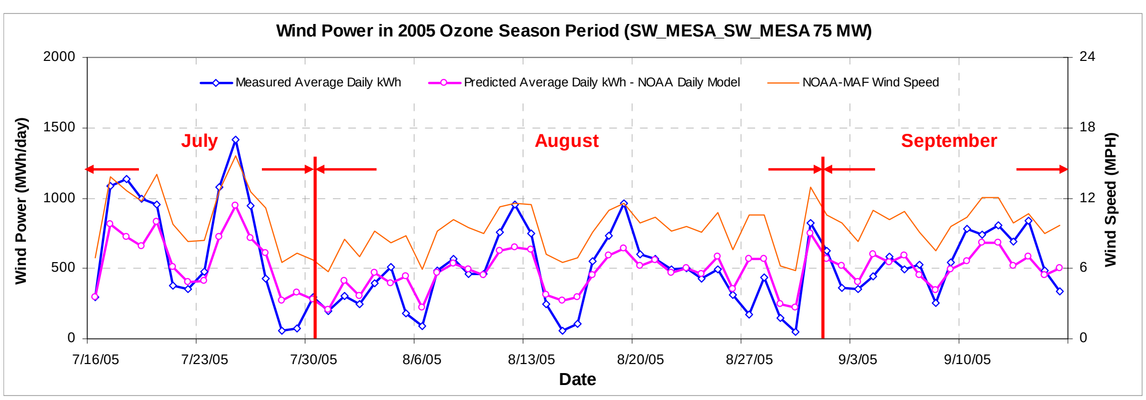


Figure 13-92: SW_MESA_SW_MESA - Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

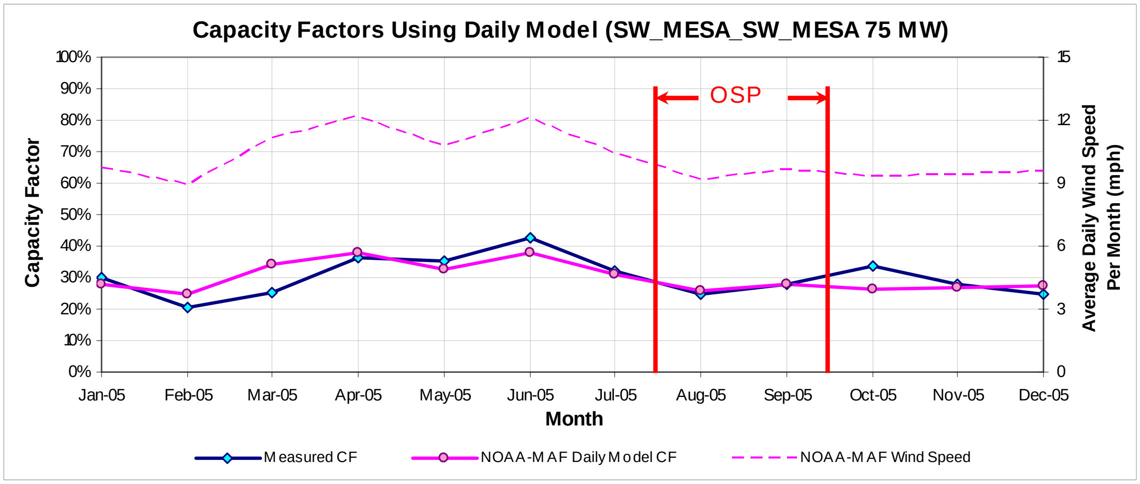


Figure 13-93: SW_MESA_SW_MESA - Predicted Capacity Factors Using Daily Models (2005).

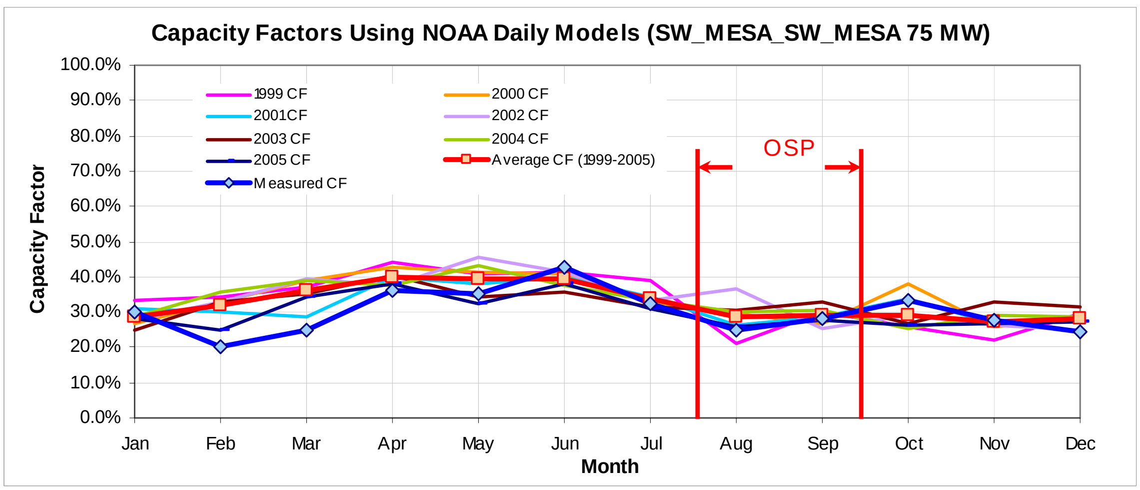


Figure 13-94: SW_MESA_SW_MESA - Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-73: SW_MESA_SW_MESA - Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
217,416	197,694
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
488	522

13.16 Woodward Mountain Ranch (WOODWRD1)

Table 13-74: Site Information for Woodward Mountain Ranch (WOODWRD1).

GENSITECODE_ ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon- nection	Weather Station
WOODWRD1	WIND	McCamey	PECOS	Jul-01	80	FPL/Cielo/TXU	Woodward Mountain Ranch	Vestas V-47 (121)	ERCOT	AEP-West	WTU	FST

SUBGENCODE_ ERCOT	GENSITECODE _ERCOT	Capacity (MW)
WOODWRD1_WOODWRD1	WOODWRD1	80

13.16.1 Woodward Mountain Ranch (WOODWRD1_WOODWRD1)

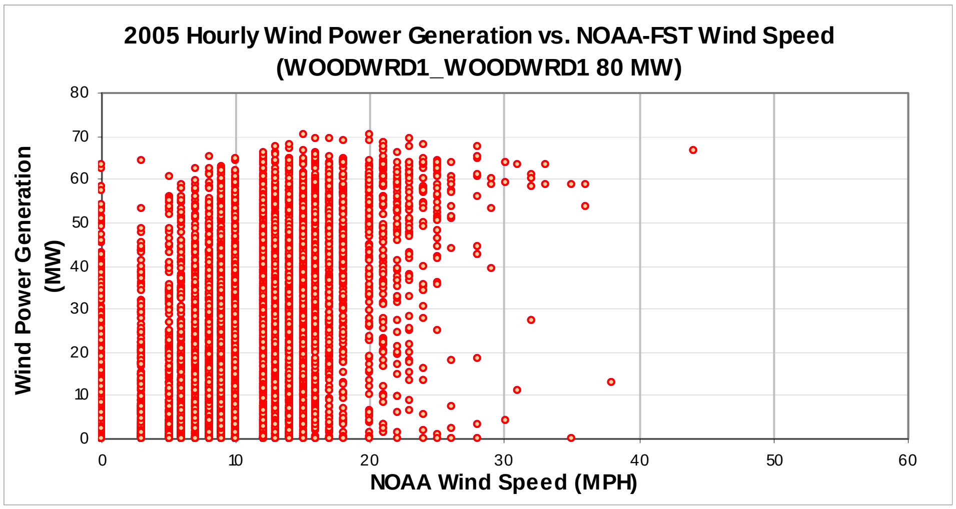


Figure 13-95: WOODWRD1_WOODWRD1- Hourly Wind Power vs. NOAA Wind Speed (2005).

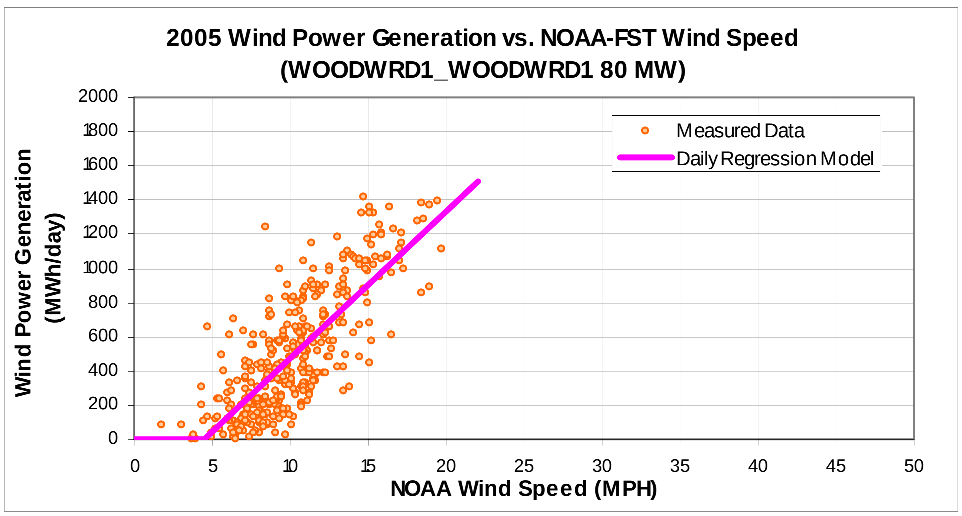


Figure 13-96: WOODWRD1_WOODWRD1- Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-75: WOODWRD1_WOODWRD1- Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-379.2437
Left Slope (MWh/mph-day)	85.7060
RMSE (MWh/day)	219.0336
R2	0.6112
CV-RMSE	43.3%

Table 13-76: WOODWRD1_WOODWRD1– Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	10.20	16,477	15,354	6.81%	28%	26%
Feb-05	28	9.24	9,716	11,587	-19.26%	18%	22%
Mar-05	31	11.08	14,550	17,691	-21.58%	24%	30%
Apr-05	30	12.46	20,318	20,662	-1.70%	35%	36%
May-05	30	11.73	18,638	18,791	-0.82%	32%	33%
Jun-05	30	12.45	23,401	20,625	11.86%	41%	36%
Jul-05	31	10.61	13,510	16,544	-22.46%	23%	28%
Aug-05	31	8.49	11,380	10,802	5.08%	19%	18%
Sep-05	30	9.17	13,528	12,191	9.88%	23%	21%
Oct-05	31	9.68	16,188	13,955	13.79%	27%	23%
Nov-05	30	10.26	13,660	14,995	-9.78%	24%	26%
Dec-05	31	8.62	12,838	11,507	10.37%	22%	19%
Total	364	10.33	184,203	184,704	-0.27%	26%	26%
Total in OSP (07/15-09/15)	63	9.29	25,271	26,380	-4.39%	21%	22%

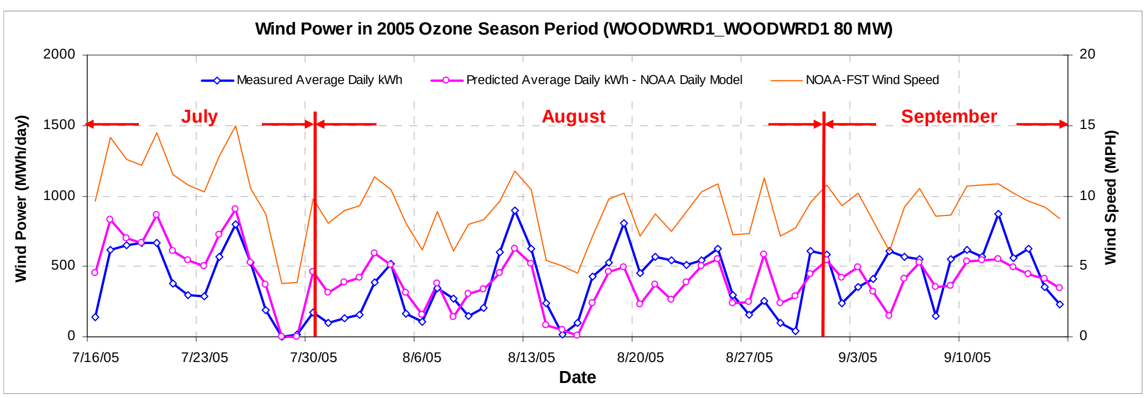


Figure 13-97: WOODWRD1_WOODWRD1- Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

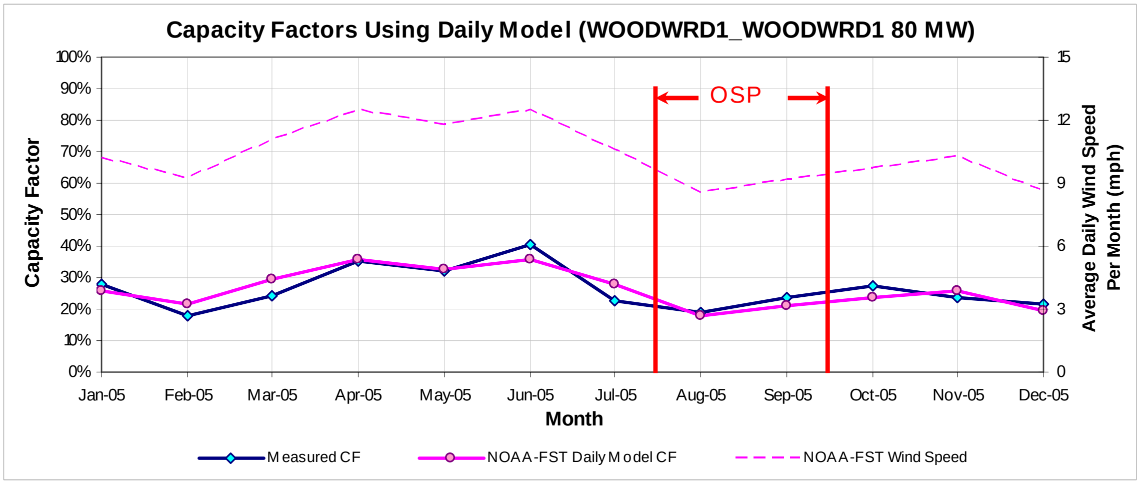


Figure 13-98: WOODWRD1_WOODWRD1- Predicted Capacity Factors Using Daily Models (2005).

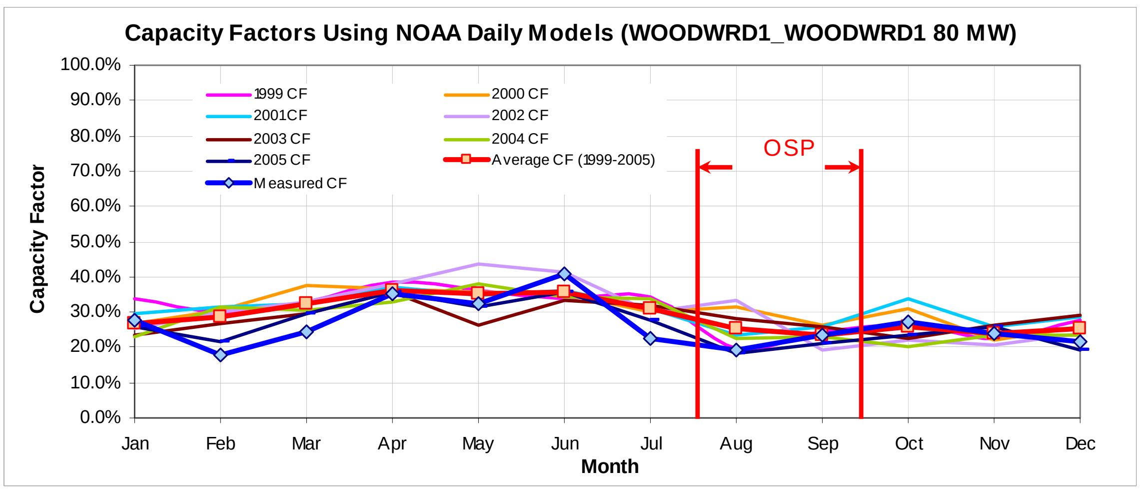


Figure 13-99: WOODWRD1_WOODWRD1- Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-77: WOODWRD1_WOODWRD1- Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
211,627	185,149
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
474	401

13.17 Woodward Mountain Ranch (WOODWRD2)

Table 13-78: Site Information for Woodward Mountain Ranch (WOODWRD2).

GENSITECODE_ERCOT	Renewable Energy	City	County	Date in Service	Capacity (MW)	Company	Facility	Wind Turbine Information	Region	PCA	Intercon-nection	Weather Station
WOODWRD2	WIND	McCamey	PECOS	Jul-01	80	FPL/Cielo/TXU	Woodward Mountain Ranch	Vestas V-47 (121)	ERCOT	AEP-West	WTU	FST

SUBGENCODE_ERCOT	GENSITECODE_ERCOT	Capacity (MW)
WOODWRD2_WOODWRD2	WOODWRD2	80

13.17.1 Woodward Mountain Ranch (WOODWRD2_WOODWRD2)

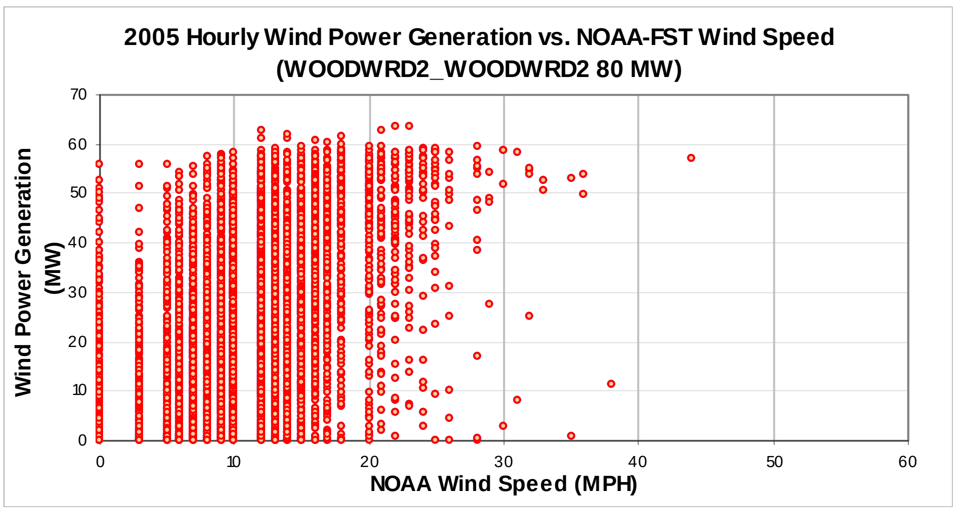


Figure 13-100: WOODWRD2_WOODWRD2- Hourly Wind Power vs. NOAA Wind Speed (2005).

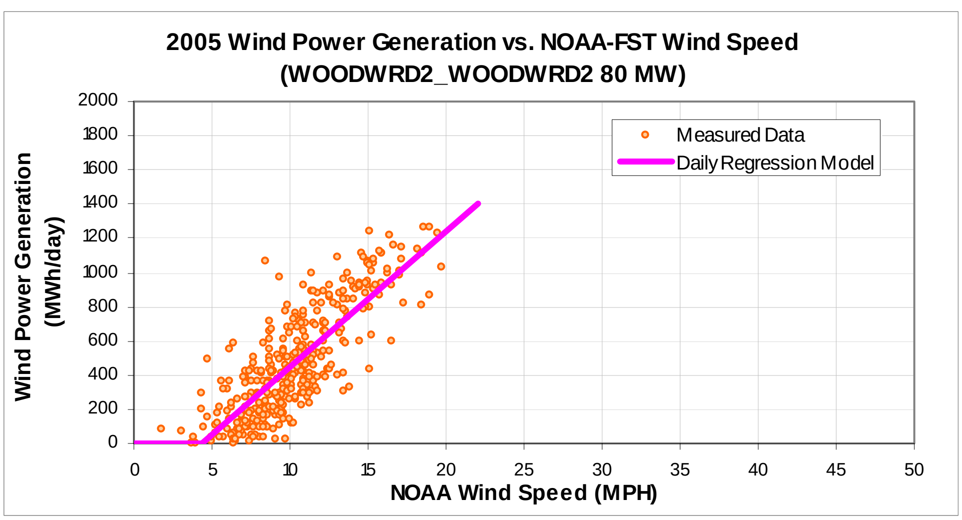


Figure 13-101: WOODWRD2_WOODWRD2- Daily Wind Power vs. NOAA Wind Speed (2005).

Table 13-79: WOODWRD2_WOODWRD2- Model Coefficients.

IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-350.5275
Left Slope (MWh/mph-day)	79.5867
RMSE (MWh/day)	182.5598
R2	0.6612
CV-RMSE	38.7%

Table 13-80: WOODWRD2_WOODWRD2– Comparison of Predicted Power vs. Measured Power.

Month	No. Of Days	Average Daily Wind Speed (MPH) NOAA	Measured Power Generation (MWh) NOAA	Predicted Power Generation Using Daily Model (MWh) NOAA	Diff. NOAA	Measured Capacity Factor	Capacity Factor Using Daily Model NOAA
Jan-05	31	10.20	15,330	14,309	6.66%	26%	24%
Feb-05	28	9.24	9,290	10,804	-16.29%	17%	20%
Mar-05	31	11.08	13,938	16,478	-18.23%	23%	28%
Apr-05	30	12.46	18,896	19,236	-1.80%	33%	33%
May-05	30	11.73	17,029	17,498	-2.76%	30%	30%
Jun-05	30	12.45	21,483	19,202	10.62%	37%	33%
Jul-05	31	10.61	15,764	15,410	2.24%	26%	26%
Aug-05	31	8.49	11,038	10,082	8.66%	19%	17%
Sep-05	30	9.17	12,071	11,370	5.81%	21%	20%
Oct-05	31	9.68	13,766	13,010	5.50%	23%	22%
Nov-05	30	10.26	12,219	13,974	-14.36%	21%	24%
Dec-05	31	8.62	10,824	10,731	0.87%	18%	18%
Total	364	10.33	171,648	172,103	-0.27%	25%	25%
Total in OSP (07/15-09/15)	63	9.29	26,681	24,596	7.81%	22%	20%

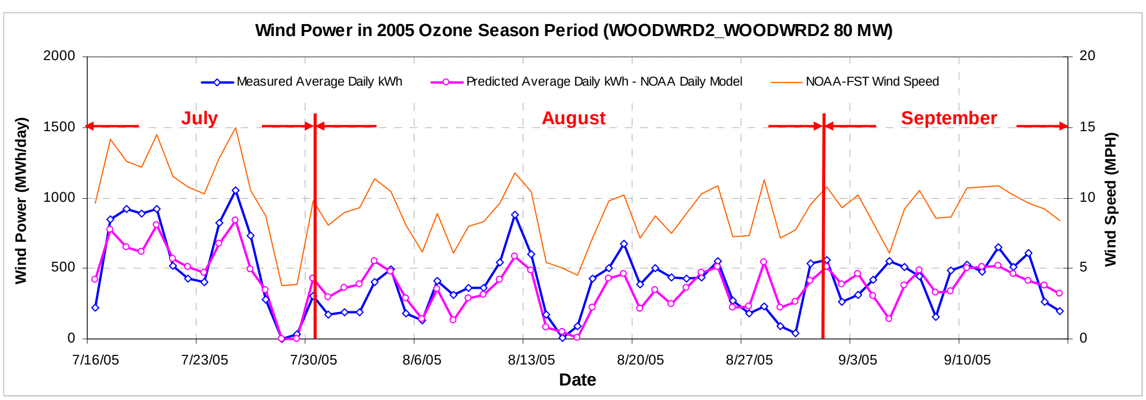


Figure 13-102: WOODWRD2_WOODWRD2- Predicted Wind Power in OSP Using NOAA Wind Speed (2005).

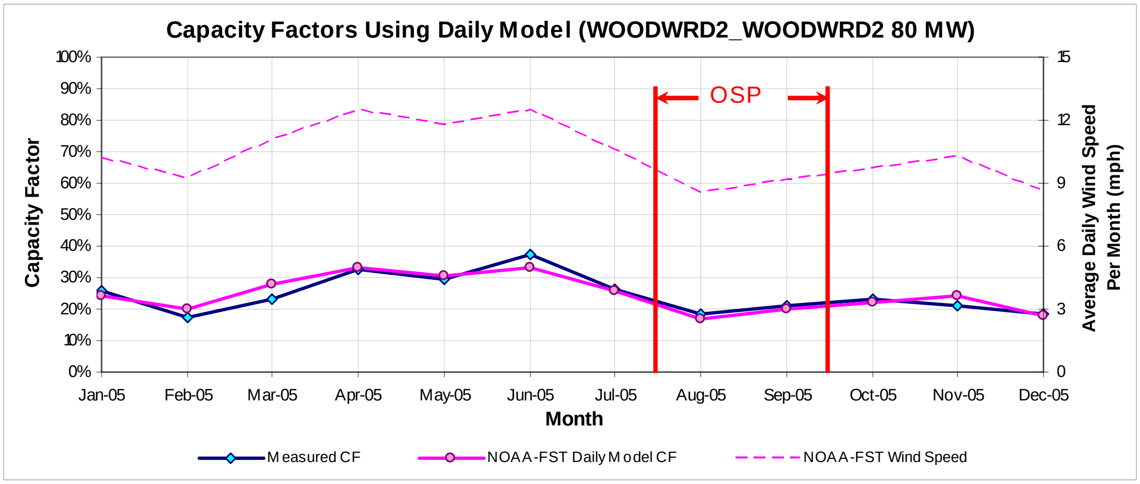


Figure 13-103: WOODWRD2_WOODWRD2- Predicted Capacity Factors Using Daily Models (2005).

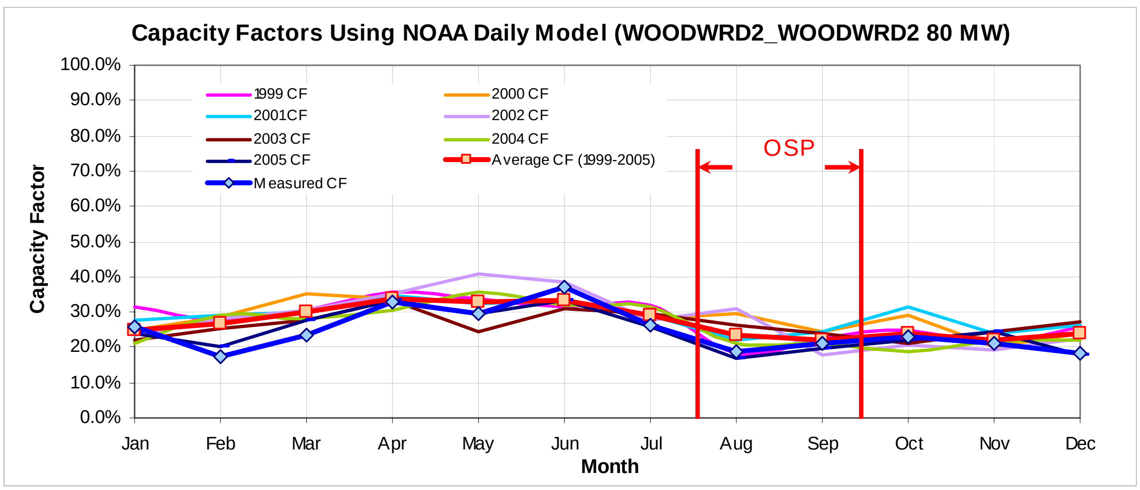


Figure 13-104: WOODWRD2_WOODWRD2- Predicted Capacity Factors Using Daily Models (1999-2005).

Table 13-81: WOODWRD2_WOODWRD2- Predicted Power Production in 1999.

1999 Estimated MWh/yr (2005 Daily Model)	2005 Measured MWh/yr
197,112	172,532
1999 OSP Estimated MWh/day (2005 Daily Model)	2005 OSP Measured MWh/day
442	424

14 APPENDIX B

14.1 Data Files for Wind Energy Production

14.2 Weather Data Files

14.3 Papers presented