Attachment A

Analysis of Transmission Alternatives for Competitive Renewable Energy Zones in Texas

ERCOT
System Planning

December, 2006

ANALYSIS OF TRANSMISSION ALTERNATIVES FOR COMPETITIVE RENEWABLE ENERGY ZONES IN TEXAS

EXECUTIVE SUMMARY

ERCOT has performed an independent evaluation, with input from its stakeholders and the Southwest Power Pool, of the potential for wind generation development in Texas and of the transmission improvements necessary to deliver a portion of this new wind generation capacity to electric customers in ERCOT. This study was conducted to support the Public Utility Commission of Texas (PUCT) in meeting its requirements under the Public Utility Regulatory Act of 2005, Section 39.904 (g), to designate competitive renewable energy zones (CREZs).

Report Findings

- There is significant potential for development of wind resources in Texas.
- There are currently 2,508 Megawatts (MW) of wind generation in-service in ERCOT. At least 4,850 MW of wind resources are likely to be in-service by the end of 2007, and around 17,000 MW of wind generation has requested interconnection analysis. Much of that current wind generation development is in West Texas.
- Studies indicate that the existing transmission network is fully utilized with respect to wind transfers from West Texas to the remainder of ERCOT. Thus, new bulk transmission lines are needed to support significant transfers of additional wind generation from the West Texas area.
- From a transmission planning perspective, there are four general areas of wind capacity expansion: the Gulf Coast; the McCamey area, central-western Texas, and the Texas Panhandle. Transmission solutions for each of these areas are described in this report which provide an incremental plan for each area and form the basis of transmission solutions to support combinations of wind development between two or more areas.
- Some common projects will be needed to mitigate the impact of the new CREZ-related generation on existing wind generation. Even with these projects, existing wind generation facilities will be more susceptible to curtailment due their generally higher shift factors on the remaining system constraints.
- This study does not attempt to capture all of the benefits and costs associated with the designation of CREZs, but focuses primarily on the direct costs and benefits related to the electric power system.
- The production cost savings per kW of new wind generation varies little between the different areas.
- The Coastal area has lower annual capacity factor sites than the other areas but the wind output is somewhat more coincident with the ERCOT electrical load.
- The Panhandle area has more resources with high annual capacity factors.
- The Coastal area requires the least transmission investment per MW of installed new wind capacity.

- The transmission cost per MW is higher for the Panhandle area; the higher annual capacity factor of the resources in this area does not offset this higher cost.
- The first level solution for the Central and McCamey areas use the same bulk transmission addition, so the designation of CREZs and addition of resources in these areas must be generally considered in conjunction.
- While transmission solutions were generally developed that provided 1,000 MW incremental steps for each area, the second step for the McCamey level is larger, in terms of both cost and MW of wind generation supported; although the cost per MW of supported wind is similar to the other levels for McCamey and Central areas.
- ERCOT will be performing an analysis of the impact of significant additional wind generation on the level of the different ancillary services that it procures to maintain system reliability. In addition, further ERCOT analysis of several issues is needed once a specific set of CREZs is designated by the PUCT and wind generation developers have indicated specific locations. These additional analyses include reactive support needs, dynamic stability analyses, optimization of the "on-ramps" within the CREZs and analysis of the specific projects or operational procedures needed to mitigate curtailments of existing wind generation.

Study Overview

To complete this study, ERCOT first solicited input from wind developers and other stakeholders about the areas of the state (by county) in which they were interested in developing wind generation. ERCOT then contracted with a leading wind consultant, AWS Truewind, to identify areas throughout the state with the best wind resource potential, covering at least the general areas identified by wind developers. AWS Truewind used a complex meteorological and terrain model that provided localized prediction of wind patterns and resulting wind power output across the state. The 100 MW sites with the highest annual capacity factors (a measure of the utilization of the installed wind capacity – typically between 30 - 45% for wind generation in Texas) were identified and clustered into 25 areas. AWS Truewind also provided one year of typical hourly wind output for each site. Figure ES-1 shows the location of the 4,000 MW with the highest annual capacity factor within each of the 25 areas.

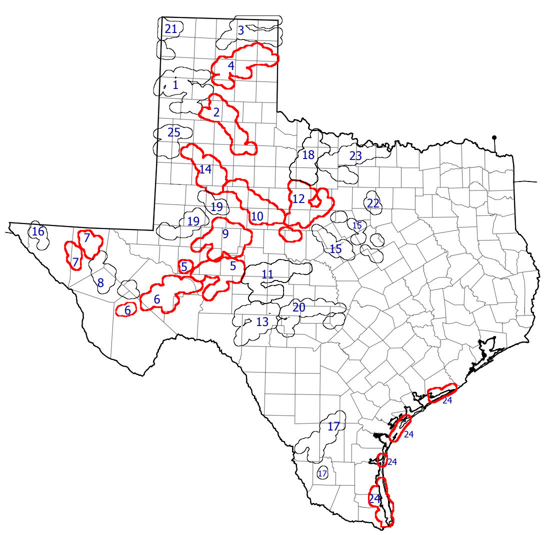

Figure ES -1

The AWS Truewind analysis shows that there is a large amount of wind generation potential in Texas. The wind resources within each area are not uniform; for example, two areas may have the same average annual capacity factors, but one may have a few very high capacity factor sites while the other has a larger number of sites with lower capacity factors. In addition, the time of year and time of day that the wind blows were found to vary significantly across some areas (for example between the areas closer to the Gulf Coast and west Texas). All of these characteristics of the potential wind power output in the different areas were taken into account in the subsequent transmission analysis.

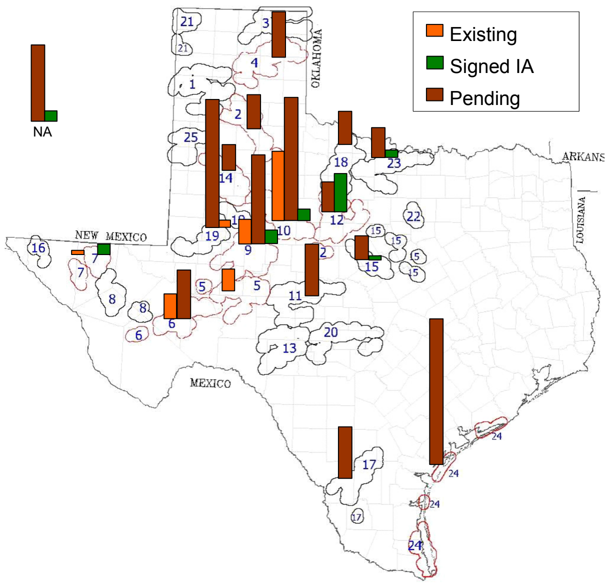

Figure ES -2

There are 2,508 MW of installed wind generation currently in service in ERCOT, and interconnection studies have been requested for almost 17,000 MW of additional wind generation. The estimated distribution of this existing generation and interconnection study requests among the 25 areas is shown in Figure ES-2.

In early 2006, as part of the Five-Year Transmission Plan, ERCOT began a study of possible curtailment of wind generation in 2007 and 2008. Working with stakeholders, ERCOT developed an expected wind scenario, which included 4,850 MW of wind generation. This amount included all in-service wind generation, wind projects with an executed interconnection agreement, and 1,500 MW of wind generation that served as a proxy for the wind generation in the ERCOT interconnection queue expected to be in-service in 2007. Using this scenario, ERCOT analyzed short-lead-time transmission upgrades that could significantly reduce curtailment of wind generation. The result of this analysis of short-lead-time projects, i.e., the final case with 4,850 MW of installed wind generation and all economical short-lead-time projects, became the base case for the analysis of CREZ transmission upgrades.

The transmission analysis portion of this CREZ study was based on the strategy of developing incremental transmission improvements that each fit into an overall design, in order to provide a menu of options from which the PUCT could designate areas and amounts of wind generation as CREZs. Ten of the 24 potential CREZ areas were chosen as representative of all the areas; these ten areas are outlined in red on Figure ES-1. The transmission network upgrades needed to increase export capacity were studied in four discrete groups, based on the similarity of the transmission upgrades required for the different areas in the group. These groups were:

- Coastal (area 24)
- McCamey (areas 5, 6)
- Central Western Texas (areas 7, 9, 10, 12, 14)
- Panhandle (areas 2, 4)

For each group, many transmission solutions were studied (over 60 different solutions were studied for the McCamey area alone). The solution that allowed the connection of the highest amount of high annual capacity factor wind generation into the system with limited curtailment of total wind generation at the lowest capital cost was identified for each grouping individually. This analysis was repeated at several different levels of installed wind capacity and distribution of that capacity among the areas within each group. Finally, the same process was repeated with the new wind generation installed in two or more areas (e.g. Central and McCamey). The previously identified transmission solutions for each grouping were analyzed in different combinations and with different distributions of wind capacity between these areas. The goal was to evaluate how much total wind generation could be supported by that combination if the generation were distributed among the areas in such a way as to maximize the supported wind generation. For example, a solution might accommodate 2,000 MW in Central and 1,000 MW in McCamey or 2,500 MW in Central and 800 MW in McCamey.

A simulation of the hourly security-constrained economic dispatch of all of the generators in ERCOT to serve the total ERCOT system load for a year was performed for each scenario and compared to a similar simulation without any new CREZ wind generation and associated transmission. In these simulations, the wind generation was modeled using the hourly outputs developed by AWS Truewind. Since the marginal cost of the wind generators are near zero, the output of each wind site in a particular hour would be equal to the hourly output provided by AWS Truewind, so long as it is not curtailed due to transmission limitations. An equivalent amount of output from the thermal generation having the highest marginal costs on the system would be displaced, also respecting the reliability limits of the transmission system. The cost savings associated with this displaced thermal generation were calculated, as well as the change in total generator revenues (based on marginal costs), for each scenario.

Figure ES-3 provides a summary of the preferred solutions for each area, as well as several combinations. While the analysis performed for this study provides the PUCT with the data necessary to judge the relative costs and benefits of potential CREZ designations, ERCOT will need to perform several additional analyses once the PUCT has designated a specific set of CREZs; it was not feasible to perform these analyses on every option within the allotted timeframe. Specific terminations of the transmission lines will need to be evaluated based on feedback from Transmission Owners on the feasibility of connections to specific substations, particularly in the Hill Country and Fort Worth areas. Once wind developers have indicated specific geographic locations at which they will site new wind generation, an additional analysis of the appropriate "on-ramps" (lines and substations to most efficiently connect the wind

Figure ES -3

Scenario	New Wind Capacity (MW)	Transmission Capital Cost ($M)	Annual System Production Cost Savings ($M/Yr)	Annual System Generator Revenue Reductions ($M/Yr)	New Wind Average Capacity Factor (%)	New Wind Generator Capital Cost ($M)	Average New Wind Generator Revenue ($/MWh)	Annual System Production Cost Savings per kW New Wind ($/kW-Yr)	Annual System Generator Revenue Reductions per kW New Wind ($/kW-Yr)	Transmission Capital Cost per kW New Wind ($/kW)	Ratio of All Investment Costs to Production Cost Savings
Coastal Projects	A	B	C	D		E		C/A	D/A	B/A	(E+B)/C
- Coastal Level 1	1,000	15	129	221	38.3	1,000	43.1	129	221	15	7.90
- Coastal Level 2	2,000	75	262	437	37.1	2,000	40.7	131	218	38	7.93
- Coastal Level 3	3,000	320	383	713	37.0	3,000	33.3	128	238	107	8.68
Central Western Texas Projects											
- Level 1	2,000	376	276	464	40.1	2,000	29.9	138	232	188	8.62
- Level 2	3,000	723	406	727	39.0	3,000	29.6	135	242	241	9.18
- Level 3	3,800	1,019	495	963	39.3	3,800	28.9	130	253	268	9.74
McCamey Projects											
- Level 1	1,500	320	198	406	40.5	1,500	32.3	132	271	213	9.21
- Level 2	3,800	861	506	1,069	41.0	3,800	30.2	133	281	227	9.22
Panhandle Projects											
- Level 1	800	265	112	247	43.2	800	33.2	139	309	331	9.55
- Level 2	1,800	645	249	474	43.3	1,800	32.8	138	263	358	9.84
- Level 3	2,400	715	297	620	42.8	2,400	26.2	124	258	298	10.50
- Level 4	4,600	1,515	587	1,250	42.5	4,600	27.1	128	272	329	10.42
Combination Projects											
- Central Level 2 with New Wind in Central (2,000 MW) and McCamey (1,250 MW)	3,250	863	443	796	39.8	3,250	30.0	136	245	266	9.29
- Central Level 3 with New Wind in Central (3,000 MW) and McCamey (1,000 MW)	4,000	1,159	520	992	39.0	4,000	29.1	130	248	290	9.92
- Central Level 2 and Coastal Level 2 with New Wind in Central (2,000 MW), McCamey (1,250 MW) and Coastal (2,000 MW)	5,250	938	705	1,278	38.8	5,250	31.9	134	243	179	8.78

New Wind Capacity for each scenario is the level of new installed wind generation that results in ~2% overall wind energy curtailment

Transmission Capital Cost for each scenario does not include the cost of projects that may be needed to mitigate the impact of the added CREZ generation on existing resources (as described in Section IV (I) of the report).

generation into the CREZ-related bulk transmission system) must be performed. An analysis of the reactive support devices necessary to maintain system voltages within appropriate levels will be needed. A study of the dynamic response of the system to critical contingencies will need to be performed to determine if the level of wind generation allowed in selected CREZs should be reduced due to dynamic reliability criteria. Finally, since the overall wind curtailment allowed under each CREZ transmission solution may inordinately affect the existing wind generation that is connected to the existing lower voltage transmission system, additional analysis of the projects needed to mitigate these effects will be needed. Some upgrades of this type were included in the present study, but the actual system upgrades which are ultimately needed will depend on the location and amount of wind generation development that occurs.

ERCOT is also currently initiating a study, to be completed in 2007, of the potential need for additional ancillary services to maintain system reliability with increased levels of wind generation.

Detailed descriptions of input assumptions, analysis methodology, and study results are provided in the complete report.

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I. INTRODUCTION

This study was conducted to support the Public Utility Commission of Texas (PUCT) in its evaluation of potential areas to be designated as Competitive Renewable Energy Zones, as mandated by recent legislation. Senate Bill 20 required the PUCT to provide an initial report on activities associated with the designation of Competitive Renewable Energy Zones (CREZ) throughout the State of Texas by December 31, 2006. In its role as coordinator of transmission planning and analysis for the ERCOT region, ERCOT System Planning has completed this detailed study of possible transmission improvements to provide the PUCT with estimates of the transmission capital costs and forecasted system benefits associated with the designation of different areas in the State as CREZs.

The goal of this study was to evaluate the potential for wind generation development in Texas and the transmission improvements necessary to deliver a portion of this new wind generation capacity to electric customers in ERCOT. In order to perform the required analysis, the first step was to identify which areas of the State contained the best wind resources. Following completion of an analysis of wind potential throughout the State by AWS Truewind, ERCOT System Planning personnel, working with representatives of Transmission Service Providers (TSPs) and other stakeholders, identified specific transmission upgrades that would allow varying levels of new wind generation to be installed in these areas of significant wind potential.

Throughout this study, ERCOT stakeholders have been apprised of the interim results through presentations at the ERCOT Regional Planning Group meetings, through posting to the ERCOT Regional Planning Group mailing list, and through posting of data on the ERCOT Operations and System Planning web-site. Stakeholders have been given opportunities to submit comments, suggestions, and questions throughout this study.

The results of this study indicate that there is a significant amount of wind generation potential in the State of Texas. Transmission concepts have been identified to allow a portion of this wind to be incrementally added to the ERCOT transmission system. As a specific set of CREZ is selected by the PUCT, ERCOT System Planning will continue its planning coordination role to finalize the specific transmission improvements and to perform the additional analyses necessary to implement the selected CREZs in a reliable and efficient manner.

II. BACKGROUND

A. Legislative Requirements

In July, 2005, the Texas State Legislature passed Senate Bill 20, "An Act relating to this state's goal for renewable energy." This act increased the required installed renewable nameplate capacity to 5,880 MW by January 1, 2015. It also placed the following requirements on the Public Utility Commission of Texas (PUCT):

Section 3 (g):

The commission, after consultation with each appropriate independent organization, electric reliability council, or regional transmission organization:

(1) shall designate competitive renewable energy zones throughout this state in areas in which renewable energy resources and suitable land areas are sufficient to develop generating capacity from renewable energy technologies where sufficient;

(2) shall develop a plan to construct transmission capacity necessary to deliver to electric customers, in a manner that is most beneficial and cost-effective to the customers, the electric output from renewable energy technologies in the competitive renewable energy zones;

And later in Section 3 (j):

The commission, after consultation with each appropriate independent organization, electric reliability council, or regional transmission organization, shall file a report with the legislature not later than December 31 of each even-numbered year. The report must include:

(1) an evaluation of the commissions implementation of competitive renewable energy zones;

(2) the estimated cost of transmission service improvements needed for each competitive renewable energy zone; and

(3) an evaluation of the effects that additional renewable generation has on system reliability and on the cost of alternatives to mitigate the effects.

To comply with the requirements of this legislation, the PUCT has issued a Proposal for Publication of New §25.174 (Staff Recommendation). Based on this proposal, Section (a)(2) of §25.174 would be modified to read as follows:

(a) (2) By December 1, 2006, the Electric Reliability Council of Texas (ERCOT) shall provide to the commission a study of the wind energy production potential statewide, and of the transmission constraints that are most likely to limit the deliverability of electricity from wind energy resources. ERCOT shall consult with other regional transmission organizations, independent organizations, independent system operators, or utilities in its analysis of regions of Texas outside the ERCOT power region. At a minimum, the study submitted by ERCOT shall include:

(A) a map and geographic descriptions of regions that can reasonably accommodate at least 1,000 megawatts (MW) of new wind-powered generation resources;

(B) an estimate of the maximum generating capacity (in MW) that each zone can reasonably accommodate and an estimate of the zone's annual production potential;

(C) a description of the improvements necessary to provide transmission service to the region, a preliminary estimate of the cost, and identification of the transmission service provider (TSP) or TSPs whose existing transmission facilities would be directly affected;

(D) an analysis of any potential combinations of zones that, in ERCOT's estimation, would result in significantly greater efficiency if developed together; and

(E) the amount of generating capacity already in service in the zone, the amount not in service but for which interconnection agreements have been executed, and the amount under study for interconnection.

This report, along with the analysis described, has been completed in order to comply with these requirements.

B. Stakeholder Involvement

ERCOT, as the Independent Organization for the ERCOT region, conducts planning studies in a manner that is unbiased and seeks to achieve a balance among the various stakeholder interests. The ERCOT Planning Charter states, in part, that ERCOT will accomplish its mission through "An open and collaborative process involving electric industry members, customers and regulators." Following these guidelines, ERCOT System Planning has completed this study in consultation with Transmission Service Providers (TSPs), wind developers, and representatives of all interested stakeholder organizations through the Regional Planning process. Project status updates have been provided at regularly scheduled ERCOT Regional Planning Group meetings throughout the 2006 calendar year. Stakeholder comments have been solicited, and all comments that have been received have been carefully reviewed. Presentations from these meetings, along with other project documentation and data, have been posted on the Operations and System Planning Data page at the ERCOT web-site.

In addition, ERCOT System Planning personnel have participated in numerous one-on-one meetings, telephone calls, and email correspondence with representatives of various stakeholder organizations throughout the course of this study.

Most notably, a significant effort was made at the beginning of the study to compile the level of wind generation development interest in different regions of the state from all stakeholders, and from representatives of wind development companies in particular. Prior to this project, ERCOT System Planning had only generation interconnection requests to inform its analysis and these requests may be significantly influenced by the perceived availability of existing transmission capacity. ERCOT did not have data regarding where the significant wind resources were located in Texas, how much difference existed between the best wind resources in the State and areas with lesser resources, or the possible impediments to actual development of these wind resources. The input from stakeholders was used to determine which areas should initially be included for evaluation in the study.

C. Coordination with the Southwest Power Pool

ERCOT System Planning has coordinated the work conducted as part of this study with representatives of the Southwest Power Pool (SPP). As the Regional Transmission Organization for portions of Texas in the Panhandle and in eastern Texas (as well as areas outside of Texas), SPP is responsible for transmission planning in those areas. Through numerous telephone conferences, meetings, and participation of SPP representatives at ERCOT Regional Planning Group meetings, transmission plans for the two regions were shared as they evolved, and possible efficiencies and synergies for delivery of wind generation to loads in ERCOT were explored. The results of this effort are described later in this document.

III. ASSESSMENT OF POTENTIAL WIND GENERATION

A. Solicitation of Stakeholder Interest

The overall goal of this study is to assess the wind resource potential throughout the state of Texas, and then to analyze the need and certain costs and benefits of transmission to integrate wind resources from different areas into the existing transmission infrastructure. However, even before an analysis of wind potential could be conducted, it was important that the interest of wind developers be assessed for different parts of the state, in order to ensure both that areas with significant developer interest were considered in the study, and that areas with little or no interest on the part of wind developers were assessed in that light. As there are numerous factors that are significant to wind developers that are not within the scope of this study, factors such as opposition by local landowners, difficulty of construction due to local topography, and impacts of wind turbines on local avian or bat populations, the appropriate first step in assessing wind potential was to solicit from wind development companies the areas in which they had specific interests.

During February, 2006, ERCOT System Planning solicited information from all stakeholders regarding areas in which there was market interest in developing wind resources. Information was received from stakeholders through emails and through meetings between representatives of wind development companies and ERCOT staff. The information received is depicted in the map provided as Figure 1. This information was used to ensure that the areas of the State with market interest were adequately considered in this study.

B. Meteorological Modeling of Wind Resources

In order to obtain a qualified, independent analysis of wind resources throughout the State of Texas, ERCOT System Planning solicited proposals from outside consultants who specialized in meteorological modeling and wind generation analysis. ERCOT reviewed the proposals that were received and selected AWS Truewind of Albany, New York, to provide the requested services.

ERCOT stakeholders were notified of the selection of AWS Truewind by an announcement sent to the Regional Planning Group electronic mailing list on May 4, 2006. ERCOT System Planning also requested that stakeholders contact AWS Truewind directly if they were willing to share, on a confidential basis, any of their proprietary wind speed data to help benchmark the modeling results.

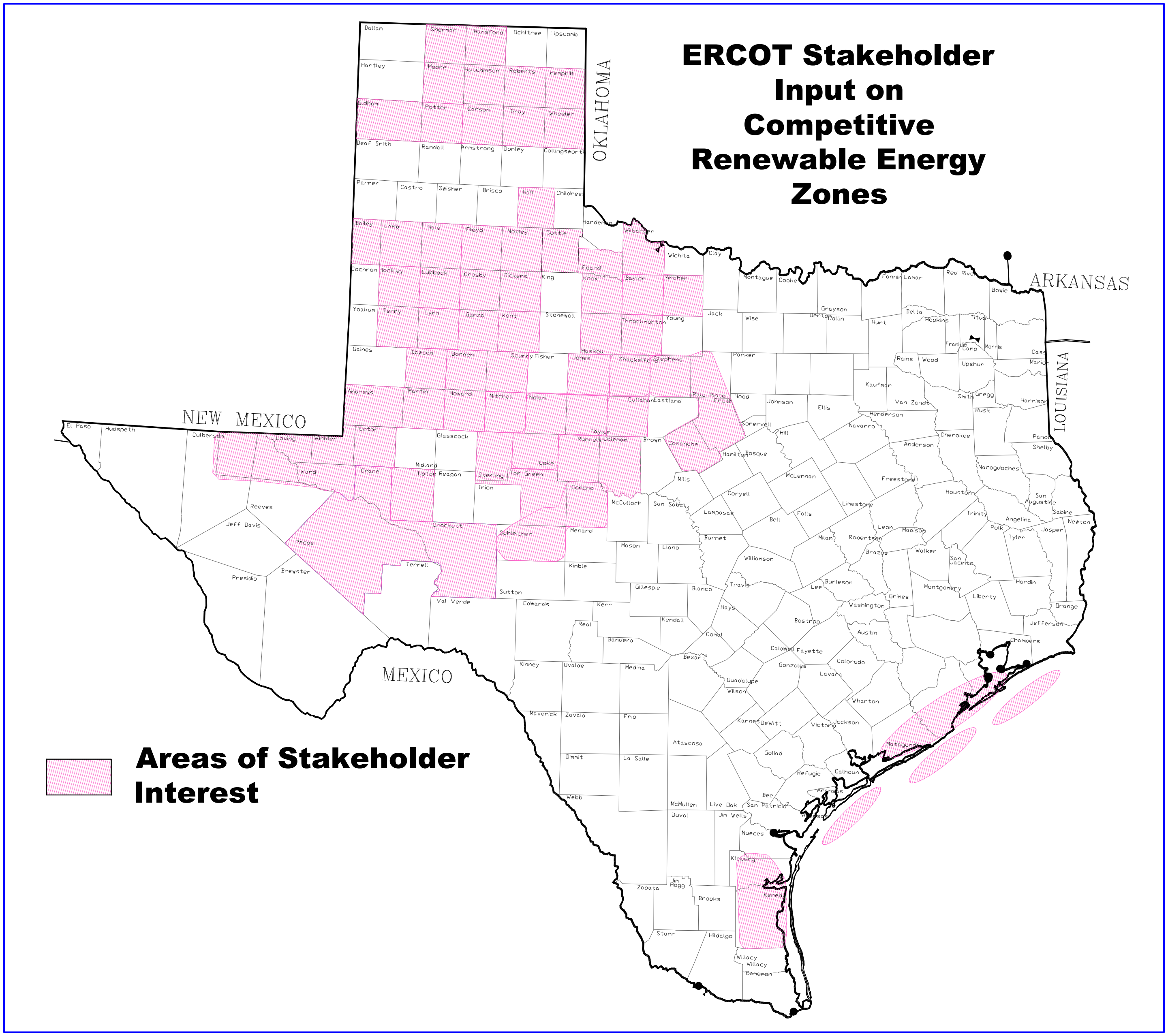


Figure 1: Areas of Interest as Expressed by ERCOT Stakeholders

1. Methodology

AWS Truewind conducted its analysis of wind generation potential using a proprietary model called Mesomap. This model is an integrated set of atmospheric models, computer systems, and meteorological and geophysical databases. The two main models are a mesoscale numerical weather prediction model (MASS) and a mass-conserving microscale wind flow model (WindMap). The main source of meteorological data is the reanalysis database produced by the National Centers for Environmental Prediction (NCEP); reanalysis data provide a snapshot of global weather conditions (including temperature, pressure, wind, atmospheric moisture, and other parameters) every 6 hours at multiple levels above the earth's surface. In its normal mode of operation, MesoMap simulates wind conditions in a region for a sample of 366 days from 1989 to 2004 at a resolution of 200 m. Aside from wind speed maps, MesoMap generates hourly wind speed, direction, temperature, and other weather parameters, which can be used to calculate turbine output for specific turbine models. The system runs on a distributed computer network consisting of about 130 processors.

As part of this study, AWS Truewind benchmarked its modeling results against wind data from existing tall towers in the state of Texas. Some of these data are publicly available, and some were provided on a confidential basis by ERCOT stakeholders. In addition, land use patterns were analyzed to determine the amount of land available for wind development. Land-use data included roads, administrative boundaries, designated federal and state forests and parks, military reserves, water bodies, populated areas, and topography. All of these data except elevations, residential, and water bodies were provided by ESRI, Inc. Elevation data were obtained from the 30-meter National Elevation Dataset, and water bodies and populated areas are from the 30-meter National Land Cover Database (NLCD 2001).

The initial step in the wind generation resource modeling process was to produce a map of potential wind project sites and a summary of their basic characteristics (e.g., location, rated capacity, mean speed, net capacity factor, distance to nearest road and transmission line, and cost of energy). The wind speed map and speed and temperature distributions generated by MesoMap were combined to create a map of expected gross capacity factors for a generic large wind turbine (1.5-2.5 MW class). Typical losses were applied to convert from gross to net unit output. Exclusion zones, including national and state parks and forests, other wilderness or protected areas, military reservations, areas within one mile of an inhabited area, water bodies, and terrain with a slope greater than 20% were then identified and mapped.

Using this geographical information system data, specific sites that had sufficient available land to support 100 MW of installed wind generation and a capacity factor above a specified minimum value were selected. Capacity factor is a measure of the level of utilization of the wind generators on the site. The term capacity factor means the amount of energy produced by a generator over the period of a year, as a percentage of the product of the generator's nameplate capacity multiplied by the number of hours in a year (8,760). In other words, the capacity factor is the percentage of energy actually produced by a unit compared to the amount it would have produced if it ran at its nameplate rating over an entire year. The minimum capacity factor was adjusted until a sufficient number of potential sites in diverse parts of Texas, covering at least the logical portion of each of the areas for which wind development interest had been identified by ERCOT stakeholders, were located.

Once these sites were located, they were grouped into 25 zones based on similarity of wind resource (as characterized by mean speed and seasonal/diurnal patterns). A map depicting the location of these initial 25 zones is provided as Figure 2. The numbering of these zones run generally from left to right, as they had not been ranked in any way at this stage.

For each zone, a generation supply curve was developed, based on the amount of developable land in each zone, the existing wind resources, and the output power curve of a generic large wind turbine (1.5 - 2.5 MW class). These generation supply curves are provided in Appendix A.

These initial results were presented at the Regional Planning Group meeting on June 2, 2006. The generation supply curves in Appendix A were made available on the ERCOT Operations and System Planning Data web-site at that time.

Using the results of the MesoMap model, AWS Truewind selected the 40 best 100-MW wind sites in each zone, based on annual average wind-speed, for a total of 4,000 MW in each zone. For each of the sites, an hourly pattern of wind speeds and air density representative of an average weather year was developed, using weather data derived from 15 years of actual meteorological data. An appropriate class of wind turbine was assigned to each of these sites based on maximum wind speeds, and then hourly generation patterns were calculated using generic power curves representing a mix of commercially available wind turbines. The results were hourly generation patterns for each of these modeled sites that could used to represent likely hourly wind output from existing and future wind generation projects.

The boundaries of the areas enclosing the best 4,000 MW of generation from each of the zones are depicted on the map provided as Figure 3. The zones in this map have been ordered generally by the quality and quantity of wind generation, with zone 1 having the strongest overall wind resources and zone 25 the weakest. A similar map depicting areas that enclose the best ten 100-MW wind generation sites from the 25 zones is provided in Figure 4.

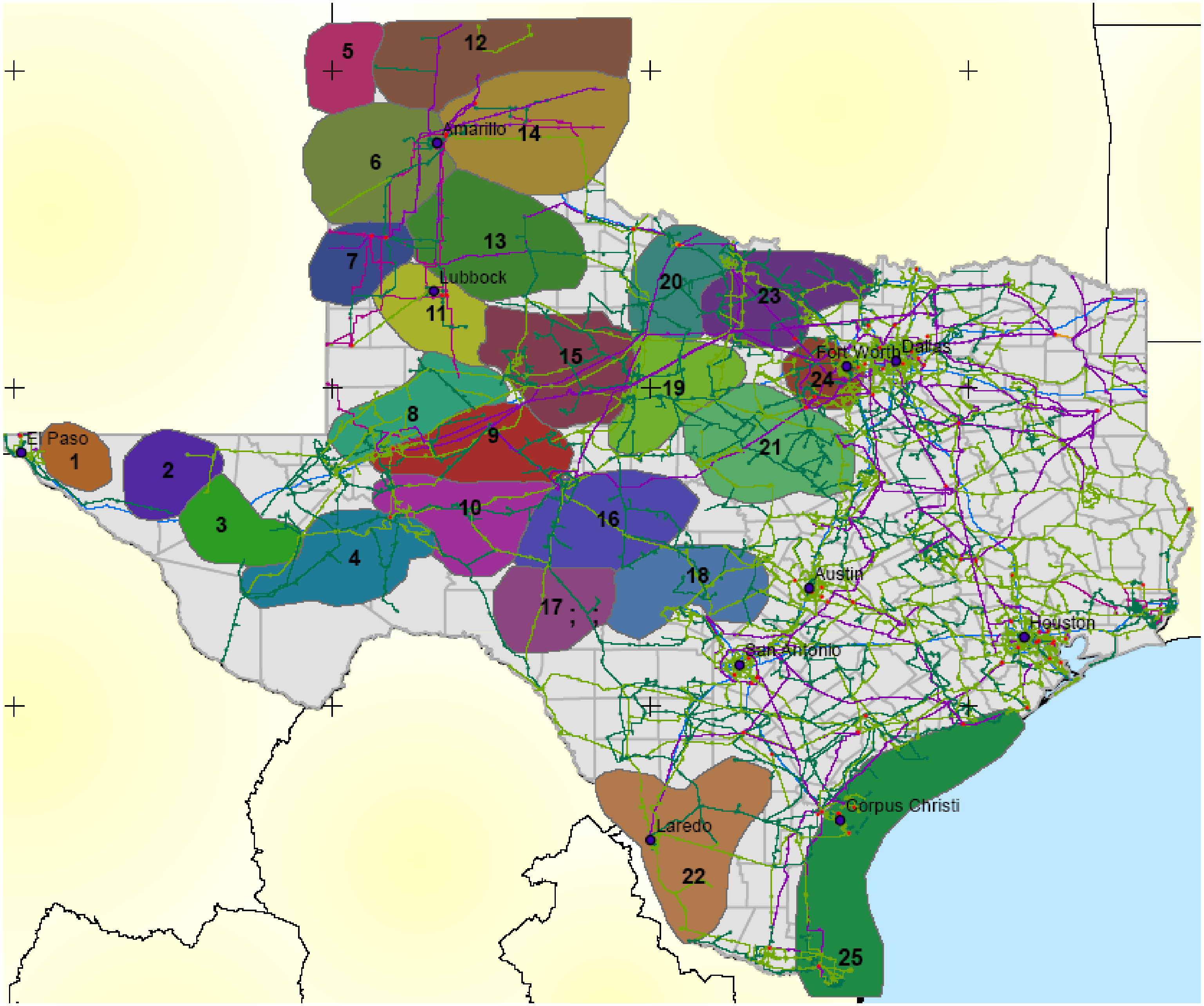


Figure 2: Map of Wind Resources Zones

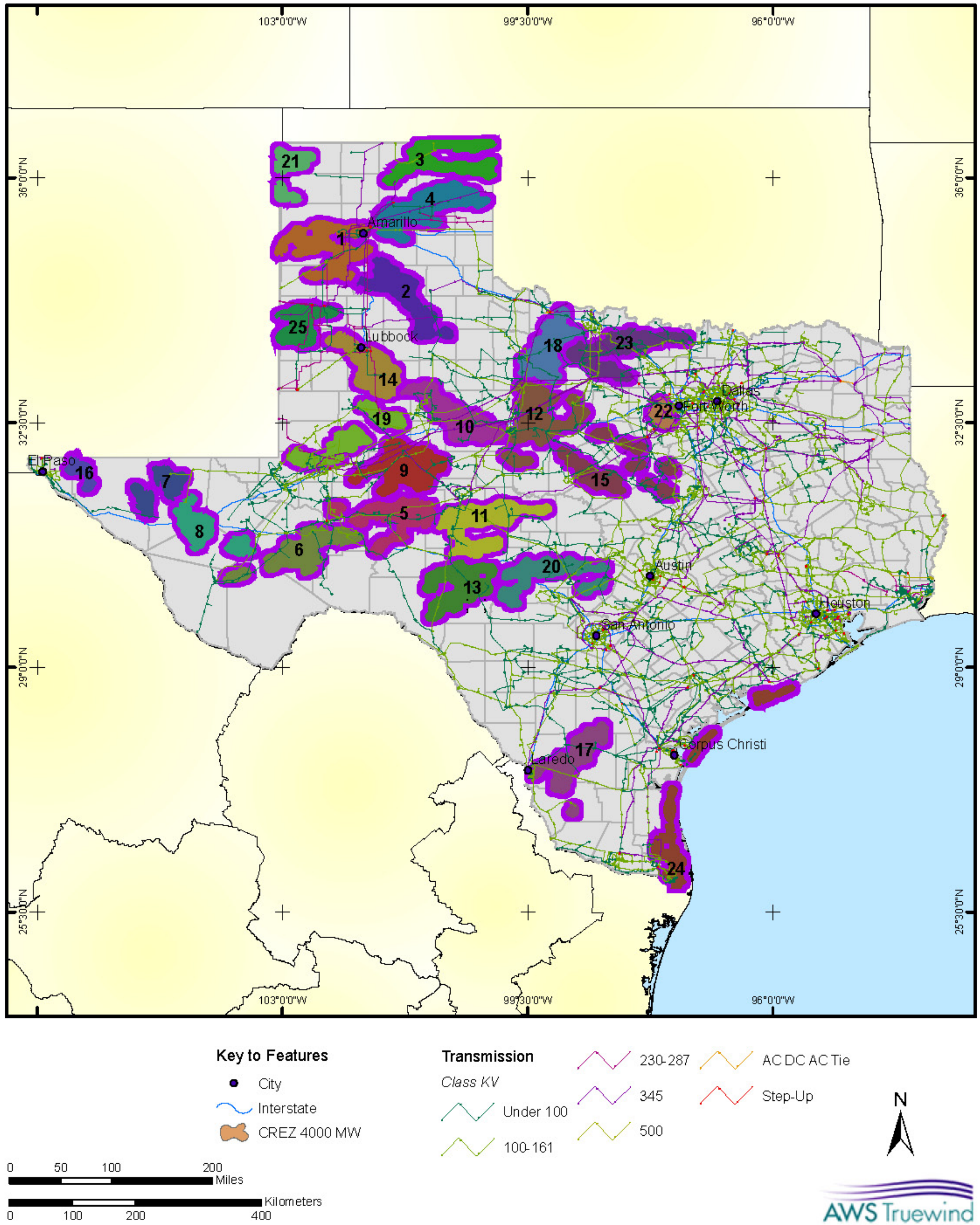


Figure 3: Areas Enclosing the Best 4,000 MW in Each of the Wind Resource Zones

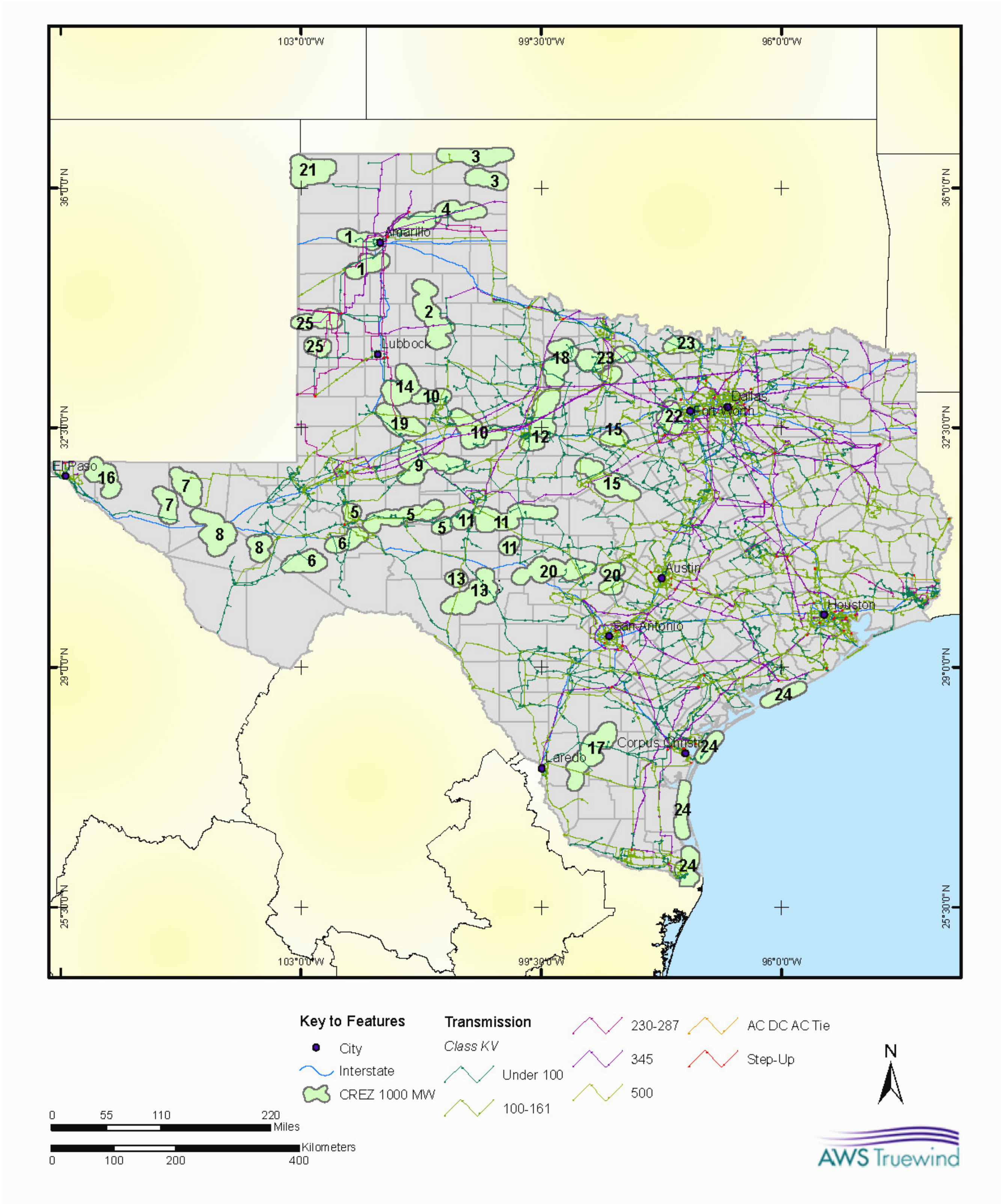


Figure 4: Areas Enclosing the Best 1,000 MW in Each of the Wind Resource Zones

Note that, although the areas extend beyond the land boundaries of Texas, only on-shore sites within the administrative boundaries of the State were considered. The hourly generation data produced by AWS Truewind were presented at the Regional Planning Group meeting on July 21, 2006. The hourly generation data were also made available that day on the ERCOT Operations and System Planning Data web-site.

After the modeling results had been released to stakeholders, several parties indicated that they had site-specific wind measurement data that was not consistent with the output of the AWS Truewind model. The areas of concern to these stakeholders were primarily located in the upper panhandle and along the coast. Although these stakeholders had not provided these data following ERCOT's earlier request, due to the discrepancies between the model results and their data, these parties felt that it would be beneficial to provide the data at this point and allow AWS Truewind to adjust their model to reflect the additional information.

As a result, representatives of AWS Truewind reviewed and normalized the additional data that was provided, and, if appropriate in their professional judgment, modified some of the parameters of the Mesomap model, and recomputed the generation supply curves and the hourly energy data for several of the wind zones. The revised results were posted on the ERCOT Operations and System Planning web-site as they were completed by AWS Truewind.

2. Results

As has previously been noted, the two primary results of the AWS Truewind study were the delineation of areas in the State of Texas where wind resources were sufficient to be evaluated as potential Competitive Renewable Energy Zones, and the development of modeled hourly energy patterns for representative sites in these high wind areas. The data developed by AWS Truewind represented the output of a wind farm built with a generic wind turbine, i.e., one based on a composite power curve developed from a mix of several different currently commercially available wind turbines. The hourly output data also represented the output during an average weather year. In order to develop an average weather year, the weather patterns from 24-hour periods (from hour 0 to hour 23 Greenwich Mean Time) from different years were selected and placed in chronological order by day and by month.

An initial analysis of the AWS Truewind data output was presented at the Regional Planning Group meeting on July 21, 2006. Three aspects of the data were reviewed: monthly capacity factors, average hourly output, and diversity.

Monthly average capacity factors for several zones are depicted in Figure 5. This chart also depicts the forecasted ERCOT energy demand by month in gold (with scale provided along the secondary y axis). These data indicate that the representative areas in West Texas have their highest monthly capacity factors in the spring months and in late fall. The areas modeled along the coast have fairly consistent wind output throughout the year, although somewhat less in the summer months. None of these patterns has a high correlation with the typical ERCOT monthly energy demand pattern, with maximum electric demand occurring in July and August.

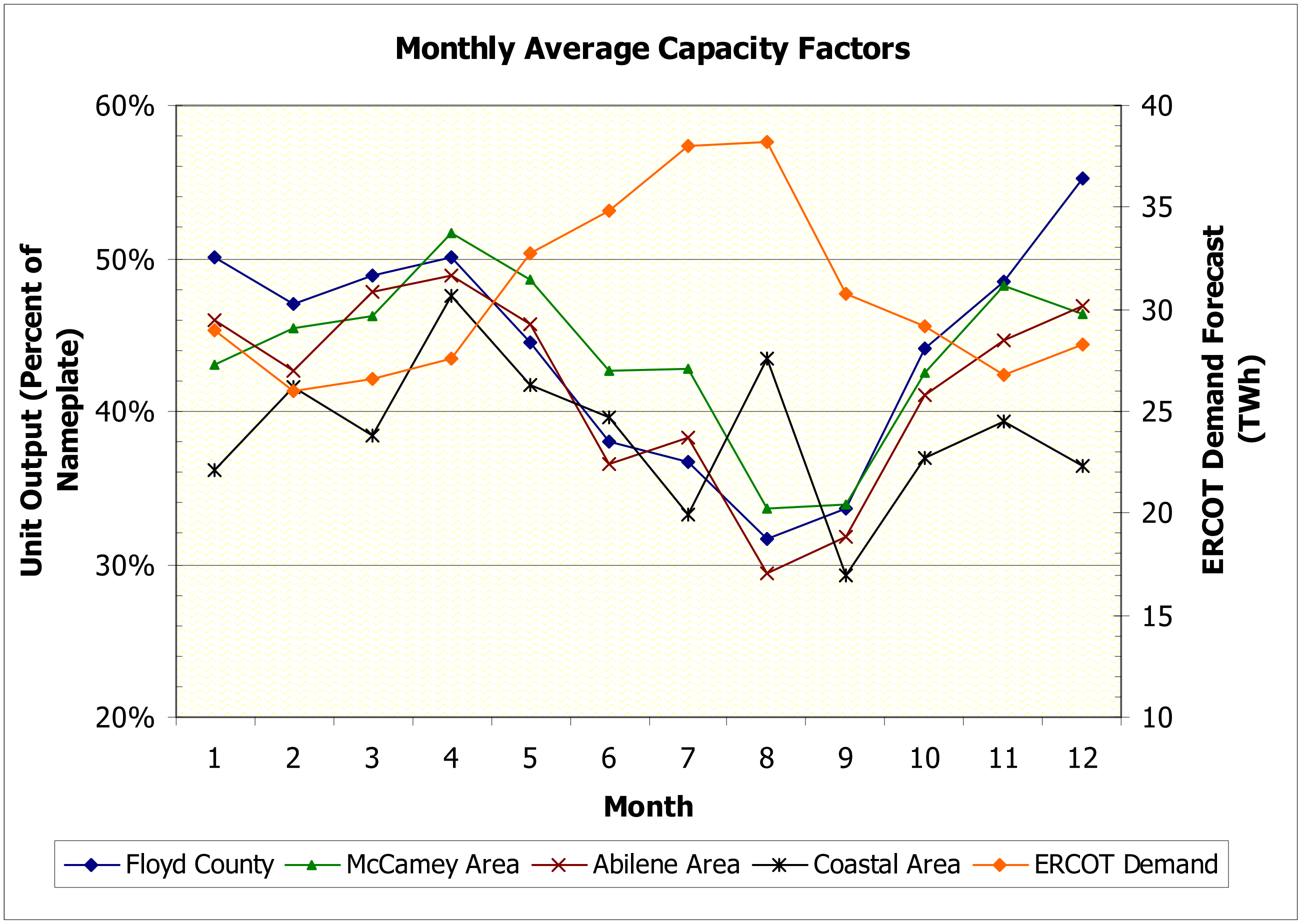


Figure 5: Typical Monthly Average Capacity Factors for Several Zones

Daily average wind generation patterns from April and July for representative zones are provided in Figures 6 and 7. These data are derived from the hourly energy patterns for the 10 best sites (approximately 1,000 MW) in each of the zones represented. Figure 7 indicates that, during the month of April, typical wind resources in West Texas have significantly higher average output in the early morning hours in April than during the afternoon. The sites modeled along the coastal area have more constant output throughout the day, with slightly higher output in the early morning hours.

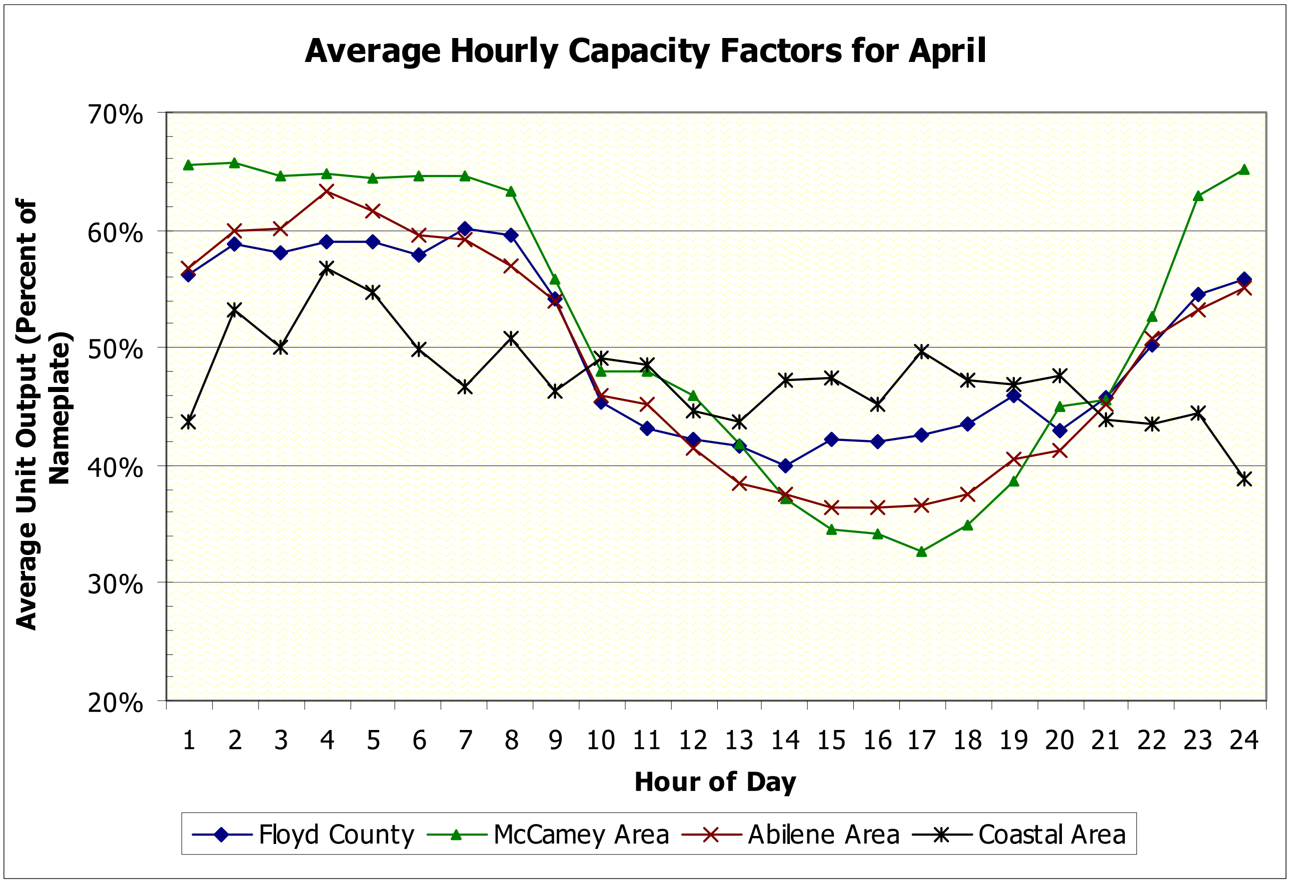


Figure 6: Typical Average Hourly Wind Generation in April

Similarly, the AWS Truewind modeling data for July, as depicted in Figure 8, indicates that typical wind generation in West Texas peaks in the early morning hours. Wind generation from the coastal area, on the other hand, increases throughout the afternoon to a maximum average output at 8 or 9 PM. Figure 8 also shows a typical ERCOT hourly load pattern for July in gold.

Table 1 presents the results of a correlation analysis of the zones presented in Figures 5 through 7, as well other representative zones. The locations of these zones are depicted in Figure 4. Zones 2 and 4 are in the Texas Panhandle (Floyd County is in Zone 2); Zones 5 and 6 are in and around McCamey, Texas; Zone 7 is in the vicinity of Culberson County, Texas; Zones 9, 10, 12, and 14 are in the central western portion of the State, and Zone 24 is along the Gulf Coast.

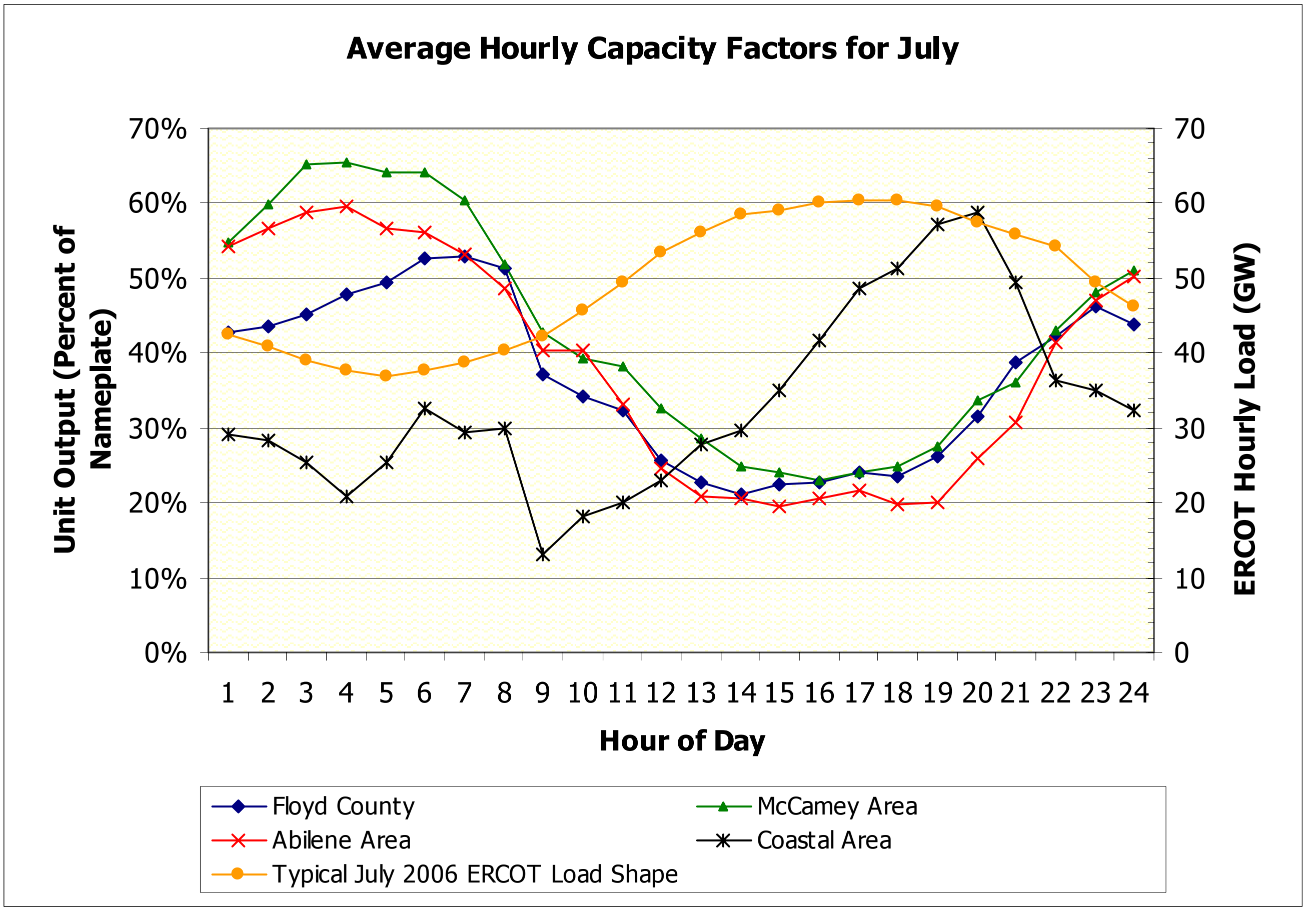


Figure 7: Typical Average Hourly Wind Generation in July

The correlation analysis was conducted on the hourly sum of the modeled output from the first 10 sites, representing the best 1,000 MW, in each zone. These results show that sites that are close together will be strongly correlated. In general, two data streams that always increase or decrease at the same time will have a correlation approaching 1.0; two data streams that always move in opposite directions will have a correlation approaching -1.0. The two areas around McCamey (Zones 5 and 6) are strongly correlated (0.75), as are the two areas in the Panhandle (Zones 2 and 4: 0.65). The areas in Central western Texas are strongly correlated (zones 9, 10, 12, and 14, with correlations ranging from 0.71 to 0.90). The zone along the Gulf Coast (Zone 24) is not correlated strongly with any of the other zones presented in this chart.

The complete data results from the AWS Truewind study are available on the ERCOT web-site.

Table 1: Correlation Matrix for Hourly Wind Generation Pattern

	Zone 2								
Zone 4	0.65	Zone 4							
Zone 5	0.52	0.37	Zone 5						
Zone 6	0.49	0.44	0.75	Zone 6					
Zone 7	0.38	0.24	0.43	0.38	Zone 7				
Zone 9	0.63	0.40	0.83	0.64	0.50	Zone 9			
Zone 10	0.69	0.43	0.77	0.59	0.48	0.90	Zone 10		
Zone 12	0.64	0.41	0.72	0.55	0.46	0.81	0.90	Zone 12	
Zone 14	0.77	0.47	0.61	0.53	0.48	0.77	0.81	0.71	Zone 14
Zone 24	0.09	0.10	0.05	-0.01	0.19	0.08	0.08	0.12	0.10

C. Selection of Zones for Initial CREZ Transmission Analysis

It was not feasible to perform detailed transmission needs analysis on all 25 zones identified by the AWS Truewind analysis within the available timeframe. Based on the output of the AWS Truewind study, it was clear that certain zones that had similar transmission needs also had similar wind resources, such that the transmission analysis only had to be conducted on a subset of the zones. Thus, ten zones (2, 4, 5, 6, 7, 9, 10, 12, 14, and 24) were selected for this analysis of transmission improvements required for development of additional wind resources. These zones, depicted in red on Figure 8, were selected in order to ensure that a variety of transmission solutions were developed and to include areas of specific stakeholder interest. The selection of these zones was discussed at the Regional Planning Group meeting on June 2, 2006, and the selected zones were posted for comments on June 8, 2006 on the ERCOT Operations and System Planning web-site.

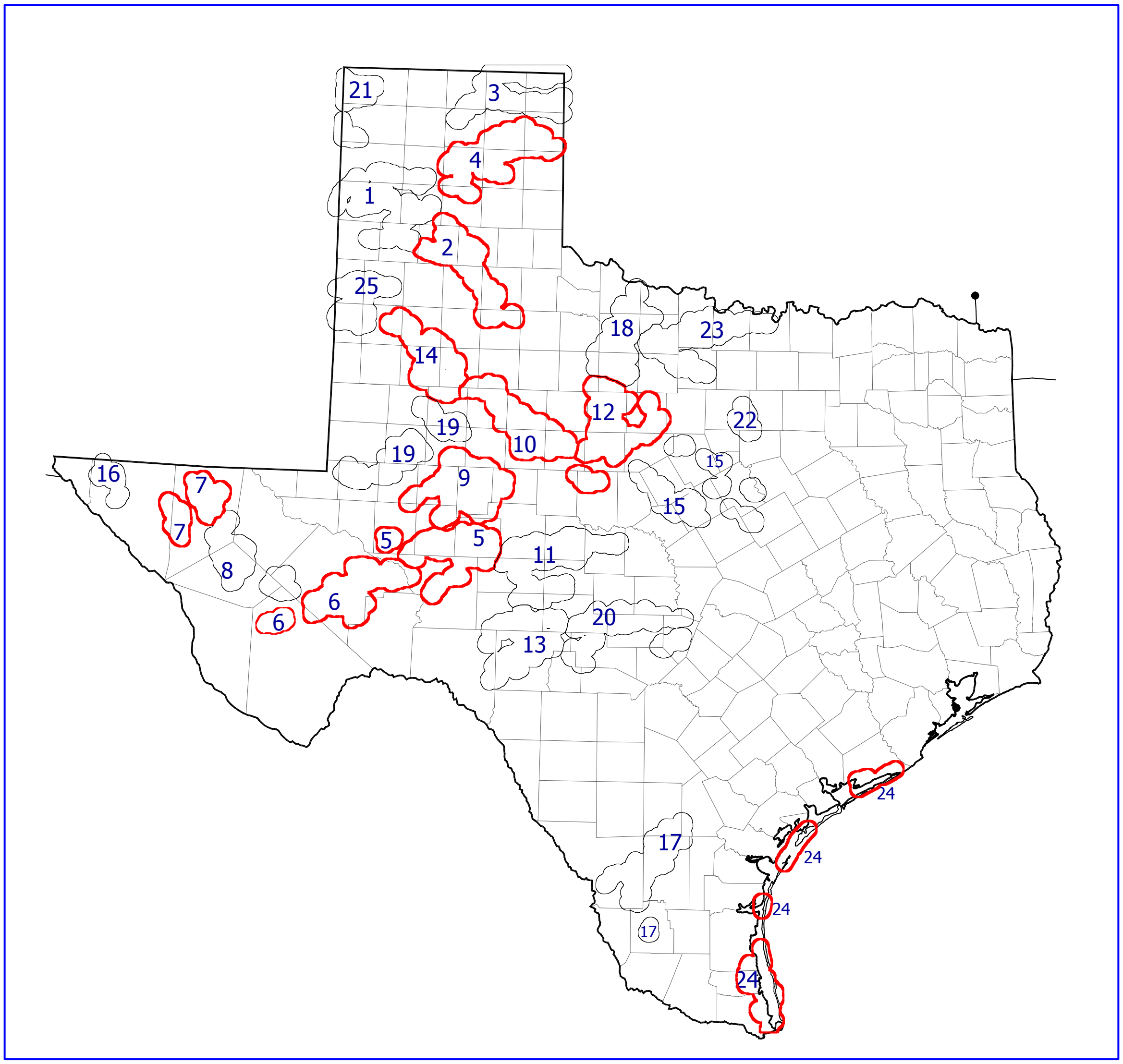


Figure 8: Wind Zones Selected for Initial Transmission Analysis

IV. ANALYSIS OF TRANSMISSION IMPROVEMENTS

A. Modeling Tools

The analysis for this study was conducted using the models UPlan (LCG Consulting, Version 7.4.6.2), Powerworld (Powerworld Corp., Version 12) and PSS™E (Siemens PTI, Version 30.2). Powerworld and PSS™E are tools for analyzing transmission system power flows under steady-state conditions. UPlan is an hourly security-constrained unit-commitment and economic-dispatch model that can be used to forecast changes in system operations on an annual basis. The UPlan model is configured to determine an optimal unit commitment and dispatch based on the assumption that units will be bid into a nodal market at their variable cost of generation production (including their cost of SO_2 and NO_X emissions).

B. Transmission Base Case Development

The underlying transmission topology for these analyses was developed from the work of the ERCOT Steady State Working Group (SSWG). This group of Transmission Owner representatives compiles changes to the existing transmission topology and develops projected topologies for five years into the future.

In 2006, ERCOT began what will henceforth be an annual stakeholder study of the forecasted transmission topologies of the Steady State Working Group, to develop a comprehensive and coordinated Five-Year Transmission Plan for the ERCOT System, revising and adding specific projects to meet established reliability and economic benefit criteria. The analysis of transmission projects for CREZ designation used the latest case that was available through the Five-Year Transmission Plan development at the start of the CREZ study, which was the 2009 case.

The analysis described in this report was completed using this 2009 case as the base case. Several additional projects that have been endorsed by the ERCOT Board of Directors but will not be completed prior to the peak season of 2009 were added to this case. The most notable of these are the 345-kV improvements associated with new rights-of-way connecting the Clear Springs and Salado substations, as well as the 345-kV improvements between the San Miguel electrical generating facility and the new Lobo substation near Laredo.

Several additional significant projects that were included in the Five-Year Plan to meet reliability or economic criteria were also incorporated into the base case. However, not all of the projects included in the Five-Year Plan were included in this analysis due to time constraints.

ERCOT is also leading a Long-Term System Assessment (LTSA) of the needs for generation and transmission of the ERCOT system for 10 years into the future. Although it was originally proposed to stakeholders that this CREZ analysis would be studied in the same timeframe (2016) as the LTSA, the complexities of extending the transmission planning horizon an additional five years into the future, including forecasting future load growth, future generation additions, and lower-voltage transmission projects to meet reliability criteria, delayed the development of a workable 2016 base case to the point that this CREZ analysis had to be conducted using the Five-Year Plan case for 2009 in order to meet the regulatory deadline.

C. Base Case Wind Capacity

As part of the Five-Year Plan development, a review was made of wind generation projects under development. It was noted that, at the time, approximately 12,000 MW of wind generation projects were in the ERCOT interconnection request queue, in addition to the approximately 3,200 MW of wind generation projects that were either in-service or had an executed interconnection agreement. (Additional interconnection agreements have since been signed, and at the time of the drafting of this report, the total wind capacity in-service and with signed interconnection agreement is 4,068.5 MW.) Following previous ERCOT planning procedures, the generating units with a signed interconnection agreement were included in future planning model cases, but none of the other units in the interconnection queue were represented.

Table 2 lists the total operating and proposed wind capacity by wind zone (as of October 20, 2006). While a significant portion of the wind generation projects in the interconnection queue may not be built, it was generally agreed by stakeholders that including only the units with a executed interconnection agreement would underestimate the amount of transmission congestion, especially in West Texas, and would likely lead to incorrect assessments of the need for specific transmission system improvements. Since several of these projects appeared likely to be completed prior to the end of 2007, ERCOT System Planning personnel proposed to stakeholders that some additional wind generation capacity be included in the Five-Year Plan analysis of the needs for 2007. These proxy wind projects would be representative of the amount of wind generation capacity in the interconnection queue that was expected to be completed in 2007. ERCOT System Planning proposed that approximately 1,500 MW of additional wind, for a total installed wind generation capacity of 4,850 MW, be added to the 2007 and subsequent years' planning model cases.

As a result, the 2009 planning model case for the CREZ evaluation contained 4,850 MW of wind capacity, of which 1,500 MW of wind were included above the amount that was either in-service or for which there was a signed interconnection agreement. The actual interconnection points of this additional wind capacity may not be at the same electrical bus locations modeled in the study. However, to minimize this uncertainty, the 1,500 MW of generic or proxy wind capacity was located at buses near significant clusters of projects in the interconnection request queue.

Table 2: Existing and Planned Wind Capacity in ERCOT (as of 10/20/06)

Wind Zone	Operating Wind Capacity (MW)	Wind Capacity with Interconnect Agreement Finalized (MW)	Other Wind Capacity in the ERCOT Interconnection Queue (MW)
2			560
4			750
5	353.2		
6	403.5		800
7	74.8	175	
9	413.1	215	1,462
10	1,139	193	2,024
11			848
12		633	500
14			423
15		60	390
17			847
18			540
19	124.9		2,119
23		120	501
24			2,400
Not in any Zone		165	1,269
Total	2,508.5	1,561	15,433

Each of the wind units in the base case was assigned to a location specified in the hourly wind unit generation data provided by AWS Truewind as part of their analysis of wind generation potential. Although the exact location of the sites in the AWS Truewind data was proprietary and therefore was not included in their results, the modeled sites were assigned to actual wind units based on the zone in which they are located. The hourly energy patterns derived from the AWS Truewind model results were thus used as inputs into the hourly unit commitment and dispatch model UPlan. For existing wind sites that had a nameplate capacity greater than one of the modeled sites, sufficient sites from the AWS Truewind output were aggregated to represent adequately the existing facility.

A direct result of the AWS Truewind method of developing a representative average weather year was that the unit output data were discontinuous at the boundary between hour 23 and the proceeding hour 0, since the weather pattern used to develop these two hours often came from different years. The selection of days to develop the average weather pattern was consistent across all zones, so the output of a site in one zone could be directly compared to the output of a site from another zone. However, in order to use these data in a chronological unit commitment model, the discontinuity between hours 23 and hours 0 required smoothing. Prior to development of the actual energy patterns that were used to define a wind projects hourly generation in the UPlan model, the data from hours 22, 23, 0, and 1 were replaced by three-hour rolling averages. In this way, the shift in output from hours 23 to hours 0 were spread over several hours, but the actual amount of energy produced was not significantly altered.

D. New Wind Capacity

A similar process was used to assign hourly energy patterns to proxy wind generation units used to represent new CREZ-related wind generation located in the wind zones being studied. New substations were created in the model database, and models for the proxy wind generation units were created and connected to new substations. Each of these new units was assigned to a unique hourly energy pattern from the AWS Truewind data.

E. Other Model Inputs

ERCOT System Planning maintains a database of generating plant efficiency ratings, operating costs and unit constraints. Some of the generating unit data were provided by stakeholders, and some are generically set by generating unit type. In the study, for model reasons, all wind generators were modeled as having a small variable cost of 25 cents per megawatt-hour ($0.25/MWh).

To coincide with the use of the 2009 transmission topology, the 2009 load forecast and generation resources expected to be on-line in 2009 were included in the model inputs. ERCOT System Planning personnel maintain an updated annual peak load and demand forecasts based on econometric modeling of the electricity market in ERCOT. This load forecast is distributed to specific buses using ratios inherent in the Steady State Working Group cases.

Fuel forecasts for this study were developed through a review of current fuel fundamental market dynamics. Similarly, emissions allowance forecasts were determined based on a review of likely future scenarios. Table 3 provides the nominal price forecasts that were used for this study.

Table 3: Fuel And Emission Forecasts

Forecast Parameter	2009 Price Forecast
Natural Gas	$7.00/MMBtu
Sub-bituminous Coal	$1.70/MMBtu
Lignite	$1.28/MMBtu
SO_2 Emissions Allowance	$600/Ton
NO_X Emissions Allowance	$1,500/Ton

Unit emission rates were based on data from the Environmental Protection Agency Clean Air Markets Program (available at http://www.epa.gov/airmarkets/). SO_2 emissions were included in unit economic commitment and dispatch decisions due to the current requirements of the Federal Acid Rain program. NO_X emissions were included in unit commitment and dispatch decisions due to the expected implementation of the Clean Air Interstate Rule in 2009.

F. Cost Estimates

For the purposes of developing capital cost estimates for transmission system improvements where specific project costs had not been developed and for wind capacity improvements, the generic base component cost estimates listed in Table 4 were used. These cost estimates were reviewed with all stakeholders.

Table 4: Capital Cost Estimates

Component	2009 Capital Cost Forecast
New 345-kV Right of Way (single circuit)	$1 million/mile
New 345-kV Right of Way (double circuit)	$1.3 million/mile
New 345-kV substation	$15 million
New 345/138-kV autotransformer	$6 million
New wind generating project	$1,000/kW

The cost of wind energy is another factor that has an impact on the designation of wind energy zones. Figure 9 depicts the relationship between the total cost of energy produced by a wind farm and the project's average capacity factor. The term capacity factor means the amount of energy produced by the project over the period of a year, as a percentage of the product of the project's nameplate capacity multiplied by the number of hours in a year (8,760). In other words, the capacity factor is the percentage of energy actually produced by a unit compared to the amount it would have produced if it ran at its nameplate rating over an entire year. For wind units, typical capacity factors are in the 30% to 45% range.

These results are based on a generic pro forma analysis, using average input assumptions for construction costs ($1,000/kW), fixed operating costs ($19/kW-yr), weighted average cost of capital (9.1%), inflation (2.5%), and marginal tax rate (38%). The analysis also includes an assumption that the project receives a Production Tax Credit from the Federal government (1.7 cents/kWh), and that the company that owns the project can use these tax credits to reduce their overall tax burden.

Actual project costs will vary from these results due to site- and company-specific conditions. The purpose of this chart is not to indicate the energy value of specific projects, but rather to indicate the value of being able to locate wind projects in areas with higher average capacity factors.

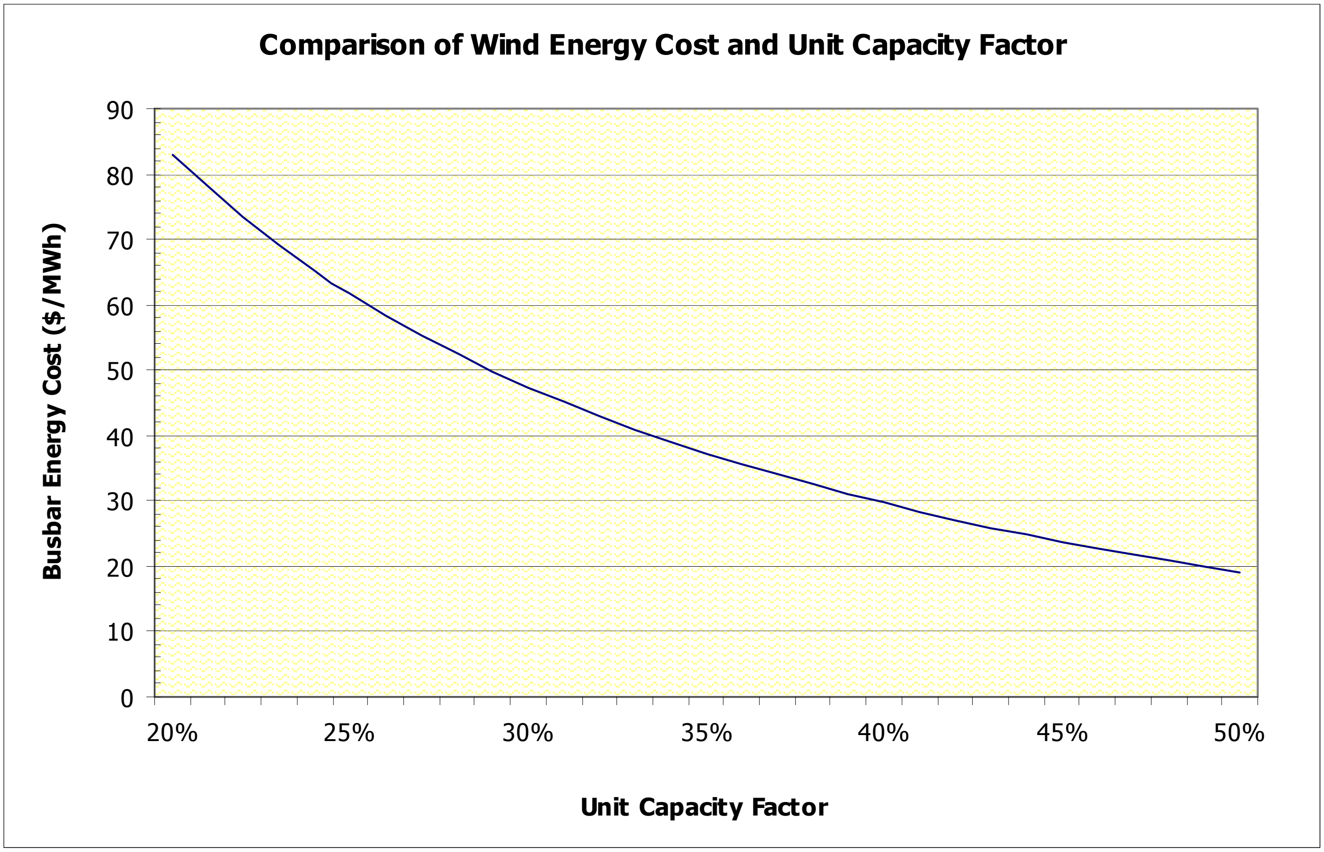


Figure 9: Comparison of Capacity Factor and Total Energy Price for Wind Capacity

This chart indicates that, all other factors being equal, for every 1% increase in capacity factor, the total energy costs from wind farms will decrease by approximately $1.50/MWh.

G. Analysis Methodology

The goal of this part of the study was to identify specific transmission solutions that would allow significant amounts of new wind capacity to be added in zones identified by the AWS Truewind analysis. In addition, the analysis was designed to provide incremental solutions, each of which provided significant system benefits, which would lead to an overall solution to provide transmission capacity for a significant amount of wind capacity. A basic component of this analytical strategy was to only propose transmission projects that were consistent with an overall solution.

Transmission project analysis was conducted using a combination of the three models described above. The UPlan model was used to evaluate transmission system improvements over periods from several weeks to a full calendar year. UPlan was used to provide wind generation results, by generating unit, as well as a list of significant transmission line binding constraints restricting wind unit output. By exporting the transmission system model for a specific hour from the UPlan results database, these line constraints under contingency were analyzed using the steady-state models Powerworld and PSS™E. Most of the analysis for this study relied on a DC approximation to the actual AC power flows; however, an AC solution was developed using PSS™E for some of the scenarios. .

Using the steady-state models, the impacts of potential transmission solutions on the limiting elements of the system were reviewed under contingency conditions specified by the UPlan output. Although the transmission system database included constraints on 69-kV, 138-kV, and 345-kV lines, the goal of this investigation was to select new corridors for 345-kV (and above) transmission improvements.

Revised transmission solutions were analyzed using the UPlan model, and the cycle of analysis continued for each scenario until a significant amount of wind had been added to the case and additional line improvements did not provide significant relief to the resulting system constraints.

Following discussions with system engineers and representatives of Transmission Service Providers, it was agreed that the new system improvements should not have any single point of failure that would result in the loss of more than 1,500 MW of generation capacity to the system. As an example, it would be within the thermal limitations of the wire to connect approximately 3,400 MW of generation to a double-circuit radial 345-kV transmission line. However, if there was a loss of that line on a windy day, the overall power system might be forced to respond to an instantaneous loss of over 3,000 MW of generation. Currently, there are no other single points of failure that can result in this extensive a loss of generation. The largest single point of failure on the system is the loss of a generating unit with a maximum output of 1,250 MW. The amount of responsive reserve required to be present on the system at all times was derived based on the risk associated with an instantaneous loss of generating capacity. Allowing the largest single point of failure to increase to 1,500 MW may require a minimal increase in the level of responsive reserves required, but the system should not be designed in such a manner as to allow a larger MW impact of a single point of failure until the potential effects are evaluated.

Hundreds of possible solutions were analyzed as part of this study. Over 60 scenarios were analyzed for new generation capacity in the McCamey area alone. The results presented in this report do not represent all of the possible transmission improvements studied. Rather, they are the solutions that resulted in the most wind generation capacity being added to the system with a reasonable range of wind generation curtailment.

H. Study Limitations

As was noted above, most of the analysis conducted as part of the study utilized a DC approximation to AC power flows. Although this type of power flow approximation is widely accepted in the industry for many applications, it cannot show the benefits of certain significant system improvements in areas where under-voltage issues can potentially occur following certain contingencies, nor can it be used to select the optimal bus connections in these same areas. In addition, this type of analysis cannot be used to evaluate reactive support requirements, which may require additional expenditures associated with significant changes to the system.

An analysis of transient stability was not included in this study. Dynamic transmission system analysis is an extremely detailed and time-consuming process. Given the number of scenarios that were analyzed, and the fact that many of these scenarios will not be included in future CREZ proposals, it was not reasonable to perform transient stability analysis for each of these scenarios within the given timeframe. This study may indicate that exports from the west zone to the north and south zones of ERCOT cannot exceed a limit which is less than the thermal limits of the actual transmission lines under contingency. Although additional high voltage connections between west Texas and the other ERCOT zones like those described in this study will generally improve transient stability as well as thermal limits, it is still possible that the limits from the transient stability analysis will be more stringent than the limitations specified in this report. It is not anticipated that this analysis, when accomplished, would change the relative costs associated with different potential CREZs, but might change the magnitude of the wind capacity at a given level of curtailment that can be accommodated by each.

In addition, ERCOT System Planning is currently engaging a consultant to provide an analysis of increased ancillary service needs resulting from additional wind capacity of the magnitude modeled in this study. It is not known at this time if this study of ancillary services requirements will indicate that additional costs will be required in order to increase the amount of wind capacity on the system above a specific level, or if there is in fact a limit to the amount of wind that can be safely absorbed by the system given specific load and thermal generating unit conditions. The effects of any additional responsive or regulation reserve services which may be indicated at the completion of the ancillary services study were not included in the present study.

It should also be noted that no routing analysis has been conducted as part of this study. ERCOT System Planning has worked with representatives of TSPs to develop feasible transmission upgrade solutions. However, until detailed routing studies are completed, it is not known if the specific connections modeled as part of this study are achievable.

I. Impacts on Existing Wind Generation

The purpose of this study is to develop transmission solutions that allow a significant amount of new wind generation to be installed in various zones with a minimal amount of aggregate wind curtailment. Over the course of the study, it was noted that in many scenarios the wind generation that was initially curtailed by increasing amounts of new wind generation capacity in a specific zone was not the new wind generation connected to proposed new system upgrade, but rather it was the existing wind units, often connected to the system on lower voltage circuits. The reason for this is that the overall transfer of wind energy from generation pocket to load is limited, under contingency of the new proposed line, by the thermal limits on the existing system. In many scenarios the limiting constraint is a 138-kV line, such as the circuits that connect the San Angelo and Gillespie substations, or the circuit that runs from Brownwood to Lampasas connection, or from the South Abilene to Selden substations. In order to relieve such a constraint, the UPlan model (as will the proposed ERCOT nodal market) will reduce the output from the system in the most cost-effective manner. All of the wind units in our database are modeled with the same variable cost (25 cents per Megawatt-hour), so, if needed, the model will reduce the output of the unit with the highest shift factor on the limiting element. This would most likely be an existing wind generating facility that is more directly connected to the specific limiting element.

In some scenarios, it was determined that the output of one or a small number of existing wind units was being disproportionately affected by transmission constraints on the system. In these cases, the least cost solution to improving the average curtailment of all wind units in the aggregate was to make a small system improvement in the immediate vicinity of the existing wind generators being affected. In some of these cases, these modeled improvements had a similar function as operational protection schemes currently in place (schemes that are difficult to model in an economic unit commitment and dispatch model). In other cases, these small system improvements were used to alleviate constraints around some of the proxy units that were included in the base case in order to represent the likely amount of wind capacity present on the system at the end of 2007.

Certain projects of this type were included into most of the scenarios from this study (they were not needed in the scenarios that included only new wind from the coastal area). These projects are listed in Appendix B.

These potential projects were developed through an iterative process, based on an analysis of the binding contingencies included in the outputs of the planning models. They represent the types of projects that will be needed to alleviate the impacts of transmission congestion on existing wind generation. They vary considerably in scale and certainty. Some are straight-forward and already under discussion by ERCOT stakeholder groups, but there may be better operational solutions for others. In particular, some may require Certificates of Convenience and Necessity (CCNs) with challenging new rights-of-way (ROWs). This list includes 110 new circuit miles, the upgrade of 73 existing circuit miles, one new autotransformer, and three new substations. The additional cost of these system improvements, beyond those found to be economically justified in the Five-Year Plan, is estimated to be $180 million.

Prior to designation of specific CREZ by the PUCT, and prior to completion of interconnection agreements for additional wind generation already in the ERCOT interconnection queue, it cannot be determined which of these projects will provide sufficient system benefits to be economically justified. While specific proxy projects were included in the present analysis, based on the input assumptions for this study, the actual projects that are ultimately needed may vary from those contained in this list. It is clear that some projects to reduce the impact of congestion on many of the existing (base-case) wind generators will be needed, and analysis of these types of projects will need to be continued following the CREZ designations by the PUCT, as part of the ERCOT annual Five-Year Plan.

One possible solution may be to sectionalize some of the existing weak circuits. As additional high-voltage circuits are added to the system in West Texas, the existing underlying 69-kV and 138-kV lines will remain the limiting elements. The results of this study indicate that the following circuits will continue to cause significant constraints on the system:

1. Contingency or non-contingency overloads of the 138-kV and 69-kV paths between San Angelo and Gillespie.
2. Contingency or non-contingency overloads of the 138-kV and 69-kV paths between Brownwood and Lampasas.
3. Contingency or non-contingency overloads of the 138-kV and 69-kV paths between South Abilene and Stephenville.

These three weak west-central ties are well understood by the TSPs to have no easy or inexpensive solutions or incremental upgrades. However, after at least two new high-voltage west-central transmission ties have been energized, it may be possible to open specific elements in the existing system and significantly reduce the impact of these existing circuits on transfer capacity. Such a solution could significantly reduce the impact of these system constraints on existing wind generation. Analysis of operational solutions to these constraints is needed and will be performed in the future.

J. Considerations for Further Analysis

1. Regional Voltage Needs

Three areas, the Hill Country, the area west of Killeen, and the Valley, have current voltage needs that can be alleviated by projects identified as part of this study. The Hill Country area is served by four hydro-power generating plants, the Ferguson gas steam plant, the 345-kV Kendall substation, and an extensive 138-kV network running generally from the 345-kV corridor east of I-35. New 345-kV lines in the Hill Country may be required in the future to alleviate local under-voltage conditions, as well as to serve increasing load in the area. The Killeen substation has a single 345/138-kV autotransformer and a single 345-kV line to Temple (this line will connect first at Salado starting in 2010) to support the entire area from Belton to Lampasas. The closest power stations are Sandow, and Lake Creek. A second 345-kV source would improve reliability in this area. Similarly, the Rio Grande Valley has import limitations due to local voltage support requirements.

2. Dynamic Analysis

As noted above, there are particular stability concerns whenever a large generator is connected to the system by a single transmission line. During very light-load conditions, a single large generator such as Comanche Peak may represent a significant portion of the thermal resources on the network. A transient stability analysis of the system with increased levels of wind generation is needed to investigate any changes in responsive reserve levels that may be needed in response to higher levels of wind generation.

A dynamic (transient stability) analysis of West Texas based on the Five-Year Plan is scheduled to be completed in December 2006 by ERCOT System Planning. However, as more wind generation is interconnected to the system, and as new circuits in West Texas are approved, the dynamics of the system will change, and additional analyses will be required. These analyses could result in export limitations that are more restrictive than the thermal limitations described in this study.

3. System Ancillary Service Requirements

ERCOT System Planning is currently engaging a consultant to provide an analysis of ancillary service requirements at different levels of wind connected to the ERCOT transmission system. This study, to be completed in 2007, will also quantify any system benefits from incorporating wind resources from different wind zones.

The results of this study will likely indicate a relationship between the amount of wind generation output on the system and the amount and operational characteristics of thermal generation resources required to balance the system reliably over different timeframes from instantaneous to several hours. The increased cost associated with the higher ancillary services requirements could alter the economic benefits of wind resources described in this study. It is generally believed that the differential ancillary services requirements between the different potential CREZs will be less significant than the overall higher level of ancillary services that will be required as the level of wind generation penetration increases. In addition, the impact of increased wind generation on some types of ancillary services may be minimized if the total wind capacity is spread over more areas, due to diversity in the instantaneous changes in wind. However, the specific impacts will not be known until the ancillary services study is complete.

V. RESULTS

A. Description of Proposed System Improvements

The analyses from this study indicate that, from the perspective of ERCOT transmission system upgrades, there are generally four discrete areas of wind generation development: the Gulf Coast region; the southwest region (including the McCamey area); the central-western Texas region (running generally along the existing 345-kV circuits from Abilene to Odessa, and including areas south to San Angelo, north to Scurry and Garza counties and as far west as Culberson County); and the Texas Panhandle region. The results of this study represent building blocks of transmission upgrades that can be used to connect wind capacity in these regions. These building blocks can be implemented individually or in combinations to provide different levels of additional transmission capacity. The individual transmission solutions are described in the following paragraphs. The results of economic analyses of these solutions, as well as several combinations, are provided in Section V (B).

1. Coastal Region

Three levels of transmission solutions have been identified for new wind resources along the Gulf Coast of Texas (Zone 24, depicted on Figure 5). These solutions are cumulative. Significantly less capital investment is required to connect additional wind capacity in the Gulf Coast region than in West Texas because there currently are no wind resources in this region. In fact, the first 1,000 MW of wind resources can be connected to the existing 345-kV circuit that runs between the Sharpe to the Rio Hondo substations.

The second level of transmission solution involves construction of a new 345-kV substation on the circuit from Lon C. Hill to North Edinburg, and a new double circuit transmission line connecting this new substation and the Armstrong 345-kV substation.

The third level of transmission solution consists of a new 345-kV circuit from the planned Lobo substation near Laredo, to a new substation west of the existing North Edinburg substation, with additional connections to both the North Edinburg and the Frontera substations. A new 345/138-kV autotransformer would be required near the existing Frontera substation.

These system improvements are depicted in Figures 6, 7, and 8. The new 345-kV circuit from Lobo to the Valley may be needed to maintain system security as load grows in the Valley area, regardless of wind interconnections.

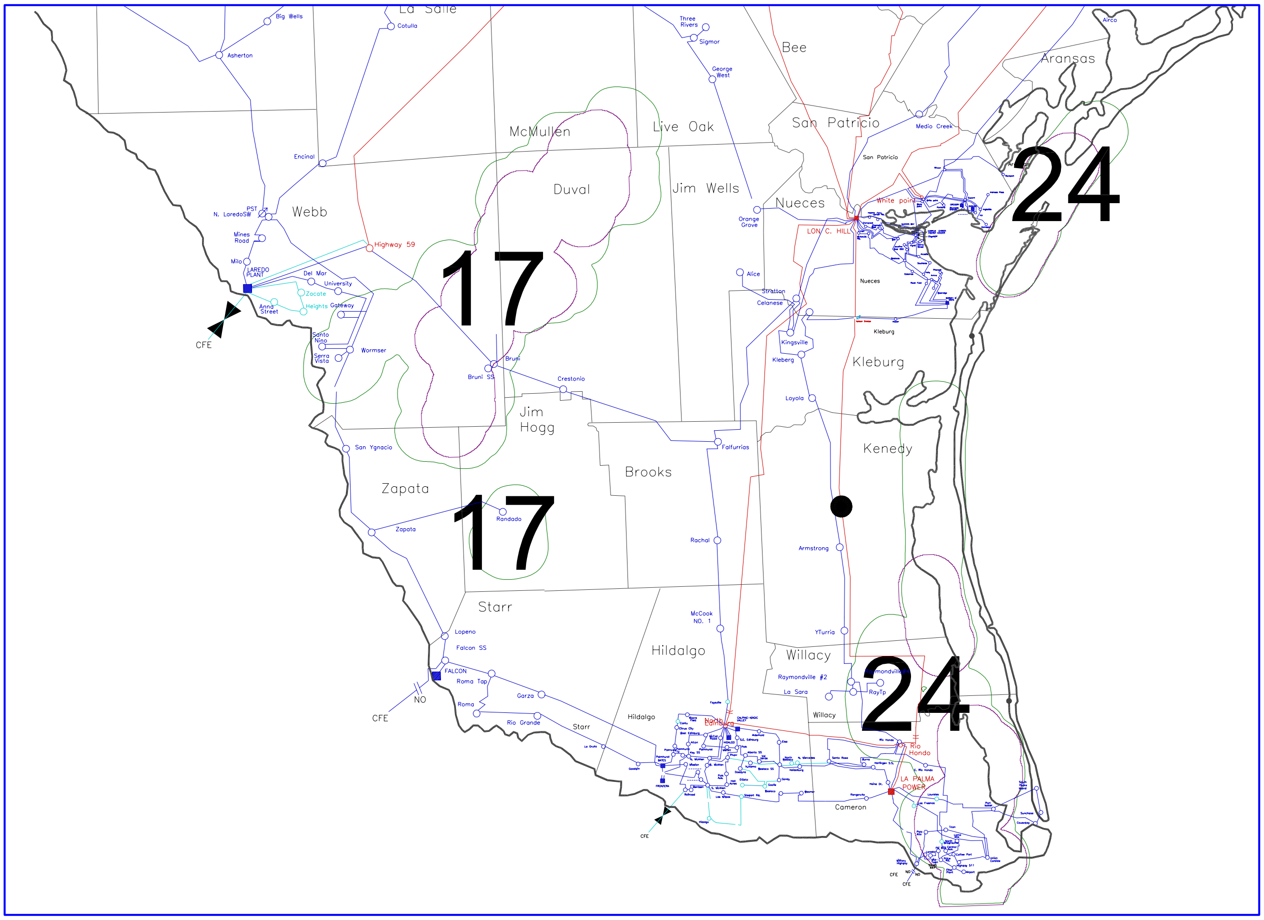


Figure 9: Initial Transmission Solution for Wind Zone 24

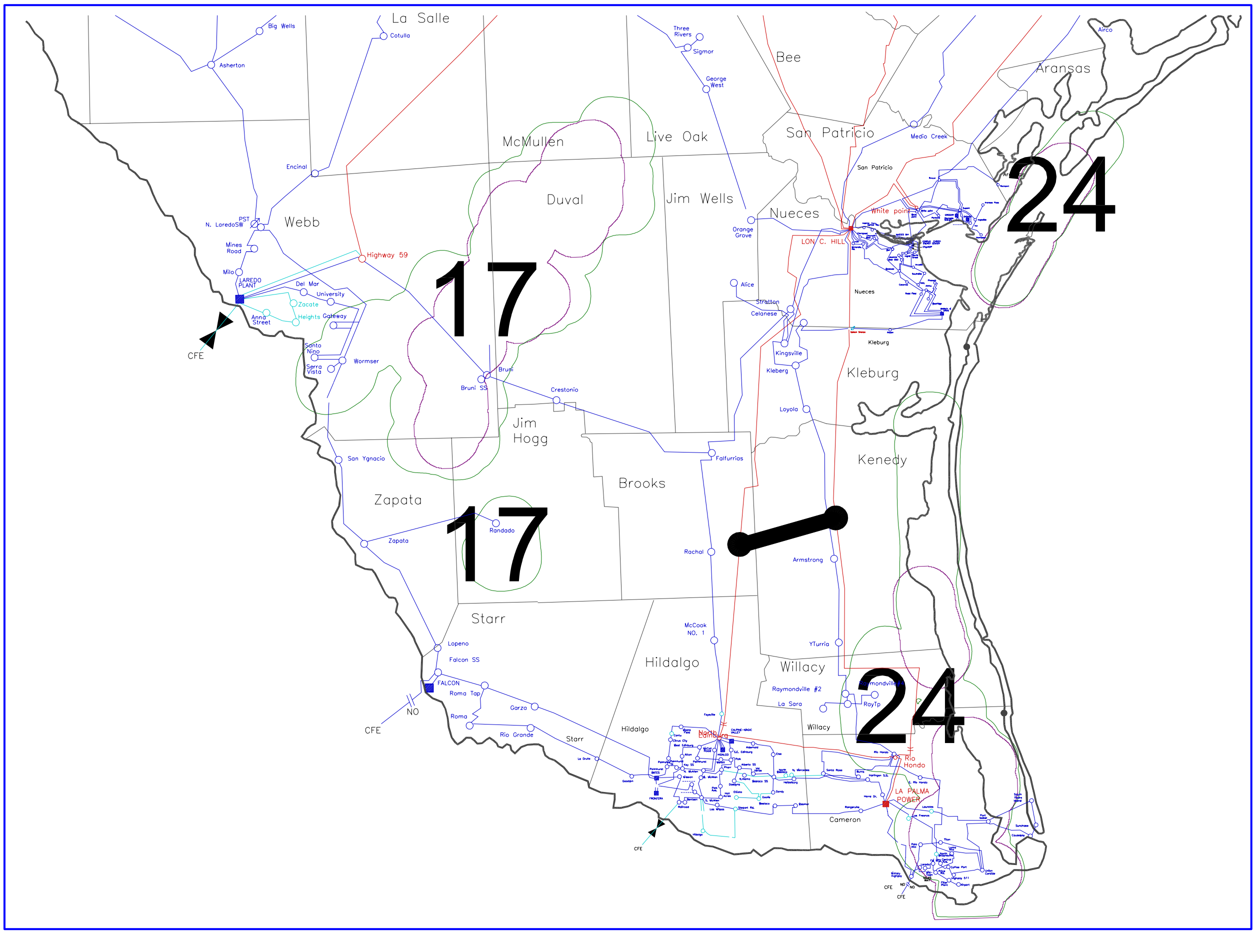


Figure 10: Second Level of Transmission Solution for Wind Zone 24

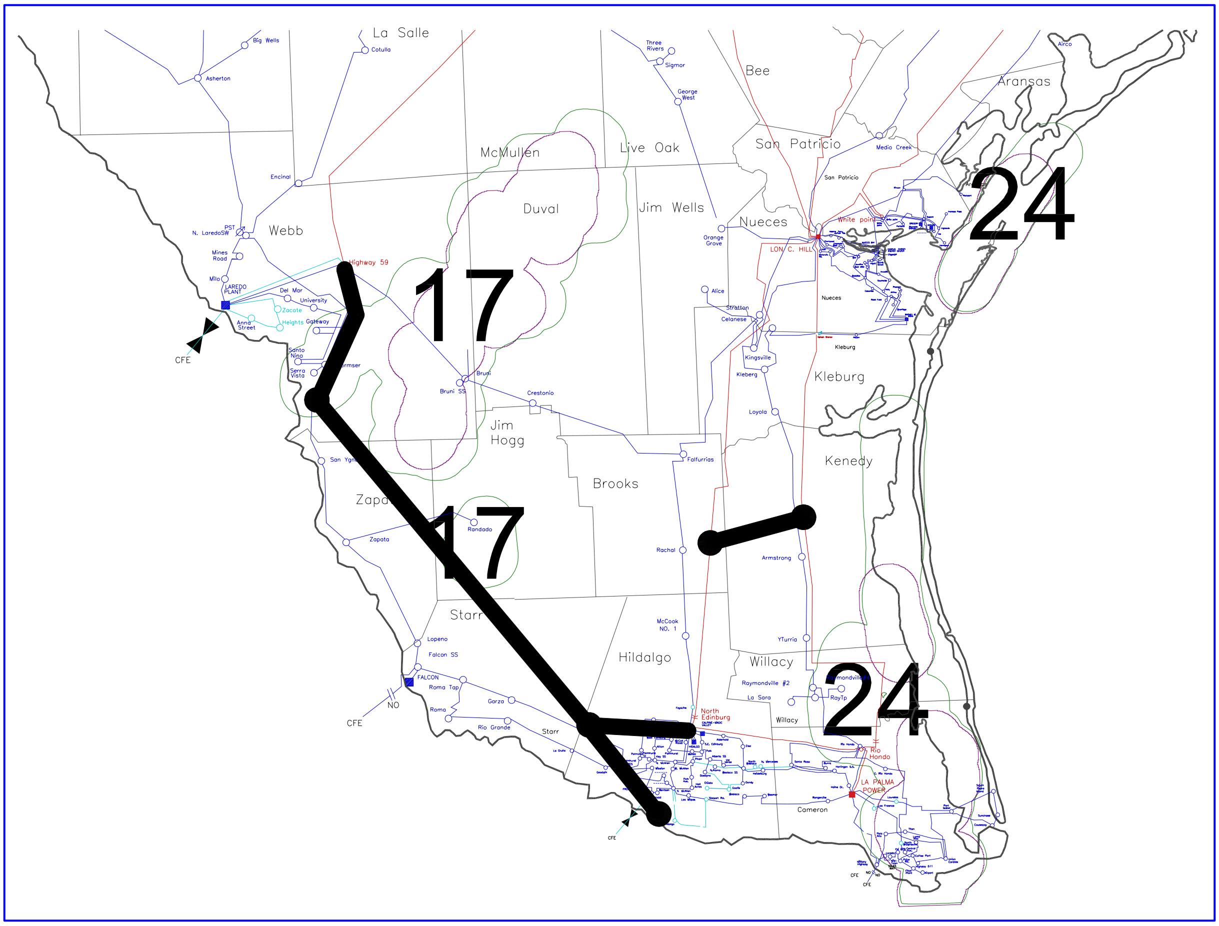


Figure 11: Third Level of Transmission Solution for Wind Zone 24

2. Central Texas

Three independent transmission system improvements have been identified for wind resources in the Central-Western portion of the state (wind zones 9, 10, 12, and 14). Alone or in combination, these improvements allow the interconnection of between 1,400 and 4,000 MW of new wind capacity to the transmission system in these zones.

The first path could integrate about 2,000 MW of new wind generation capacity in central Western Texas. This path, which generally connects the Red Creek substation to the Hill Country, is depicted in Figure 12, and includes the following components:

1. A new 345-kV line from Red Creek to Ferguson, or similarly situated substation in the Hill Country area west of Austin.
2. A second 345-kV Twin Buttes – Red Creek line on a separate right-of-way
3. A new 345-kV line to distribute the power from the 345-kV line amongst several 138-kV circuits in the Hill Country area and up to five new 345/138-kV autotransformers at or near two or more existing substations.

Specific terminations in the Hill Country area were assumed for the analysis, but additional analysis of the feasibility of specific substations and line routes is especially needed in this area.

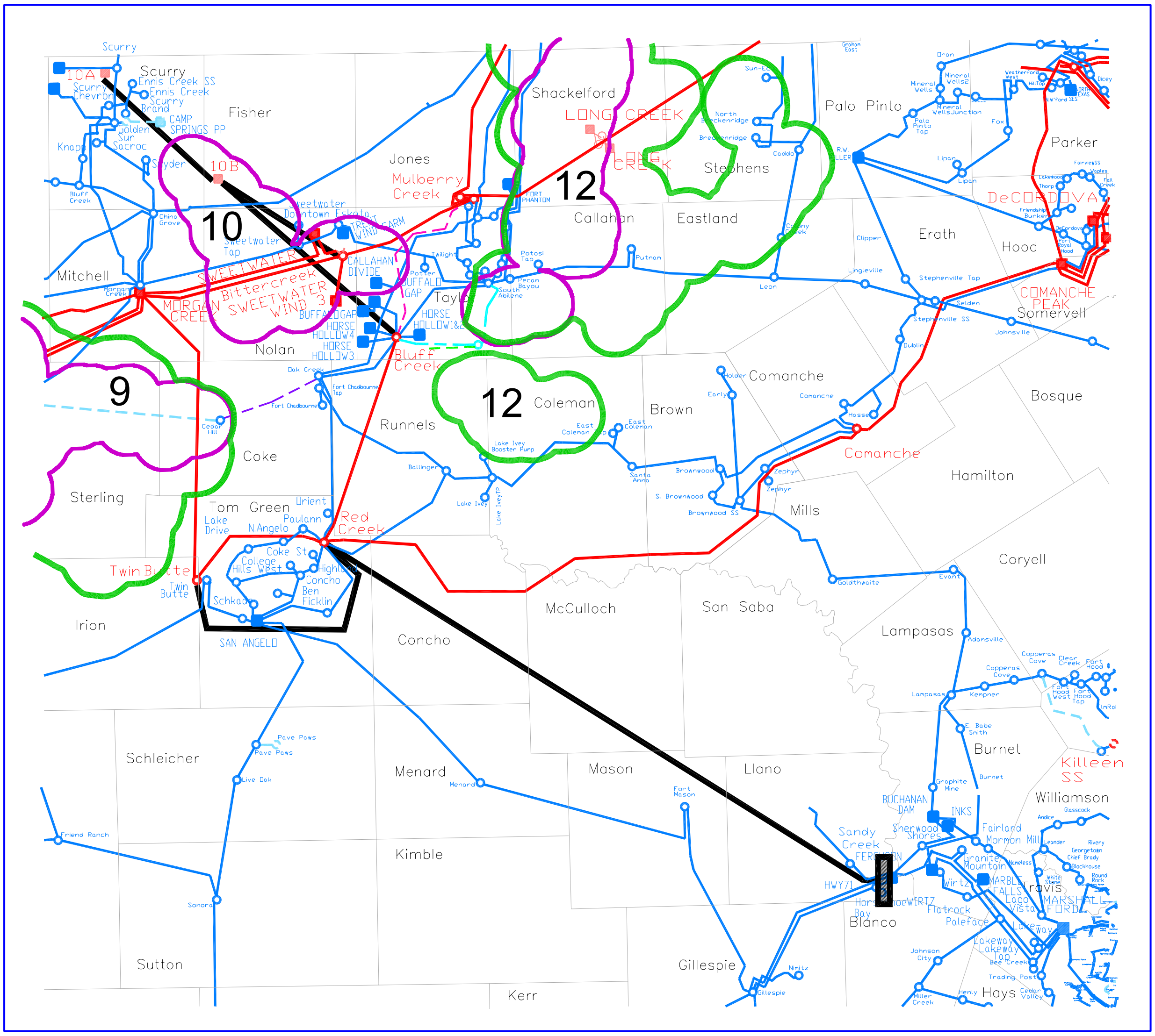


Figure 12: Red Creek to Hill Country Option

Figure 12 shows connections into wind zones 10 and 14. For these zones, the following additional system improvements would be required:

1. New substations in Fisher, Scurry and possibly Garza Counties
2. New 345-kV lines from substations in north-central Scurry County (and/or Garza County) to substation in southwest Fisher County.
3. New 345-kV lines from southwest Fisher County substation to the Bluff Creek and the Bittercreek substations.

Similar improvements would be required to connect wind resources in zones 9 and 12.

LCRA is working with ERCOT to determine the best location for new 345-kV connections in the Hill Country. The final set of connections for this set of improvements has not yet been determined, and therefore the cost estimates contained herein may vary from those stated. This project list includes 316 miles of transmission, five new autotransformers, and two new substations, for an estimated cost of $376M.

The second new path for connecting wind resources in Central Western Texas runs generally due east from the planned Paint Creek 345-kV substation to west Fort Worth. These improvements can integrate approximately 1,800 MW of new wind capacity. This alternative is depicted in Figure 13, and consists of the following improvements:

1. A new 345-kV line from the new Paint Creek 345-kV substation to the Willow Creek substation.
2. A new 345-kV line from the Willow Creek substation to the Saginaw substation.
3. Two new 345/138-kV autotransformers at the Saginaw substation.

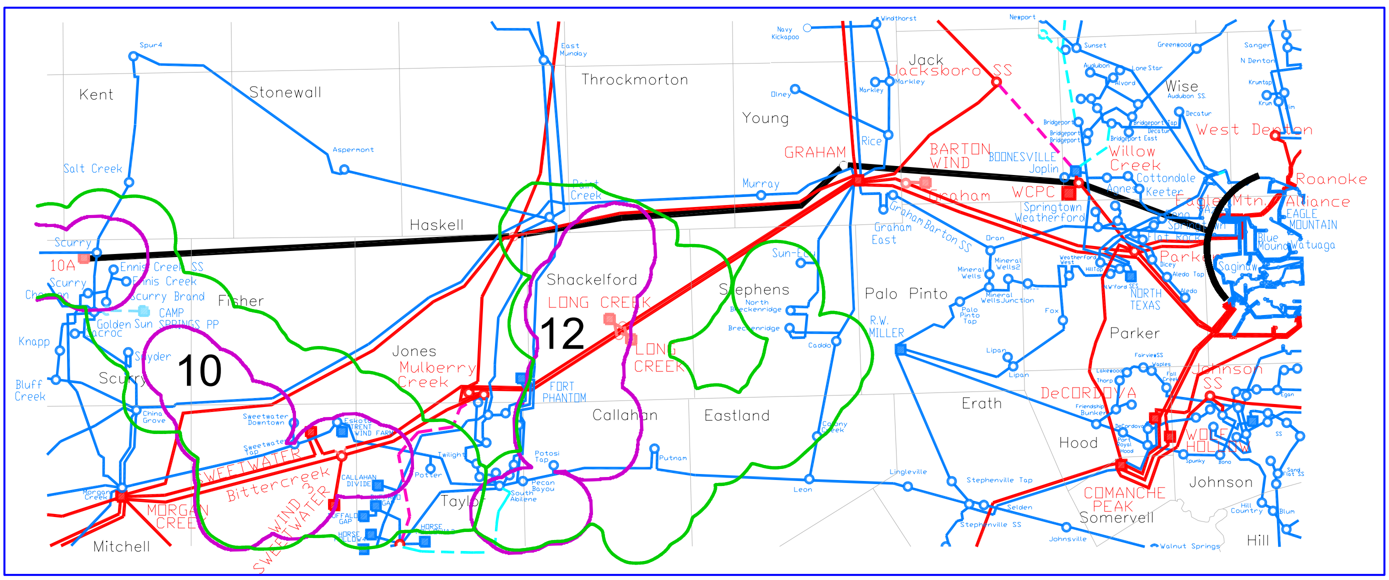


Figure 13: Paint Creek to Fort Worth Option

Additional connections are required from the Paint Creek substation to the specific wind zones to be connected. Figure 13 shows connections to wind resources in zone 10, specifically new 345-kV lines from north-central Scurry County) to the new Paint Creek substation.

TXU Energy Delivery is analyzing specific routing limitations associated with this alternative. ERCOT System Planning will incorporate the results of their analysis when they are provided.

This alternative includes 216 miles of transmission, two new autotransformers, and one new substation, for an estimated cost of $258M.

The third alternative for connecting new wind capacity in central Western Texas connects the Bluff Creek area with the Bosque substation, and includes a new switching station near Selden, on the existing Comanche Switch – Comanche Peak 345-kV line. This alternative is depicted in Figure 14, and consists of the following transmission projects:

1. A new switching substation near Selden, about half-way along the length of the existing Comanche Switch – Comanche Peak 345-kV line.
2. A new 345-kV line from Bluff Creek to Selden.
3. A new 345-kV line from Selden to Bosque.
4. A new 345-kV line from Bosque to Pecan Creek, going around the west side of Waco.
5. A new 138-kV line from Bosque to Elm Mott.
6. Moving the proposed Silver Star windpower project from the 138-kV Lingleville interconnection to a 345-kV interconnection on the Bluff Creek – Selden line.
7. A third 345/138-kV autotransformer at Whitney.

This alternative, as depicted in Figure 14, includes connections into wind zones 10 and 14. Similar connections would be required for connecting into other areas in central Western Texas.

This upgrade path by itself would allow the incorporation of approximately 1,400 MW of new wind capacity in central Western Texas. This project list includes 330 miles of transmission, one new autotransformer, and three new substations, for an estimated cost of $381M.

The three individual options for the Central West Texas area have been used to provide three cumulative solutions for this area. The first level solution for potential CREZs in the Central West Texas area is the Red Creek to Hill Country option described above, which would support approximately 2,000 MW of new CREZ wind generation in this area.

The second level solution for this area is the addition of the Bluff Creek to Bosque option described above to the Red Creek to Hill Country option. This cumulative second level transmission solution supports about 3,000 MW in the Central West Texas areas at a transmission capital cost of $727 million.

The third level solution for this area is the combination of the Red Creek to Hill Country option, the Bluff Creek to Bosque Option and the Paint Creek to Fort Worth option. This combination supports about 3,800 MW of new wind generation in the potential CREZs in this area at a cost of $955 million.

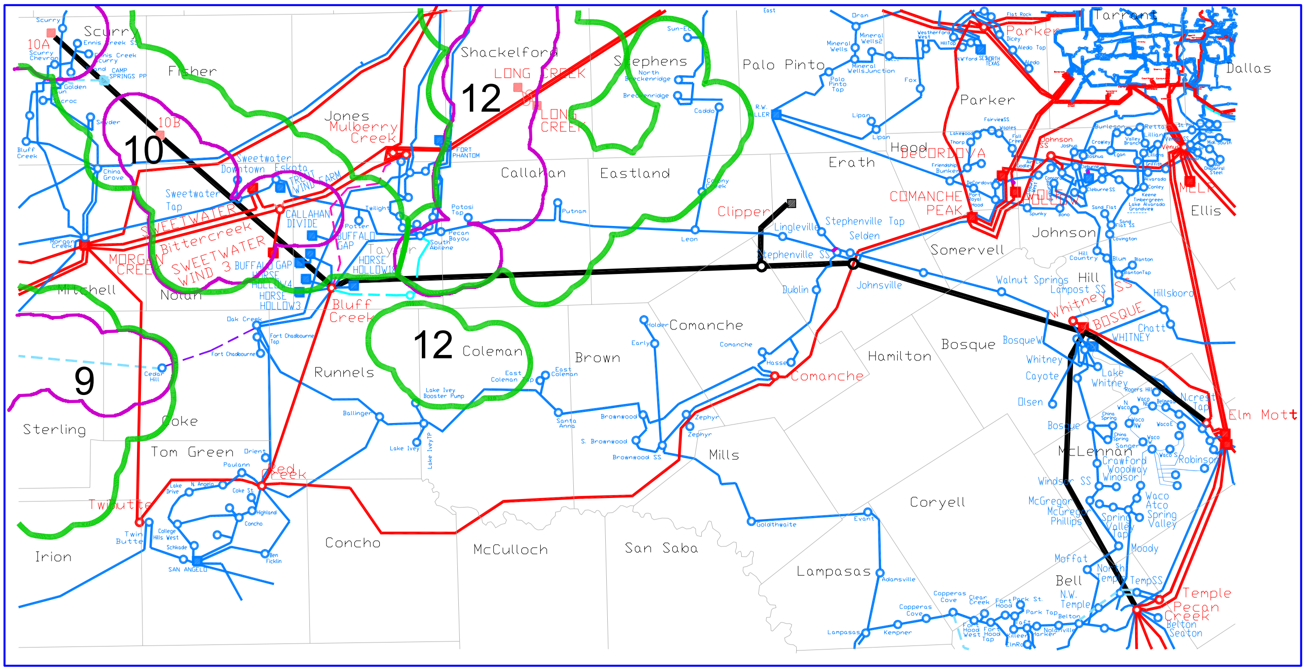


Figure 14: Bluff Creek to Bosque Option

One option was modeled for connecting wind resources in Culberson County (wind zone 7) to the ERCOT transmission grid. This option started with the Level 1 option (Red Creek to Hill Country) described above, but, instead of connecting to new wind capacity in zones 10 and 14, this scenario included a new 345-kV circuit from the Odessa EHV bus due west to Culberson County. Approximately 1,500 MW of new wind capacity in wind zone 7 could be connected to the system using this alternative. The estimated cost of this option is $380 million. Connecting additional wind generation capacity would require an additional radial line from the Odessa EHV bus to Culberson County, significantly increasing the cost of this alternative.

3. McCamey Area

Two cumulative solutions have been identified for the McCamey area. The first level of transmission improvement can be used to integrate approximately 1,500 MW of new wind capacity in the McCamey area (zones 5 and 6 on Figure 5). This solution is based on the Red Creek to Hill Country alternative presented above, except instead of connections from Twin Butte towards the north (to zones 9, 10, 12, or 14), a new 345-kV line is constructed from Twin Butte towards McCamey in the west. The exact location of the new substations in zones 5 (and or 6) would be based on wind developer interest. This alternative is depicted in Figure 15. This project list includes 250 miles of transmission, five new autotransformers, and two new substations, for an estimated cost of $320 million. The reason this solution is limited to 1,500 MW of new wind capacity is the restriction that radial transmission lines not carry more than

1,500 MW of generation capacity. In order to have more generation in this alternative, an additional radial line would have to be constructed along a separate right-of-way, increasing the overall cost of this alternative by as much as $80 million dollars.

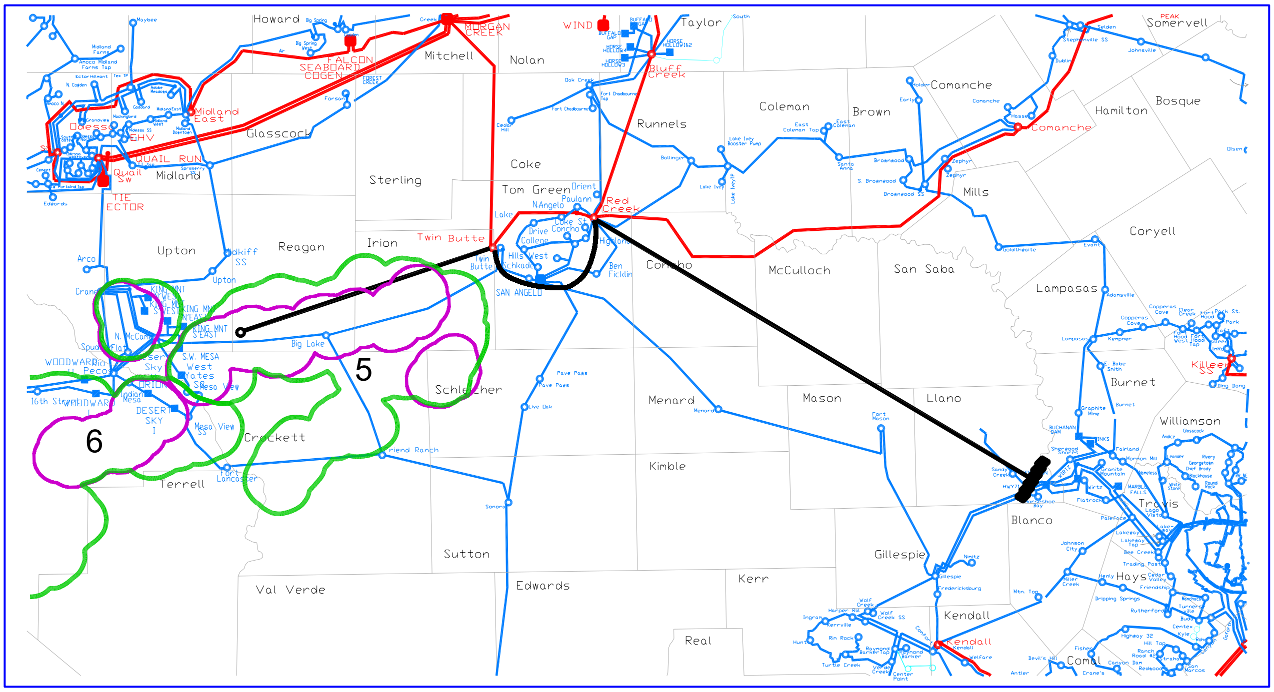


Figure 15: First Option for New Wind Resources in the McCamey Area

The second level of transmission improvement for the McCamey area can be used to incorporate approximately 3,800 MW of new wind capacity in the McCamey area. This alternative is depicted in Figure 16 and consists of the improvements described above, along with the following additions:

1. A new 345/138-kV autotransformer at the existing McCamey substation
2. A new double-circuit 345-kV line from the McCamey substation to the Kendall substation, northwest of San Antonio
3. A new double-circuit 345-kV line from the McCamey substation to the Odessa EHV substation
4. Completion of the double-circuit 345-kV line from the McCamey substation to the Twin Butte substation
5. Additional substations southwest of McCamey with 345-kV circuits connecting to the McCamey substation, as needed, to connect additional wind farms
6. A new 345-kV circuit from the Kendall substation to the Killeen substation, with intermediary connections at Gillespie, Ferguson, and possibly at Lampasas (and new autotransformers at these intermediary locations). ERCOT and LCRA are evaluating the exact configuration and connections for this circuit.

This transmission improvement includes (in addition to the improvements described in Level 1) one new substations, three new autotransformers, and 400 miles of new transmission line for an estimated cost of $861 million.

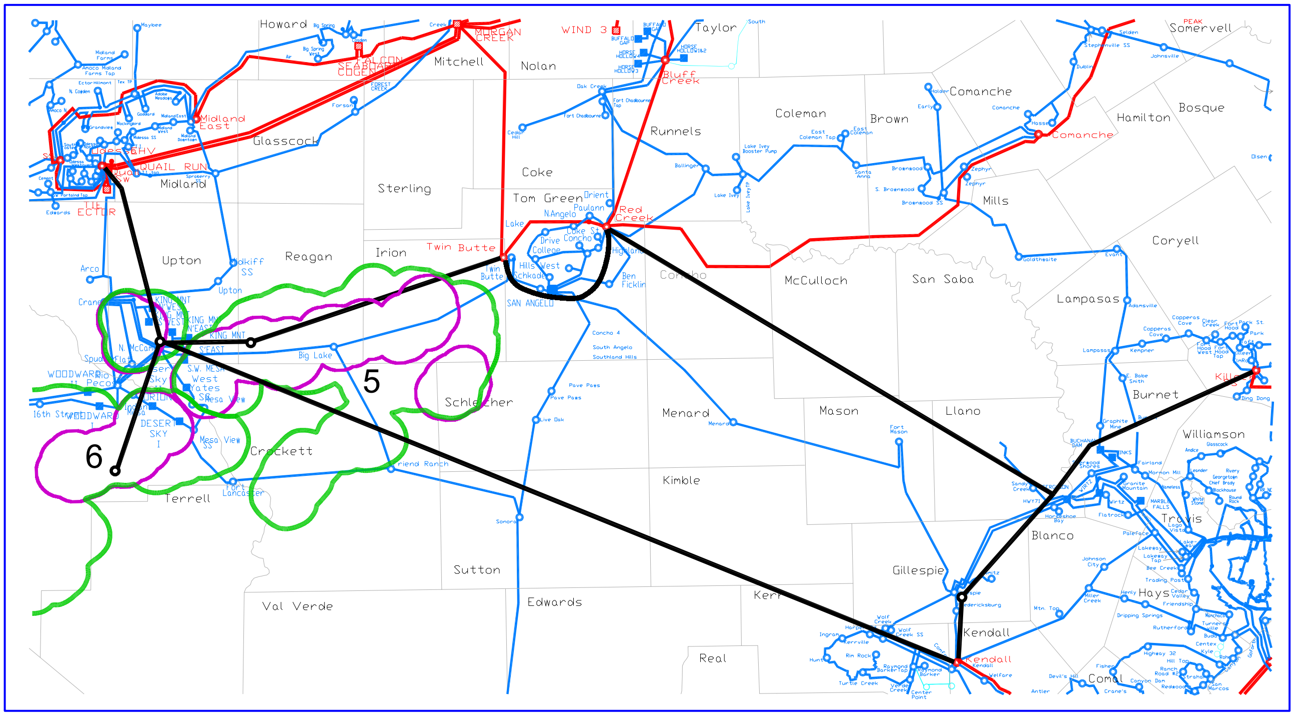


Figure 16: Second Option for New Wind Resources in the McCamey Area

4. Panhandle Region

Four options were identified for connecting resources in the Panhandle (wind zones 2 and 4) to the ERCOT transmission system. The first two options can be implemented independently from other solutions described in this section. The last two options include transmission solutions identified above, specifically the Red Creek to Hill Country and Bluff Creek to Bosque solutions. As a result, implementation of the last two options would be similar to connecting wind resources in zones south of the Panhandle (such as zones 10 and 14), and transmission capacity available would be affected by CREZ designations in other parts of western Texas.

The first level of transmission solution for the Panhandle consists of a new radial 345-kV transmission circuit from either zone 2 or zone 4 connecting to the existing Oklaunion 345-kV substation, a new 345-kV circuit from Oklaunion to Bowman, and from Bowman to Jacksboro, and then upgrades on the lines from Jacksboro to Willow Creek and then to Parker. The new circuit from Oklaunion to Bowman has been shown to have sufficient economic benefits in the Five-Year Plan to justify its construction. This transmission solution is depicted in Figure 17.

The costs of upgrades for the transmission lines from Oklaunion to Parker are estimated to be $100 million (not including the improvements that have been shown to be economic in the Five-Year Plan). This scenario also includes one new substation, and 150 miles of new transmission line (200 miles to zone 4), for an estimated cost of $265 Million to Zone 2, and $315 Million to Zone 4.

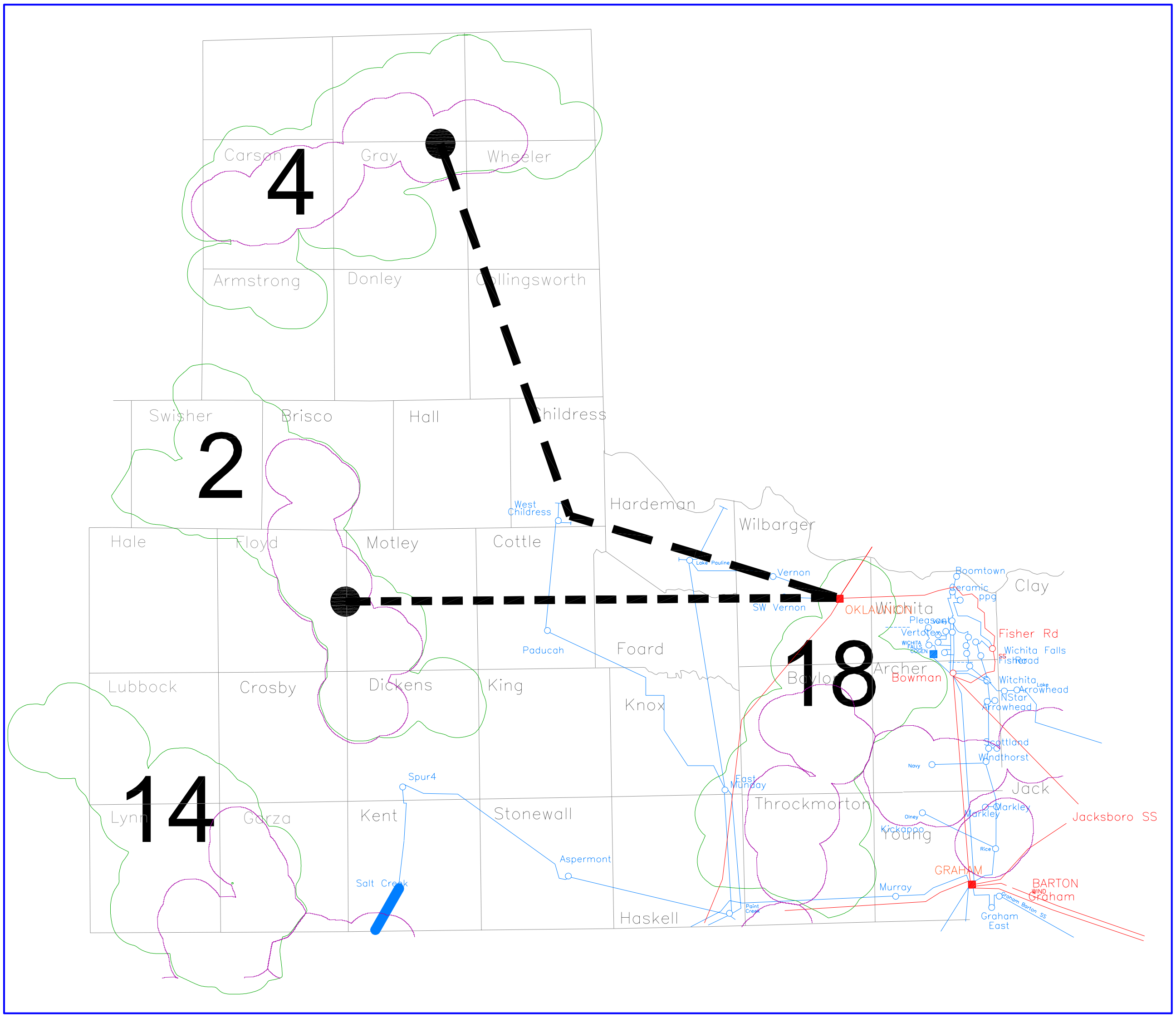


Figure 17: First Level of Transmission Improvement for Panhandle Wind Resources

The second level of transmission solution for Panhandle wind resources starts with the improvements included in level 1, but adds a new 345-kV circuit that runs east out of Oklaunion and connects to the planned West Krum substation north of Dallas. This additional circuit out of the congested Oklaunion substation allows a significant increase in the amount of wind capacity that can be installed in wind zones 2 and or 4. Since the capacity of this solution is greater than the 1,500 limit on radial transmission lines, two radial lines would be required (which would then allow connections in both zone 2 and zone 4). This transmission solution is depicted in Figure 18. It consists of two additional substations and 380 miles of new transmission line and has an estimated cost of $645 million. This price includes the cost of the level 1 upgrades described above.

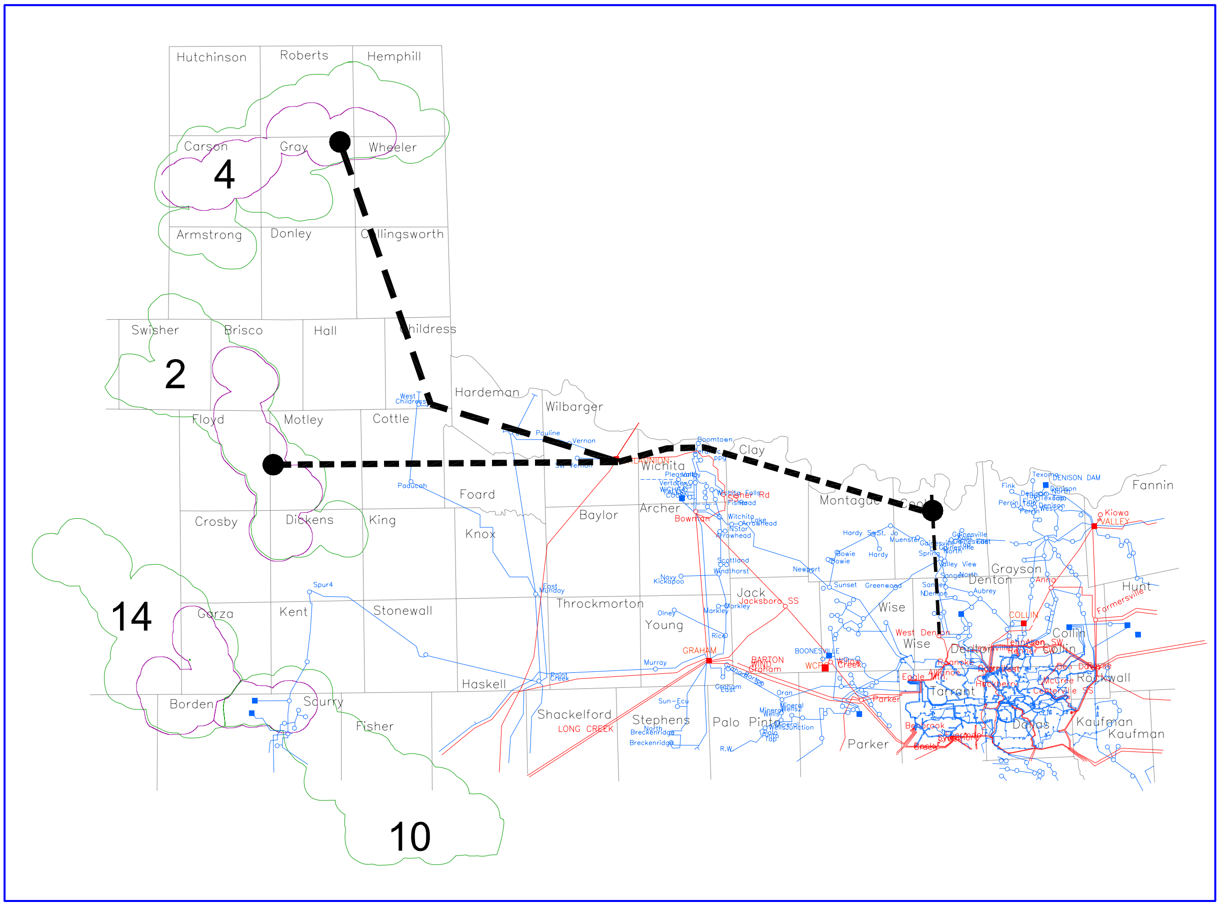


Figure 18: Second Level of Transmission Improvement for Panhandle Wind Resources

This transmission option has been designed to work with a proposed improvement on the Southwest Power Pool (SPP) system that could allow a transfer of wind capacity from the northern Panhandle of Texas to the Sunnyside substation, which is located near the Texas - Oklahoma border directly north of Dallas. A new direct-current interconnection between the Sunnyside substation and the new 345-kV substation depicted north of Dallas on the new circuit from Oklaunion to West Krum in Figure 18 would allow transfer of the wind energy through the SPP system from the Texas panhandle all the way to load customers in Dallas. Representatives of SPP have specified that their proposed long-range system upgrades will allow transfer of up to 600 MW from the Texas panhandle to the Sunnyside substation. Given the transmission upgrade shown in Figure 18, the ERCOT transmission system would be capable of supporting a 600 MW injection at this location.

The third level of transmission solution for Panhandle wind resources combines level 1, described above, and the Level 1 solution for Central Texas wind resources, also described above. The panhandle portion of this option is depicted in Figure 19 (the additional improvements would correspond to those depicted in Figure 12). This option includes all of the upgrades described as part of level 1 for the Panhandle Region, all of the upgrades included in the Level 1 alternative for Central Western Texas, as well as 70 miles of new transmission line from zone 2 to zone 10. The estimated cost of this option is $715 million.

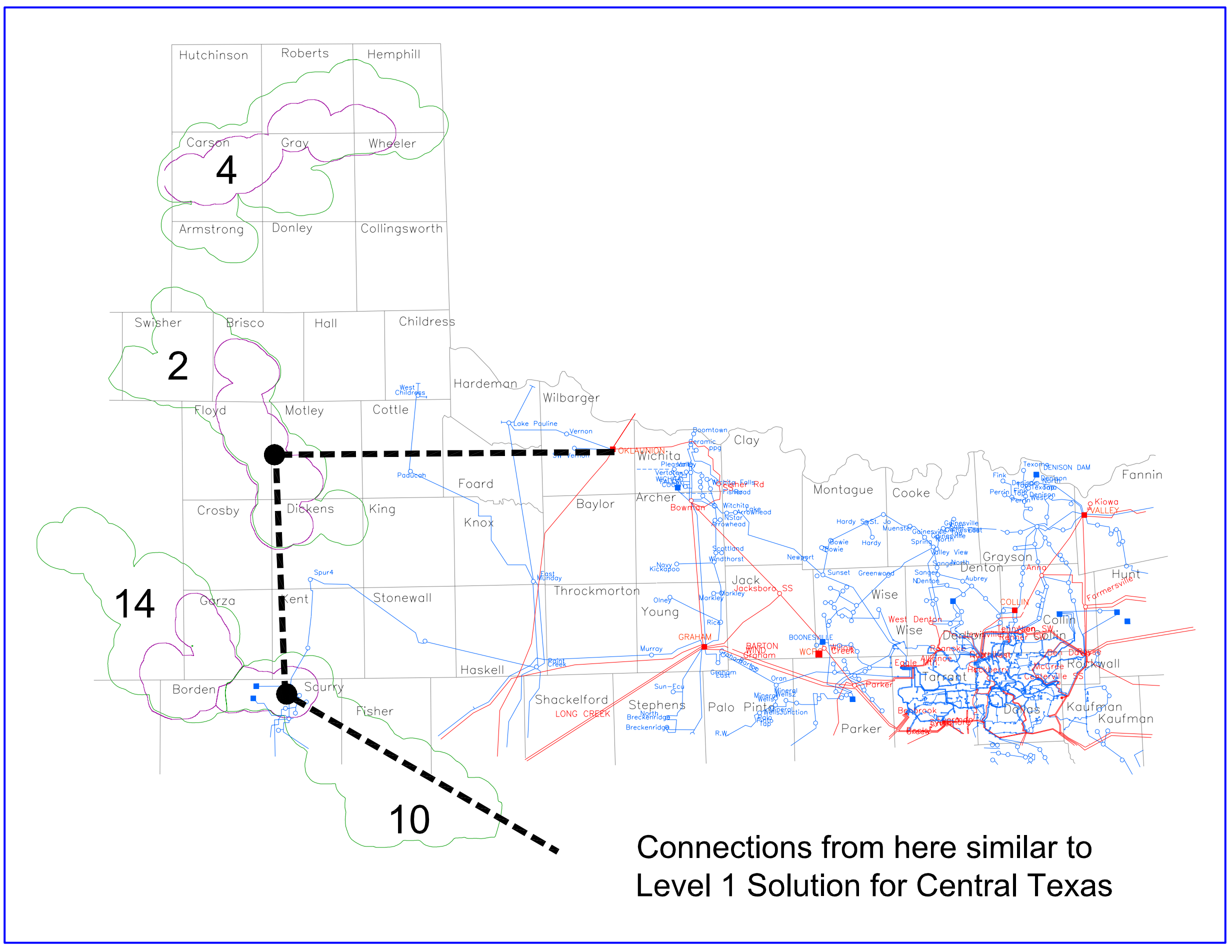


Figure 19: Third Level of Transmission Solution for Panhandle Wind Resources

The fourth level of transmission solution developed for Panhandle wind resources incorporates the improvements described in Levels 2 and 3 above (see Figure 18) along with the improvements included in both the Bluff Creek to Bosque option and the Red Creek to Hill Country option. This fourth Panhandle solution also includes the construction of a loop from the Oklaunion substation northwest up to Zone 4, and then southwest to Zone 2. This option is depicted in Figure 20. Its estimated cost includes the combined costs of the Red Creek and Bluff Creek options ($700 million), the cost of Level 2 described above ($645 million) as well as 170 miles of new 345 circuit (from zone 4 to zone 2, and from zone 2 to zone 10) for a total of $1,515 million.

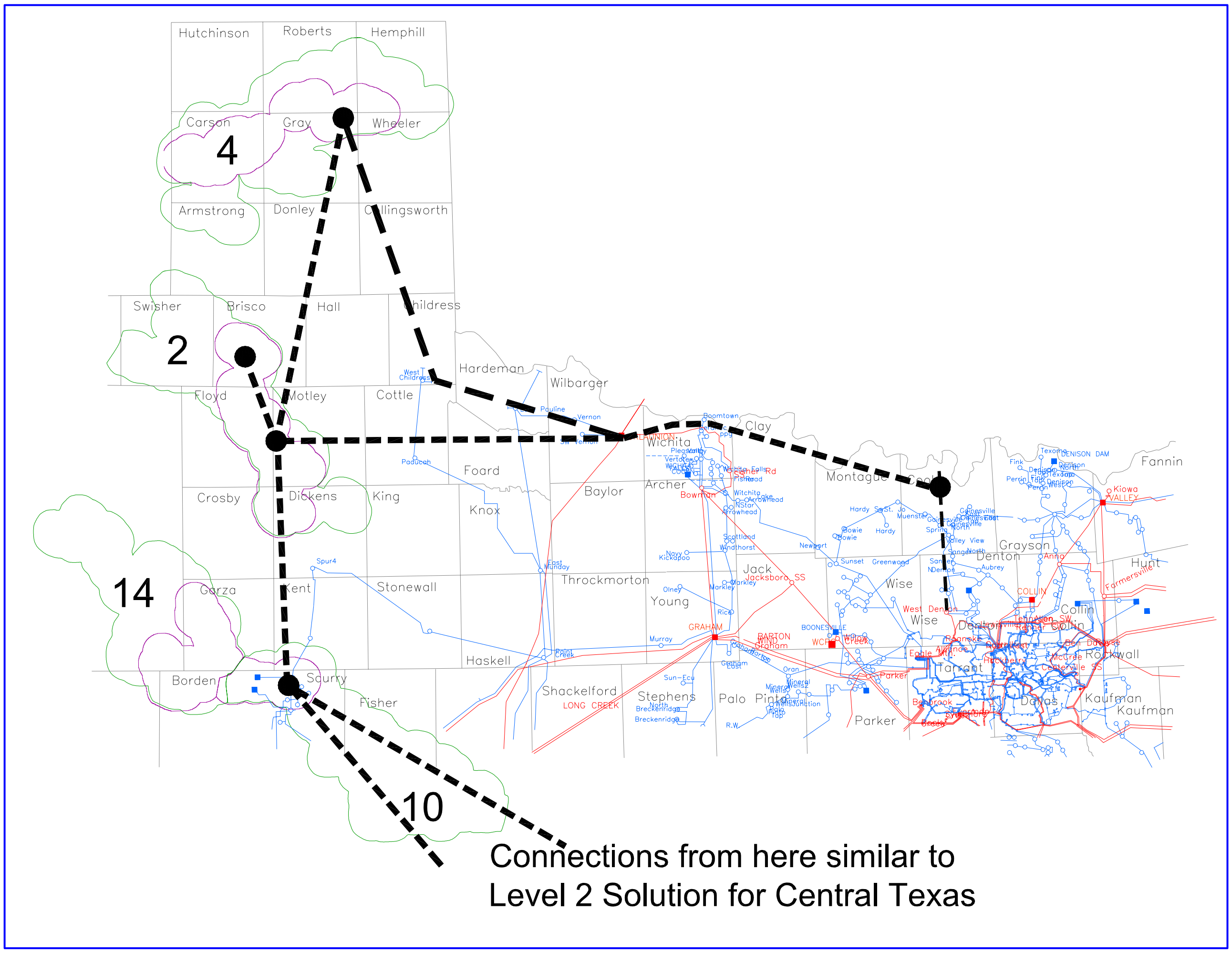


Figure 20: Fourth Level of Transmission Solution for Panhandle Region

5. Combination Scenarios

It is possible that the PUCT, after taking into account some type of commitment of interest by wind generation developers, will choose to designate some level of CREZ in more than one of the four discrete areas. It was not feasible to anticipate and evaluate all potential combinations of possible wind development interest in each zone within the available time. Therefore, ERCOT took the approach of evaluating different levels and distributions of new wind generation between two or more of the discrete areas and using different logical combinations of the building block transmission upgrades, until the distribution of wind between the areas that resulted in the highest total installed wind generation (with around a 2% total wind generation curtailment) was found for that set of transmission upgrades. Several combinations of transmission solutions were evaluated to determine their joint effectiveness at incorporating new wind capacity into the transmission system. If the level of CREZ interest varies significantly, in level or distribution, from the scenarios studied, ERCOT should perform an analysis of that combination to evaluate the exact transmission upgrades that would be needed to accommodate this interest. Several scenarios were run that included wind from central western Texas (zones 10 and 14) and the McCamey area. One additional scenario was evaluated that included wind from Zones 10 and 14, zone 5 (McCamey area), and zone 24 (the Gulf Coast area).

B. Modeling Results for Proposed System Improvements

The economic modeling results for each of these alternatives are provided in Appendix C (Tables C1 – C8). These results are summarized in Table 5. Two base cases, one with the common projects described in Section IV (I), and one without the projects, were used to calculate the changes in total system production costs and total system generator revenue. Two base cases were required because these common projects were not included in the Coastal Zone cases nor were they included in the first two scenarios for additional Panhandle wind capacity (because the new wind generation in these scenarios had a limited impact on the transmission capacity utilized by the existing wind generation). The base case without common projects had an annual total production cost of $13,378 million/year and an annual total generator revenue of $17,449 million/year. The base case with the common projects had an annual total production cost of $13,376 million/year and an annual total generator revenue of $17,459 million/year.

The term annual total production cost equals the total cost to serve energy demand for one year, i.e., the cost to run the plants that generate the electricity to meet hourly demand. This value includes the costs of fuel, variable operations and maintenance, and unit startup. The term annual total generator revenue indicates the revenue that would be received by a generator being paid the sum of each hour’s generation multiplied by the generators hourly nodal price. Generator revenue also includes a make-whole payment to dispatchable generators to compensate them for hours during which they are required to stay on-line to meet system needs yet the nodal price is insufficient to pay their hourly costs, and for startup

Table 5: Summary of Economic Modeling Results

Scenario	New Wind Capacity (MW)	Transmission Capital Cost ($M)	Annual System Production Cost Savings ($M/Yr)	Annual System Generator Revenue Reductions ($M/Yr)	New Wind Average Capacity Factor (%)	New Wind Generator Capital Cost ($M)	Average New Wind Generator Revenue ($/MWh)	Annual System Production Cost Savings per kW New Wind ($/kW-Yr)	Annual System Generator Revenue Reductions per kW New Wind ($/kW-Yr)	Transmission Capital Cost per kW New Wind ($/kW)	Ratio of All Investment Costs to Production Cost Savings
Coastal Projects	A	B	C	D		E		C/A	D/A	B/A	(E+B)/C
Coastal Level 1	1,000	15	129	221	38.3	1,000	43.1	129	221	15	7.90
Coastal Level 2	2,000	75	262	437	37.1	2,000	40.7	131	218	38	7.93
Coastal Level 3	3,000	320	383	713	37.0	3,000	33.3	128	238	107	8.68
Central Western Texas Projects											
Level 1	2,000	376	276	464	40.1	2,000	29.9	138	232	188	8.62
Level 2	3,000	723	406	727	39.0	3,000	29.6	135	242	241	9.18
Level 3	3,800	1,019	495	963	39.3	3,800	28.9	130	253	268	9.74
McCamey Projects											
Level 1	1,500	320	198	406	40.5	1,500	32.3	132	271	213	9.21
Level 2	3,800	861	506	1,069	41.0	3,800	30.2	133	281	227	9.22
Panhandle Projects											
Level 1	800	265	112	247	43.2	800	33.2	139	309	331	9.55
Level 2	1,800	645	249	474	43.3	1,800	32.8	138	263	358	9.84
Level 3	2,400	715	297	620	42.8	2,400	26.2	124	258	298	10.50
Level 4	4,600	1,515	587	1,250	42.5	4,600	27.1	128	272	329	10.42
Combination Projects											
Central Level 2 with New Wind in Central (2,000 MW) and McCamey (1,250 MW)	3,250	863	443	796	39.8	3,250	30.0	136	245	266	9.29
Central Level 3 with New Wind in Central (3,000 MW) and McCamey (1,000 MW)	4,000	1,159	520	992	39.0	4,000	29.1	130	248	290	9.92
Central Level 2 and Coastal Level 2 with New Wind in Central (2,000 MW), McCamey (1,250 MW) and Coastal (2,000 MW)	5,250	938	705	1,278	38.8	5,250	31.9	134	243	179	8.78

New Wind Capacity for each scenario is the level of new installed wind generation that results in ~2% overall wind energy curtailment

Transmission Capital Cost for each scenario does not include the cost of projects that may be needed to mitigate the impact of the added CREZ generation on existing resources (as described in Section IV (I) of the report).

costs that are incurred for system reliability. The Annual Production Cost Savings and the Annual Generator Revenue Reductions, shown on the table for each scenario, compare the annual total production cost and annual total generator revenue, respectively, for that scenario to the annual total production cost and annual total generator revenue from a simulation of the system without any new CREZ wind or associated transmission upgrades. The term "New Wind Capacity Energy Revenue" is defined as the average hourly nodal price paid to the new wind units added in each scenario.

As noted previously, the term capacity factor is the percentage of energy actually produced by a unit compared to the amount it would have produced if it operated at its nameplate rating over an entire year. As discussed in Section IV(F), the total cost of energy from a wind project will decrease by approximately $1.50/MWh for every 1% increase in capacity factor, all other factors being equal.

In order to calculate the ratio of all investment costs to the annual production cost savings, the investment capital required for the transmission improvements was added to the investment capital required for the new wind generation. The result, for each scenario, was divided by the total annual production cost savings. This result can be used to judge one possible scenario against another, based on total societal benefit. Although this number allows comparison between scenarios, it does not represent actual societal benefits. The capital costs for transmission capacity, which will be paid through a regulated rate-making process through a load-weighted charge to all customers, does not represent the same costs to society as the market-based (i.e., at risk) investment of capital for new wind generation.

VI. DISCUSSION

A. Comparison of Alternatives

The analysis described in this report has indicated a need for additional pathways between areas with significant wind resources, most notably areas west of Abilene, and significant load centers, generally along and east of the Interstate 35 corridor. The existing ERCOT 345-kV system generally resembles V rotated towards the left, with one side of the V extending from Odessa to the Dallas/Fort Worth area, and the other side made up of the relatively integrated system covering a triangular area with Dallas, San Antonio and Houston at the vertices.

Results from the base case of this study, which includes 4,850 MW of wind capacity in West Texas, indicate that in the vicinity of the vertex of this inverted V, near Fort Worth, the 345-kV system is supporting about as much wind generation as it can. The transmission system generally from the Oklaunion substation south through the Graham substation and to the Parker substation cannot support any significant new additions of wind generation beyond what the 4,850 MW in the base case (although it should be noted that this amount includes approximately 1,500 MW of proxy wind generation for which there is not signed interconnection agreements). This leads to the main result of this study: that there is a need for more corridors that cross the divide of this inverted V, i.e., corridors that run generally from West Texas to the east and southeast, rather than northeast towards Fort Worth.

It is also noteworthy that although the 345-kV system in East Texas is well-developed, there are several areas of significant load growth on the western side of this area that are not served by any 345-kV circuits. This is the case in the Hill Country, from northwest San Antonio to Killeen, where significant load growth is currently projected to be served only by the existing 138-kV system. Areas such as this can be good locations for end points for lines originating in the wind generation zones because they have sufficient load to absorb the output of new wind generation. However, because there is no existing 345-kV infrastructure in these areas, additional circuits must be planned so that the injection of wind energy does not exceed the capacity of the existing 138-kV system.

This study also shows that the existing congestion in the area from Oklaunion to the Parker substation significantly limits additional power-flows in this area, even with the addition of new circuits. Even with significant upgrades on the lines from Oklaunion to Parker, the system in that area can only support 800 MW of new wind generation capacity. With an additional new circuit from Oklaunion to north Dallas (terminating at the proposed West Krum substation), only an additional 1,000 MW of wind capacity can be supported (for a total of 1,800 MW). Because the existing system is being utilized near its limitations, incremental additions in this area do not provide significant amounts of additional transfer capability.

The exact opposite situation exists near the Gulf Coast, where there is no existing wind generation, so very few system improvements must be made in order to support the first incremental amounts of wind. However, there are currently over 4,000 MW of wind generation in the ERCOT interconnection queue in South Texas. If all of these projects are developed, the total capacity would exceed the three levels of system upgrades that have been identified during this study.

B. Economic Considerations

It is a common simplification of open markets to assume that the consumer will eventually pay for all resources required to supply a product. In the case of electricity, the consumer will eventually pay for all of the resources required to produce and to transport the electricity. In other words, the consumer will pay for the capital to build the generator, the fuel to run the generator and the transmission system designed to serve loads securely.

It is important to consider that the consumer will have to pay for the capital costs of wind generation, in addition to the transmission costs that have been estimated as part of this analysis. The same can be said for all generation technologies. The comparison of the total costs of wind energy to the total costs of other technologies is beyond the scope of this study. Quantifying the other benefits from renewable technologies, such as human health impacts from reduced fossil-fuel emissions, increased fuel diversity, reduced reliance on natural gas generation, impacts of reduced demand on related markets (such as natural gas and coal), benefits from economic development, to name a few, are also beyond the scope of this study.

This study examines one aspect of designating Competitive Renewable Energy Zones, specifically what are the most cost-effective solutions to improve the transmission system and allow transportation of additional wind energy from high wind zones to customer load while maintaining system security. The results provided in this document should not be viewed as documenting all costs or all benefits to consumers associated with CREZ designations.

C. Impact of Wind Curtailment

Defining the amount of new wind generation that can be added to the system, given a specific transmission solution, is contingent on the answer to the question of how much wind curtailment is acceptable. Unfortunately, wind curtailment is a complicated issue.

First and foremost, curtailment of energy to relieve transmission congestion can represent a significant economic impact to a wind project, since the owner of a wind project relies on generation supplied to the grid for three income streams: energy revenue, the sale of renewable energy credits, and Federal Production Tax Credits.

Further complicating this issue is the fact that curtailment is not expected to affect all wind units equally; it is more likely to affect existing wind units than the new wind generation facilities built in Competitive Renewable Energy Zones. This is demonstrated in Figure 18, which depicts the amount of wind curtailment for several scenarios. Each scenario contains the Red Creek to Hill Country transmission improvement, and in each scenario a different amount of new wind generating capacity has been added into zones 10 and 14, with total capacity of new wind ranging from 1,000 MW to 2,400 MW. The chart indicates that the new wind is not affected by curtailment of energy until more than 2,200 MW of new wind capacity has been installed. However, the existing wind resources are affected by additional energy curtailment even in the scenario with only 1,400 MW of new wind capacity.

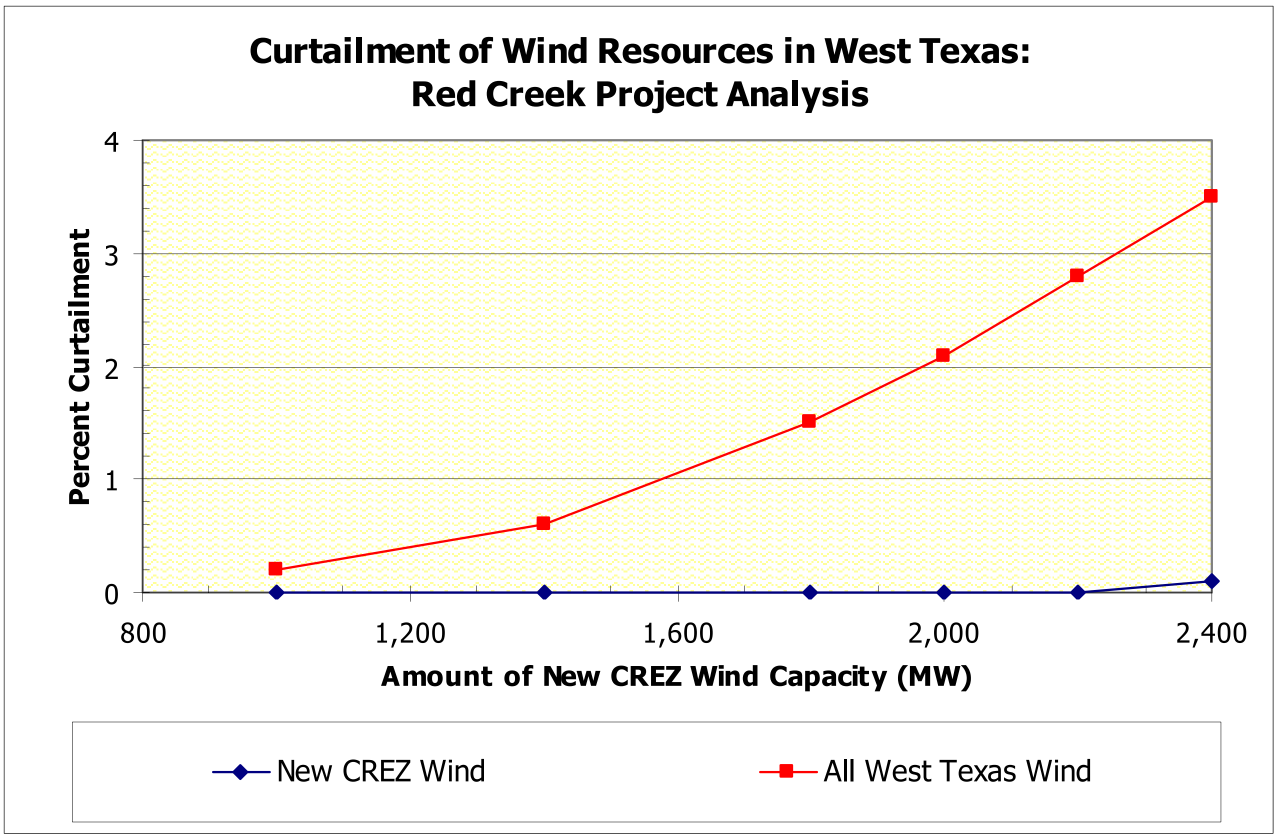


Figure 18: Curtailment of Wind Resources

Assuming that wind units will have similar bids in a nodal market, curtailment will have the largest impact on units that have the highest shift factors on the limiting elements of the transmission system. Even with the addition of significant new 345-kV lines, as identified in this study, the limiting elements for transfers from West Texas will likely include elements of the 138-kV circuits that extend from West Texas towards the North, East and South.

As proposed in this study, new wind generation projects in Competitive Renewable Energy Zones will be connected to new 345-kV circuits and will thus have lower shift factors on the existing, older 138-kV circuits. In hours in which some wind generation must be curtailed in order to relieve constraints on the transmission system, the most economic solution will be to limit generation of the wind units with the highest shift factors on the limiting element(s). The first of these wind units to be curtailed will likely be older wind projects connected to existing 138-kV circuits in the immediate vicinity of the limiting element(s).

In addition, certain existing wind generators may be more affected than others. Figure 19 shows the differential impact of expected curtailment on different wind units for the scenario with the Red Creek to Hill Country transmission improvement with 2,000 MW of new wind capacity (the fourth data point depicted on Figure 18). Note that in this run the overall curtailment of all wind units is just above 2%, which means that about 2% of the energy that all of the wind units in the case could have produced, given the meteorological modeling and analysis conducted by AWS Truewind, could not be accepted by the transmission system and had to be curtailed in order to maintain n-1 system security. In Figure 19, each of the existing wind units in the model is labeled by a number. The last of these units, number 36, represents the 2,000 megawatts of new wind capacity located in the proposed wind zone.

This disparity in unit-by-unit curtailment exists even with the common projects (described in Section IV[I]) that were generally developed to reduce the impact of new CREZ wind capacity on existing wind generation. Other scenarios provide similar results, with different existing units being affected, depending on which elements in the existing system become the most congested following incorporation of new transmission improvements.

There will be a direct relationship between the amount of wind developed in any new CREZ and the amount of curtailment of existing wind generation. For the purposes of this study, ERCOT has described levels CREZ wind capacity consistent with ~2% overall wind curtailment. The choice of the 2% overall curtailment criteria was arbitrary; the acceptable amount of wind capacity in each CREZ should be reevaluated by the PUCT recognizing the disparity of impacts.

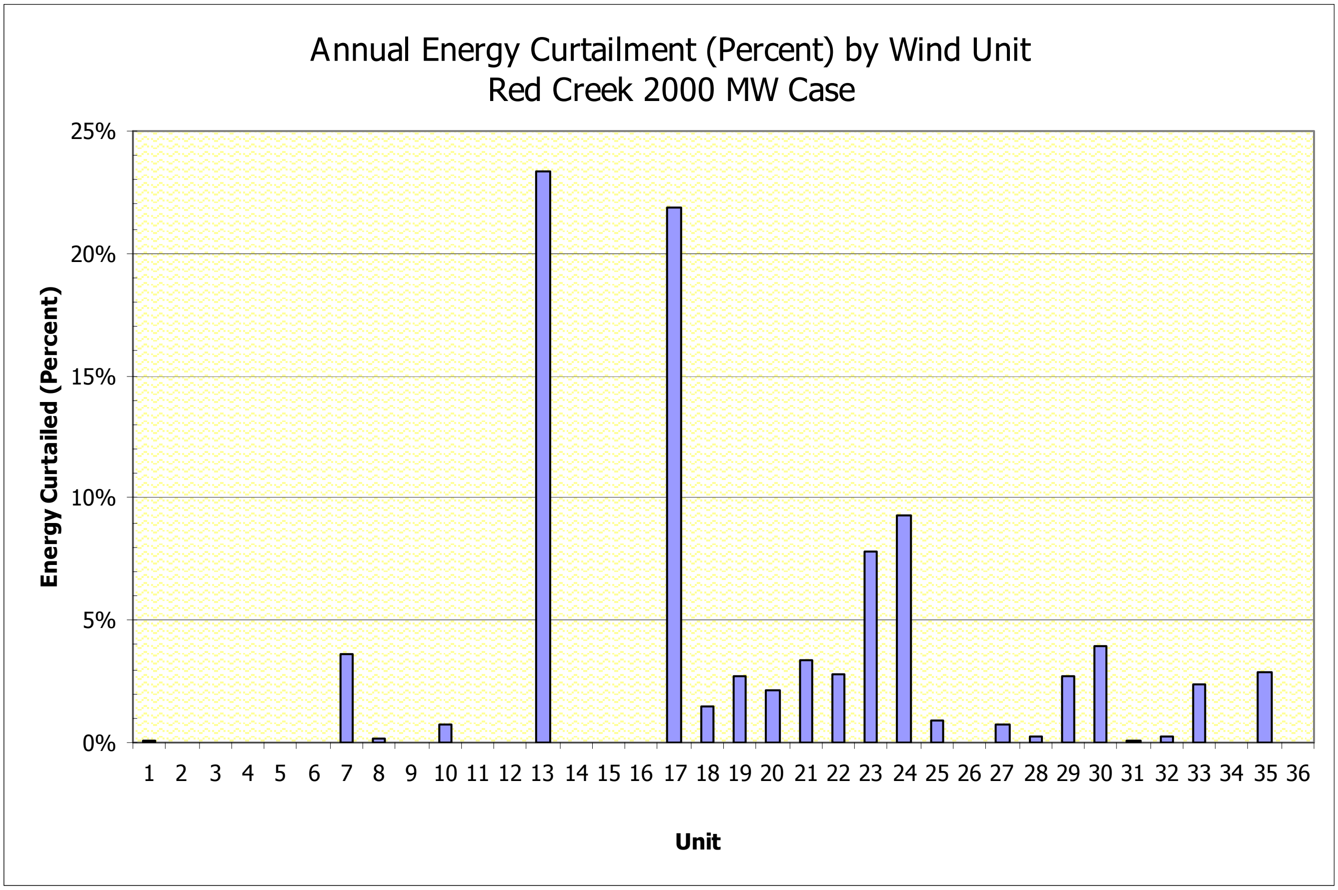


Figure 19: Wind Energy Curtailment by Unit

The established transmission planning process conducted by ERCOT System Planning through the development of the Five-Year Plan will include an evaluation of all constraints on existing wind generators. Economically feasible projects will be proposed to stakeholders and evaluated through the Regional Planning process. Remaining constraints that cannot be resolved through the economic planning process may need to be reevaluated by the PUCT as part of future iterations of the CREZ designation process.

D. Additional Wind Added to the System

One of the most important assumptions used in this study is the amount and location of wind in the base case. These 4,850 MW of "base-case wind units" are comprised of wind units that are currently in operation, wind projects that are under development and for which there is a signed interconnection agreement, and a set of proxy units, representing a small fraction of the wind generation projects that are currently in the ERCOT interconnection queue. Of these base-case units, it is likely that the existing projects and almost all of the projects in development with an interconnection agreement will be operational during the 2009 study year. However, it is likely that some of the additional projects in the interconnection queue will be operational in 2009, regardless of the CREZ designation. However, it is not known how many or where these projects will be located on the system.

The amount and location of these projects will likely have an impact on the amount of additional wind that can be added in the designated wind zones. Put another way, for a given amount of new wind resources developed in a specific wind zone, the amount and location of these other wind resources will have an impact on the distribution and aggregate amount of curtailment of wind resources. Unfortunately, there is no way to avoid this situation. The speed with which new wind projects can be developed, compared to the extensive amount of time it takes to design, permit, and construct large transmission projects, will always result in a lag between the projected wind resources when a transmission study is conducted and the actual projects implemented when the transmission project is complete.

ERCOT System Planning will continue to track generation projects as they enter and progress through the interconnection queue and will keep the PUCT apprised of any significant impacts to overall transmission planning resulting from new generation projects. In addition, ERCOT System Planning will continue to develop the annual Five-Year Plan, evaluating possible transmission system upgrades over the next five years to maintain system reliability and to maximize system cost-benefits. This Five-Year Plan will include all projects that cost-effectively relieve congestion on existing and on planned generation projects for which there is a signed interconnection agreement.

E. Other Considerations

Numerous solutions were evaluated in the course of this study. These solutions included new 345-kV rights-of-way, improvements of existing 345-kV and 138-kV circuits, and new 765-kV rights-of-way.

1. System Upgrades Using 765-kV Circuits

A significant amount of time was spent evaluating the costs and benefits of new 765-kV circuits. In general, 765-kV circuits have much lower impedances than 345-kV circuits. Given a choice of using 345-kV or 765-kV for a new connection between to buses, more current is likely to flow on the 765-kV circuit, resulting in less loading on the lower voltage circuits.

However, in contingency analysis, the loadings on the lower voltage circuits will be the same if a new 345-kV circuit is opened or a new 765-kV circuit is opened. In situations where the limiting elements on the system are existing 138-kV circuits that span significant distances, there are few, if any, benefits to building new 765-kV circuits instead of new 345-kV circuits. This is the case in much of West Texas, where the only 345-kV circuits run generally from West Texas to Fort Worth, through either the Graham or the Comanche buses.

Two other considerations regarding analyzing 765-kV circuits should be noted. The first is that the current cost estimate for construction of 765-kV circuits is $2 million/mile. This is significantly higher than the current $1 million/mile estimate for 345-kV construction. Even construction of a double-circuit 345-kV line is estimated to cost $1.3 million/mile, and such a circuit would have nearly the rate A thermal limit of a 765-kV circuit. The second consideration is that 765-kV substations are estimated to cost approximately $50 million, compared with cost of $15 million for a new 345-kV substation. Although this difference may not seem significant, since a circuit can be constructed with only two new substations, this additional cost could preclude connecting wind resources at intermediate locations along a new right-of-way. Several of the new rights-of-way proposed in this study pass through or near other areas identified by AWS Truewind as having economically viable wind resources. These rights-of-way include the new circuit from Red Creek to the Hill Country, which passes through zones 11 and 20, the circuit from Bluff Creek to Bosque, which passes through zones 12 and 15, and the circuit from McCamey to Kendall, which passes through zones 13 and 20. Although connecting the wind resources in these zones was not evaluated as part of this study, future wind development in these areas would be more likely if the right-of-way passing through them has a voltage of 345 kV rather than 765 kV.

One benefit of 765-kV circuits is that they provide significant line capacity when nearby 345-kV circuits are opened under contingency. In areas where there is already an established 345-kV infrastructure, there may be substantial economic benefits to using 765-kV circuits for future improvements, rather than 345-kV circuits. As such, 765-kV improvements should continue to be studied in future years, especially if improvements like the ones analyzed in this study are constructed.

2. Comanche Switch Circuit Upgrade

One of the system upgrades that was reviewed but not recommended in this study was installation of the second circuit on the existing towers that run from the Morgan Creek substation down to the Twin Butte substation, and then to the Comanche switch substation. This second circuit could also be extended to the Comanche substation (located at the Comanche Peak nuclear generating facility), however, in order to do so a 138-kV circuit that has been installed on these transmission towers would need to be relocated to a new right-of-way.

Over the course of this study several stakeholders have asked whether it would be reasonable to include an upgrade to this circuit as part of the proposed system improvements, primarily due to the fact that it would be relatively inexpensive (about $250,000/mile). Although this alternative was studied in several scenarios, it was not found to increase the system capability enough to justify its cost. There are two reasons for this, both of which relate to how current flows on a transmission system. Intuitively, current will flow in the easiest path, i.e., the one with the lowest total impedance, from generation to load. The line from Morgan Creek to Comanche leads towards an area with a significant amount of generation, including Comanche Peak (~2,300 MW of capacity), DeCordova (~1,100 MW) and Wolf Hollow (~800 MW), rather than towards an area with significant load. In addition, the overall length of this circuit results in its large impedance, which is why there is not a significant current flow on the existing single circuit. This impedance could be altered using series compensation devices, however this becomes problematic if the circuit is extended to the Comanche Peak substation. It is possible for series compensation devices to result in localized system impacts to nearby generators. Any such potential impacts to the steam generators at the Comanche Peak facility would require extensive study.

F. Future Steps

This study was designed to provide cost and benefit comparisons of a large number of different alternatives. As a result, it was not possible to fully delineate the system upgrades that will be needed for every scenario, nor to fully characterize the system benefits associated with these improvements. As an example, it was not possible to complete an AC power-flow analysis for each alternative, so there may be minor modifications to the proposed alternatives that could provide more system benefits than those proposed. At the same time, the benefits from the proposed system upgrades into the Hill Country and Killeen areas have not been fully quantified, as these improvements may significantly reduce the likelihood of reduced voltage events given certain system contingencies.

Specific locations of end points within the proposed wind generation zones have also not been determined (often referred to as the transmission system "on-ramps"). In almost all cases, the new transmission corridors identified in this study can be used equally to serve wind generation in multiple zones (such as the solutions that provide transmission capacity for wind generation in the central zones 9, 10, 12, and 14). The AWS Truewind model results indicate the relative level of wind resources in the different zones; however, the model results do not pinpoint these resources to specific locations. Rather, the location of the sites within a zone may be located anywhere within that zone. The geographic extent of some of the zones makes it difficult to know where exactly to place a new substation. Zone 10, as an example, stretches from Abilene to Garza County.

Proposed locations of new substations within the evaluated wind zones also have not been specified because there are numerous considerations regarding generation siting that are beyond the scope of this study. These include: differences in local taxes; inclinations of local property owners; familiarity of wind developers with different areas; site access issues; and possible discrepancies between the model results and actual site conditions, to name a few. Most, if not all, of these issues can be resolved through a process wherein the wind developers express their interest in specific locations within the proposed wind zones.

The transmission necessary to connect the wind generation facilities in a CREZ to the bulk transmission system has not been quantified in this study due to its dependence on the specific siting of that generation. These direct connection facilities will have to be evaluated after the specific generation siting has been determined. However, those direct connection costs are not expected to vary so widely between the different potential CREZ areas as to change the relative ranking of the areas.

The lowest cost solution for connecting multiple wind generation sites in a CREZ into the new 345-kV CREZ lines may be to build 138-kV lines from each of the sites to a single, central 345/138-kV substation, or it may be to build several 345/138-kV substations in order to lower the 138-kV line costs. This tradeoff cannot be analyzed until the actual wind generation locations are known.

After specific locations have been selected for proposed Competitive Renewable Energy Zones, and wind generation developers have indicated their intentions to develop projects in these zones, it is recommended that ERCOT System Planning, in coordination with the appropriate TSPs, be allowed to fine-tune both the locations for new substations in the proposed wind energy zones (the on-ramps) and the specific connection points near load.

VII. CONCLUSIONS

This study of transmission improvements to support additional wind capacity developed in Competitive Renewable Energy Zones has been conducted to support the Public Utility Commission of Texas in meeting the requirements of recently passed legislation. This study is based on input assumptions from the Five-Year Transmission Plan, and from a study of wind generation potential from areas throughout the State of Texas conducted by AWS Truewind. Detailed steady-state transmission models and security constrained unit-commitment and unit-dispatch models have been used to analyze the costs and benefits of a large number of potential transmission improvements.

The study indicates that there is significant potential for development of wind resources in Texas. There are currently 2,508 MW of wind generation in-service in ERCOT and at least 4,850 MW of wind resources are likely to be in-service by the end of 2007. Approximately 17,000 MW of wind generation has requested interconnection analysis. Much of that current wind generation development is in West Texas. Studies indicate that the existing transmission network is fully utilized with respect to wind transfers from West Texas to the remainder of ERCOT. Thus, new bulk transmission lines are needed to support significant transfers of additional wind generation in the West Texas area.

From a transmission planning perspective, there are four general areas of wind capacity expansion: the Gulf Coast; the McCamey area, central-western Texas, and the Texas Panhandle. Transmission solutions for each of these areas are described in this report. These solutions represent incremental plans for each area and form the basis of transmission solutions to support combinations of wind development between two or more areas.

Some common projects will be needed to mitigate the impact of the new CREZ-related generation on existing wind generation. Even with these projects, existing wind generation will be more susceptible to curtailment due to remaining system constraints because of its generally higher shift factors on those constraints.

This study does not attempt to capture all of the benefits and costs associated with the designation of CREZs, but focuses primarily on the direct costs and benefits related to the electric power system. In general, the production cost savings per kW of new wind generation varies little between the different areas. The Coastal area has lower capacity factor sites than the other areas but the wind output is somewhat more coincident with the ERCOT electrical load. The Coastal area also requires the least transmission investment per MW of installed new wind capacity. The Panhandle area has more, high capacity factor resources. The transmission cost per MW is also higher for the Panhandle area; the higher capacity factor of the resources in this area does not offset this higher cost.

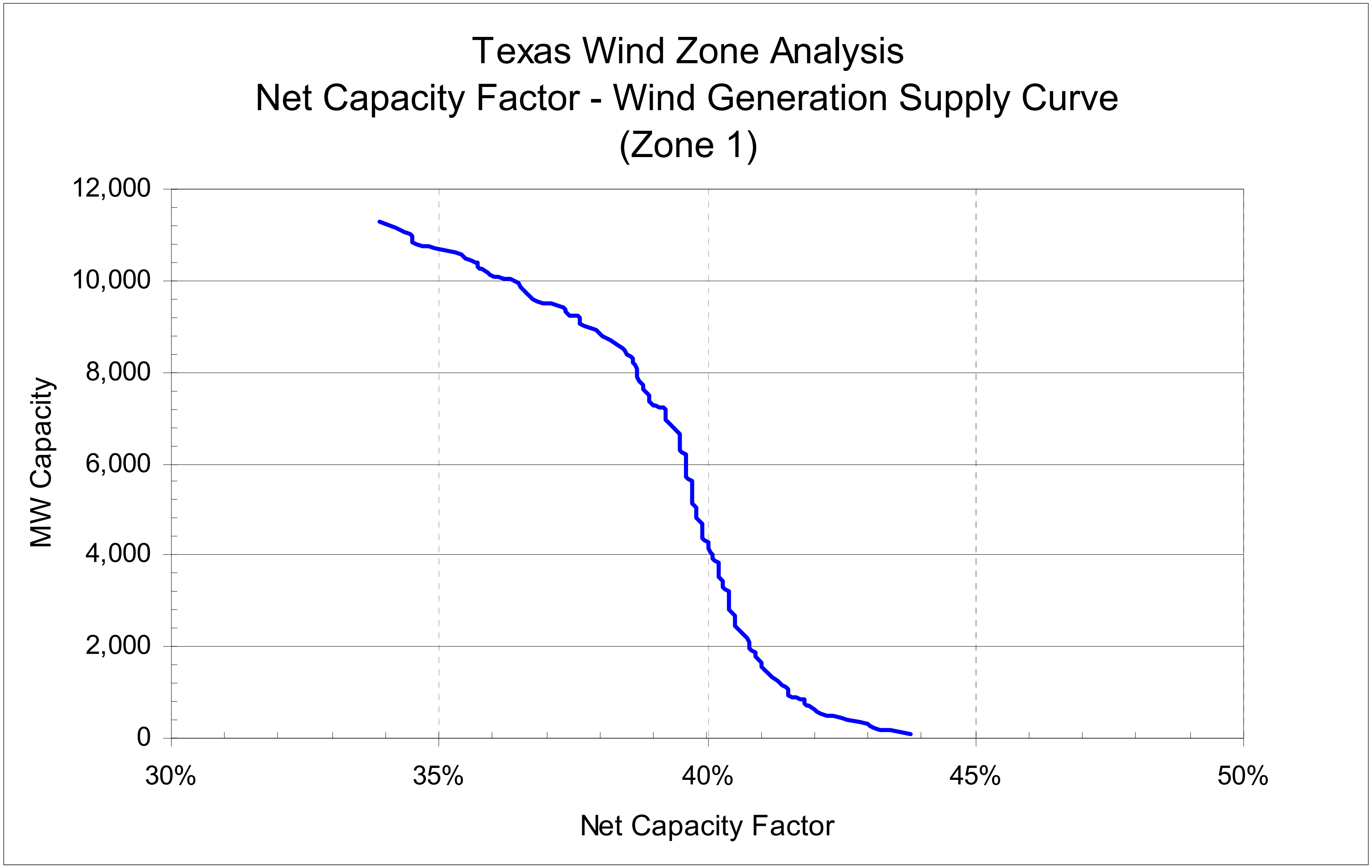
The first level solution for the Central and McCamey areas use the same bulk transmission addition, so the designation of CREZs and addition of resources in these areas must be generally considered in conjunction.

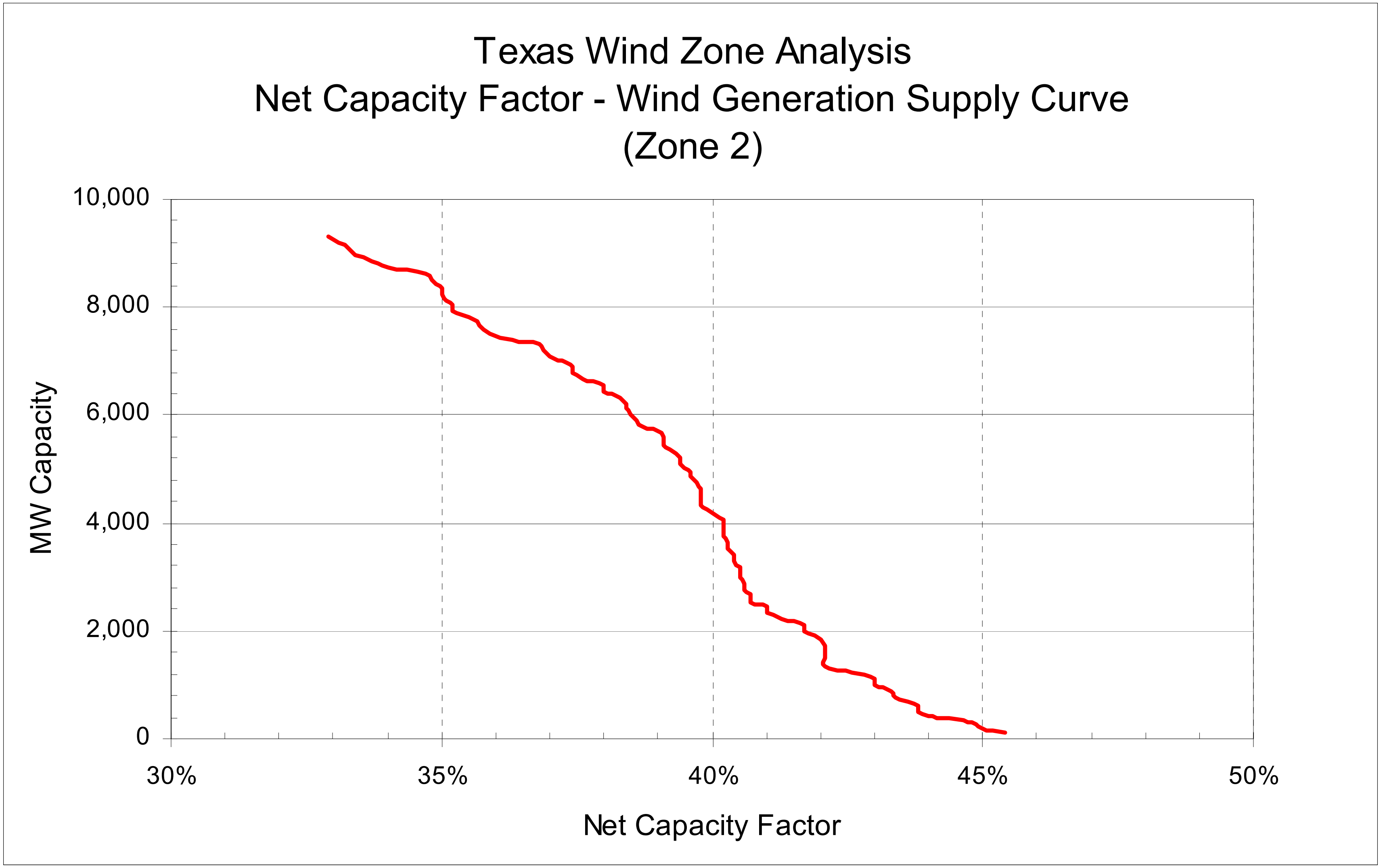
While transmission solutions were generally developed that provided 1,000 MW incremental steps for each area, the second step for the McCamey level is larger, in terms of both cost and MW of wind generation supported; although the cost per MW of supported wind is similar to the other levels for McCamey and Central areas.

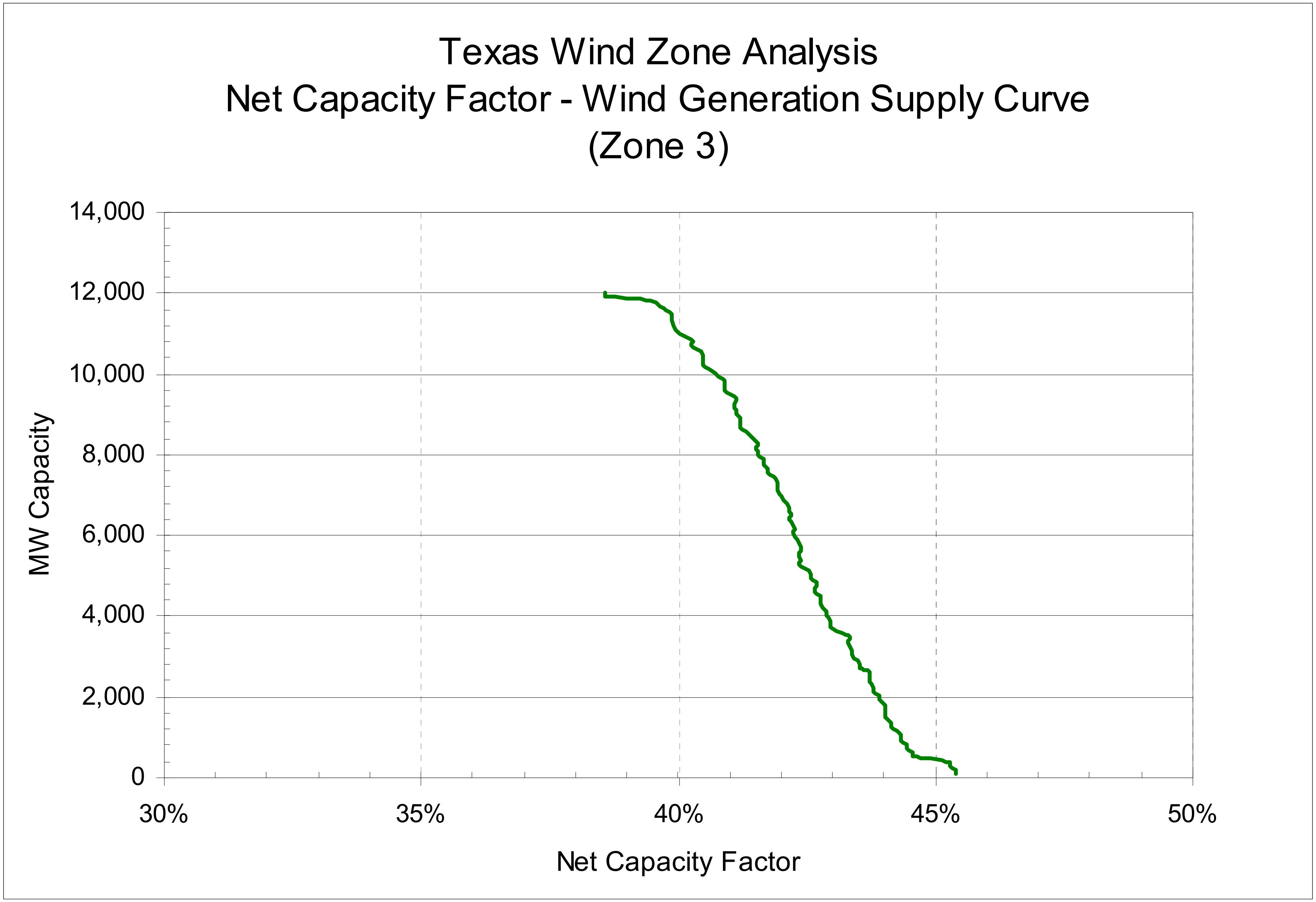
ERCOT will be performing an analysis of the impact of significant additional wind generation on the level of the different ancillary services that it procures to maintain system reliability. In addition, further ERCOT analysis of several issues is needed once a specific set of CREZs is designated by the PUCT and wind generation developers have indicated specific locations. These additional analyses include reactive support needs, dynamic stability analyses, optimization of the "on-ramps" within the CREZs and analysis of the specific projects or operational procedures needed to mitigate curtailments of existing wind generation.

APPENDIX A

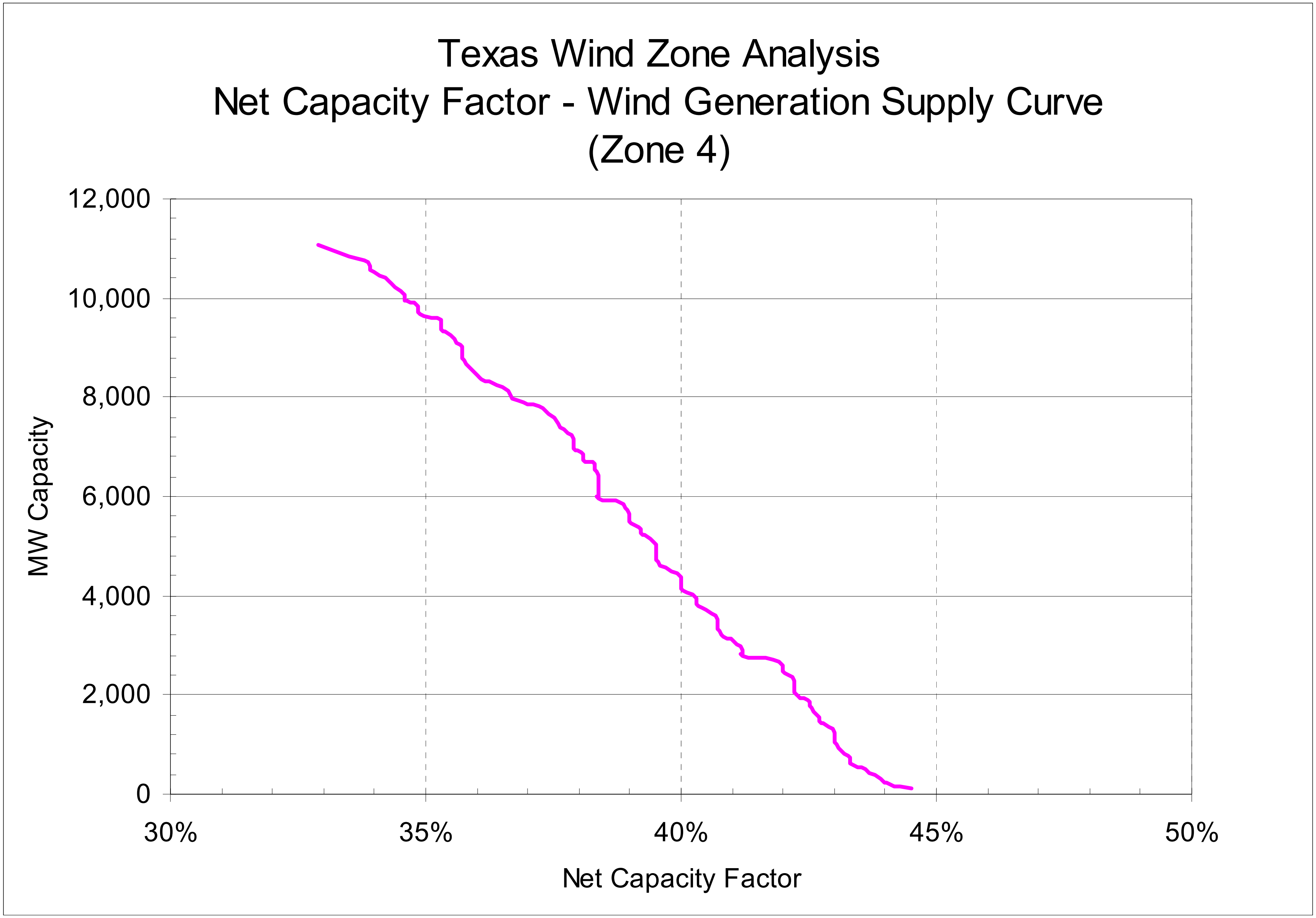
Wind Generation Potential by Wind Energy Zone

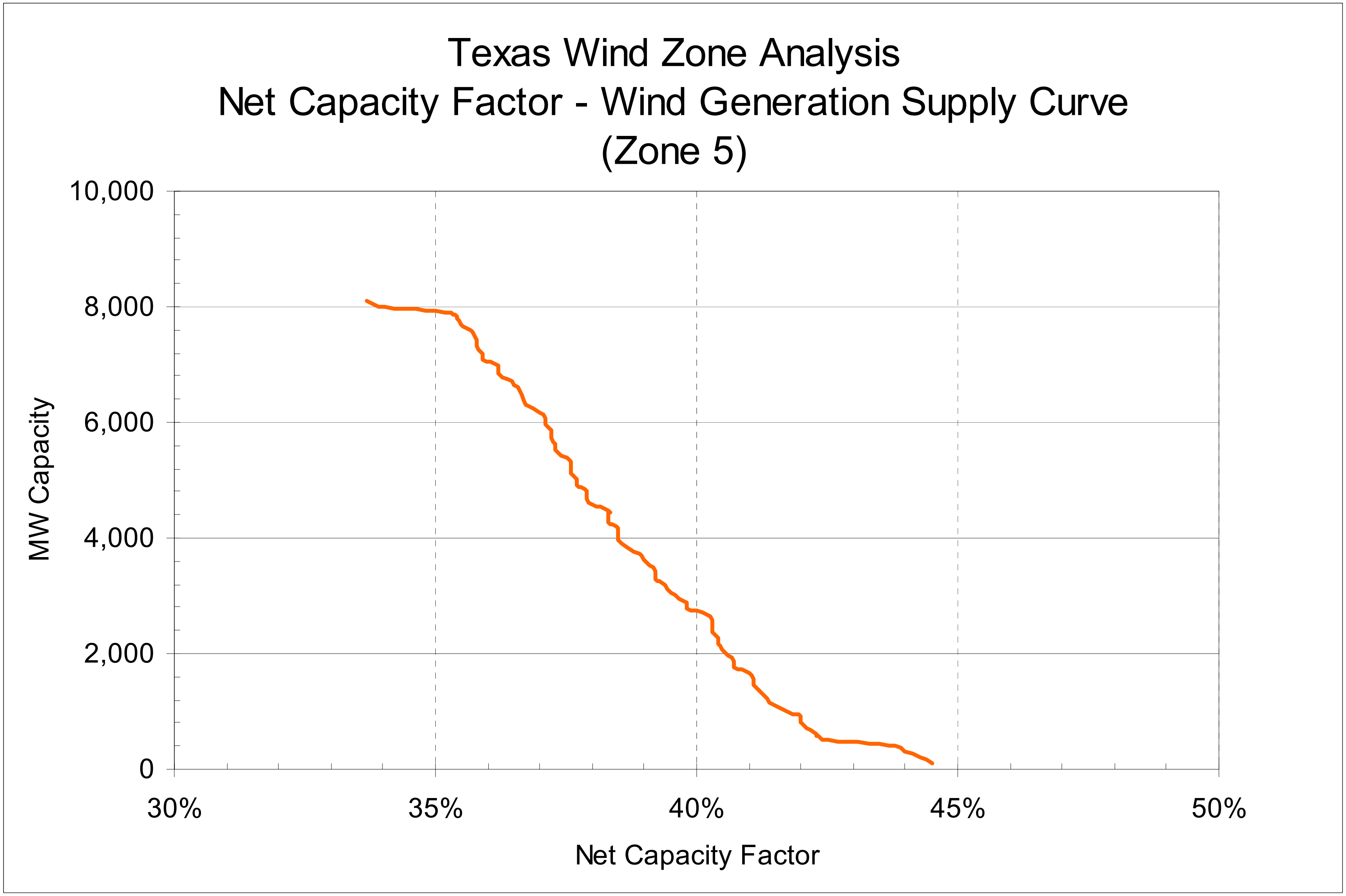

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 1)
MW Capacity
12,000
10,000
8,000
6,000
4,000
2,000
0
30%
35%
40%
45%
50%
Net Capacity Factor

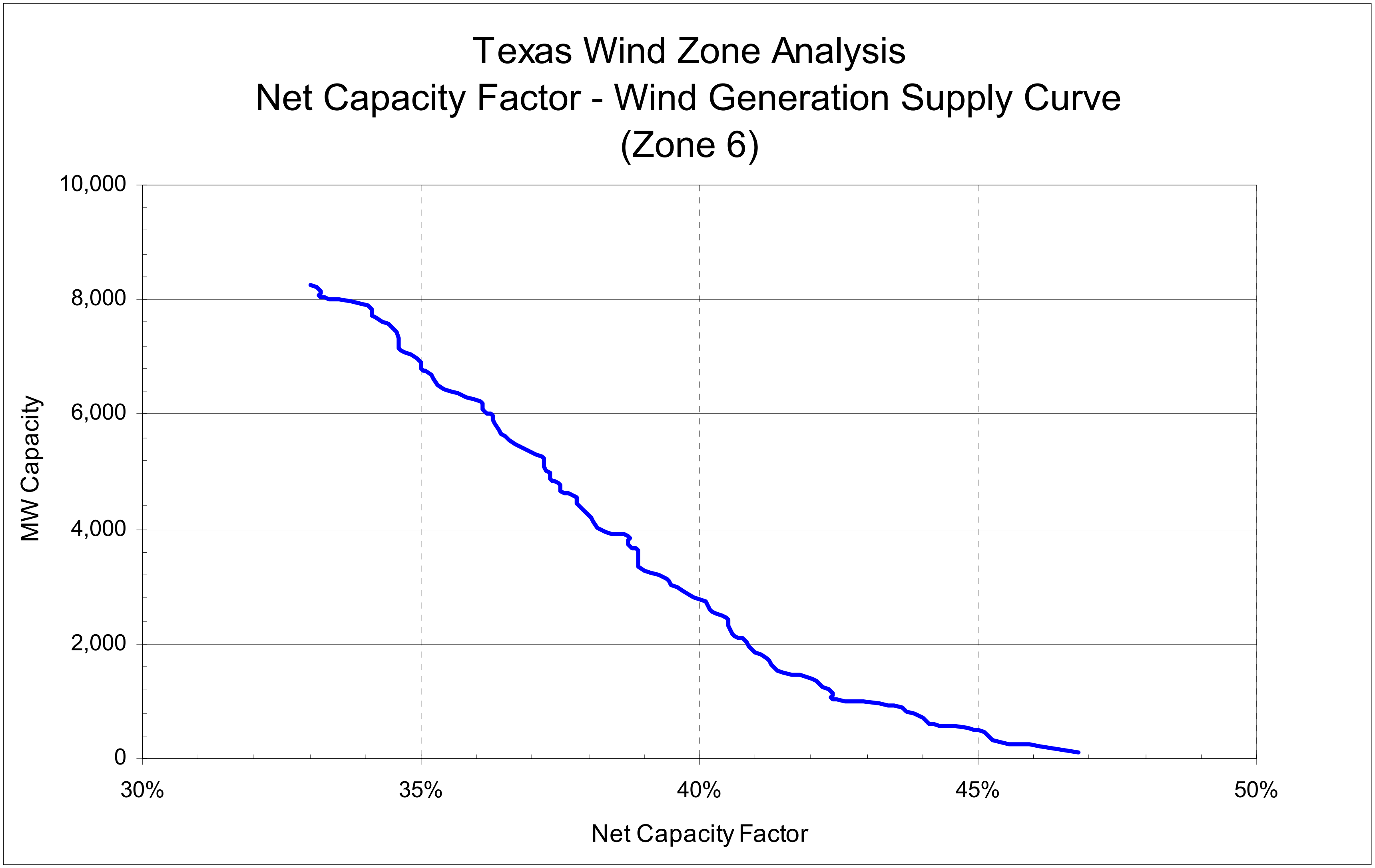

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 2)
MW Capacity
10,000
8,000
6,000
4,000
2,000
0
30%
35%
40%
45%
50%
Net Capacity Factor

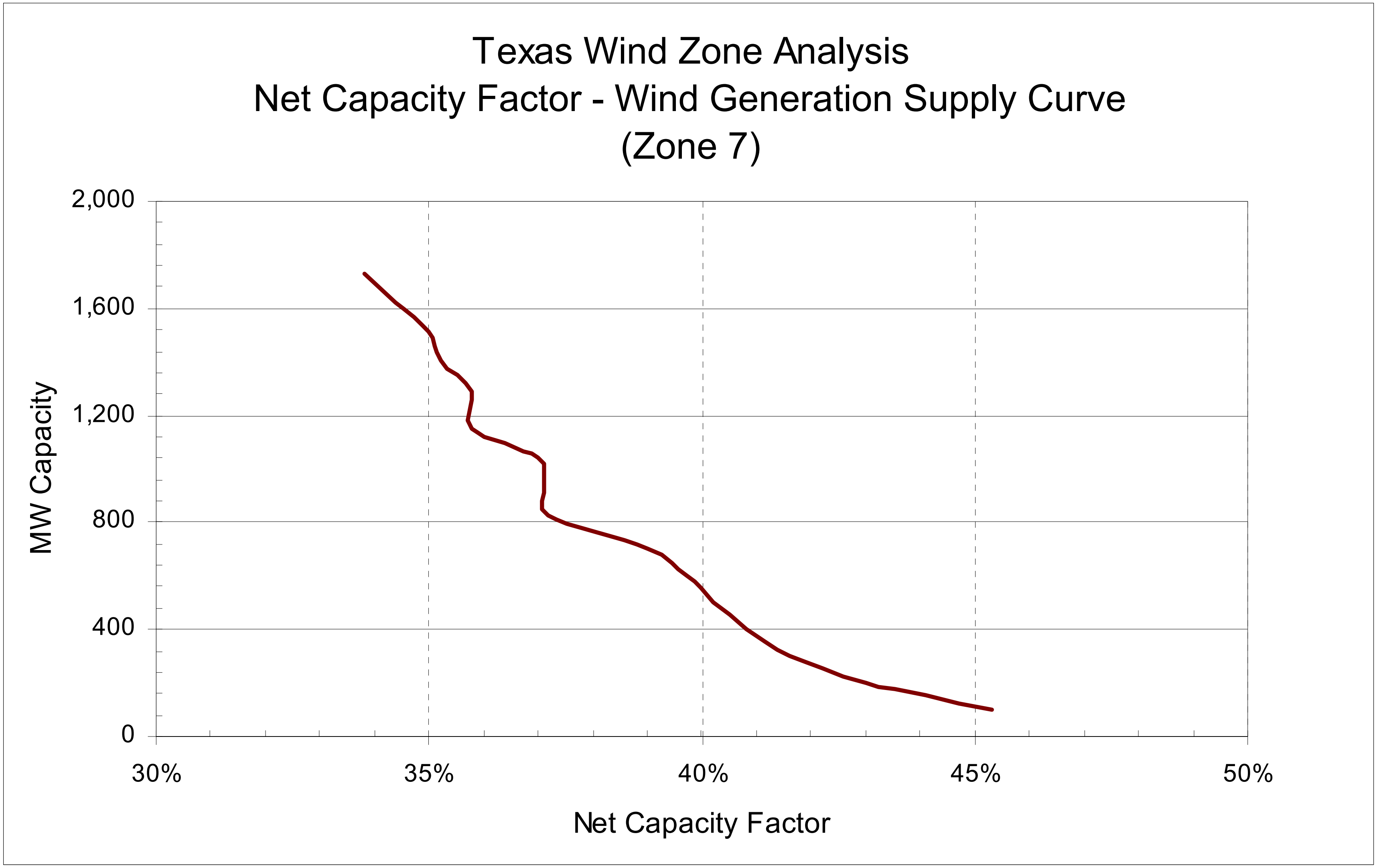


Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 3)
MW Capacity
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
30%
35%
40%
45%
50%
Net Capacity Factor

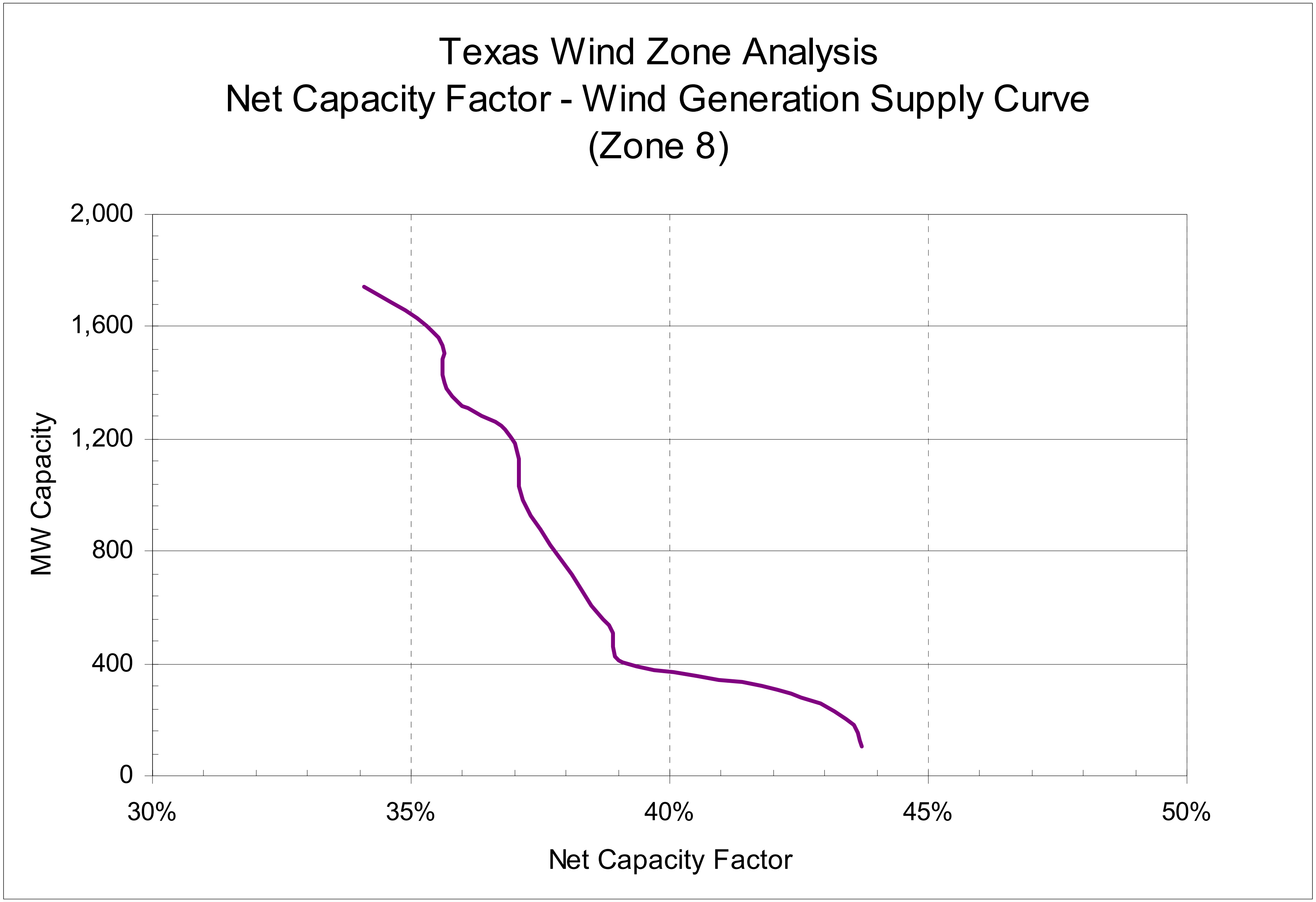

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 4)
12,000
10,000
8,000
6,000
4,000
2,000
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

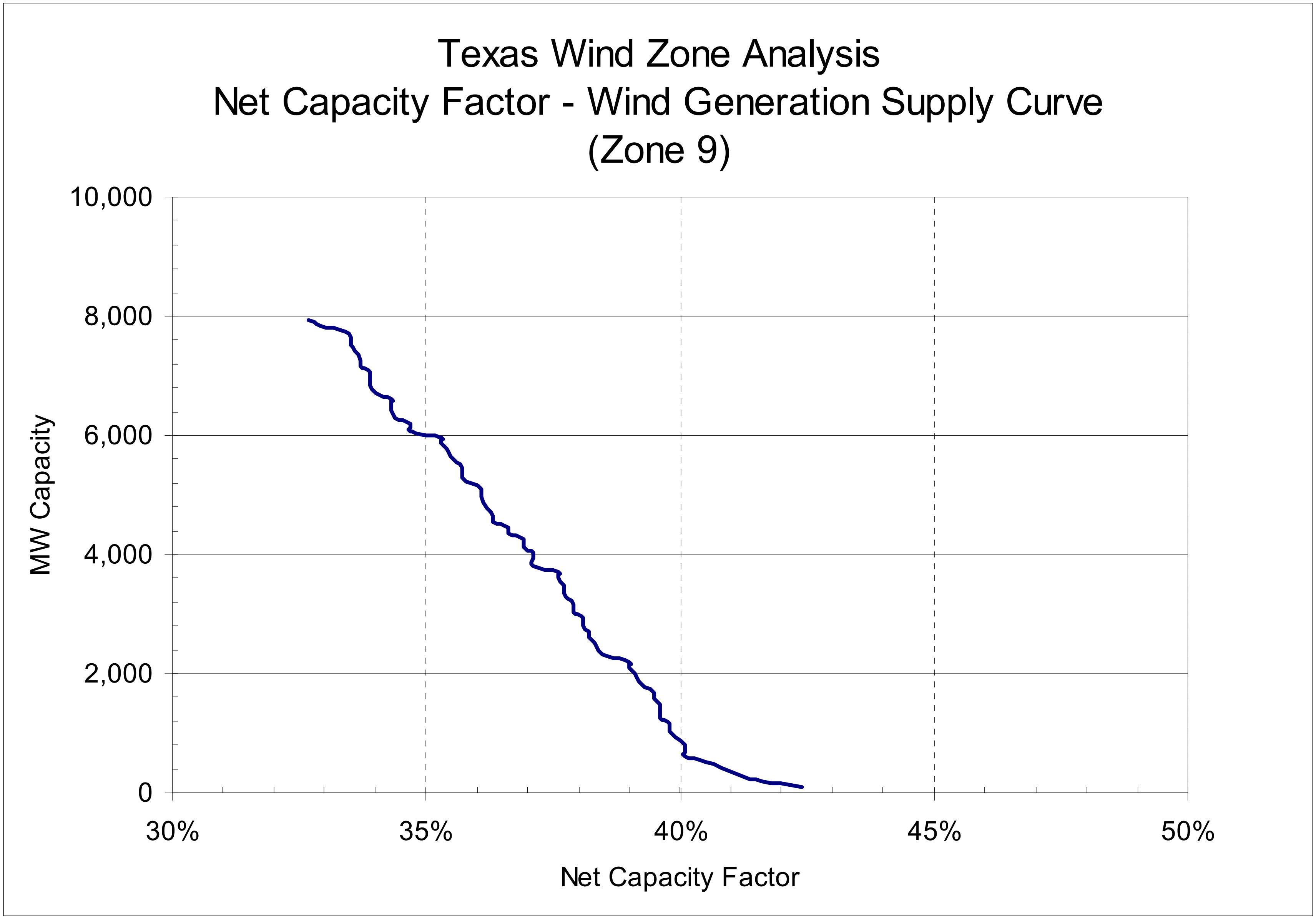

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 5)
10,000
8,000
6,000
4,000
2,000
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

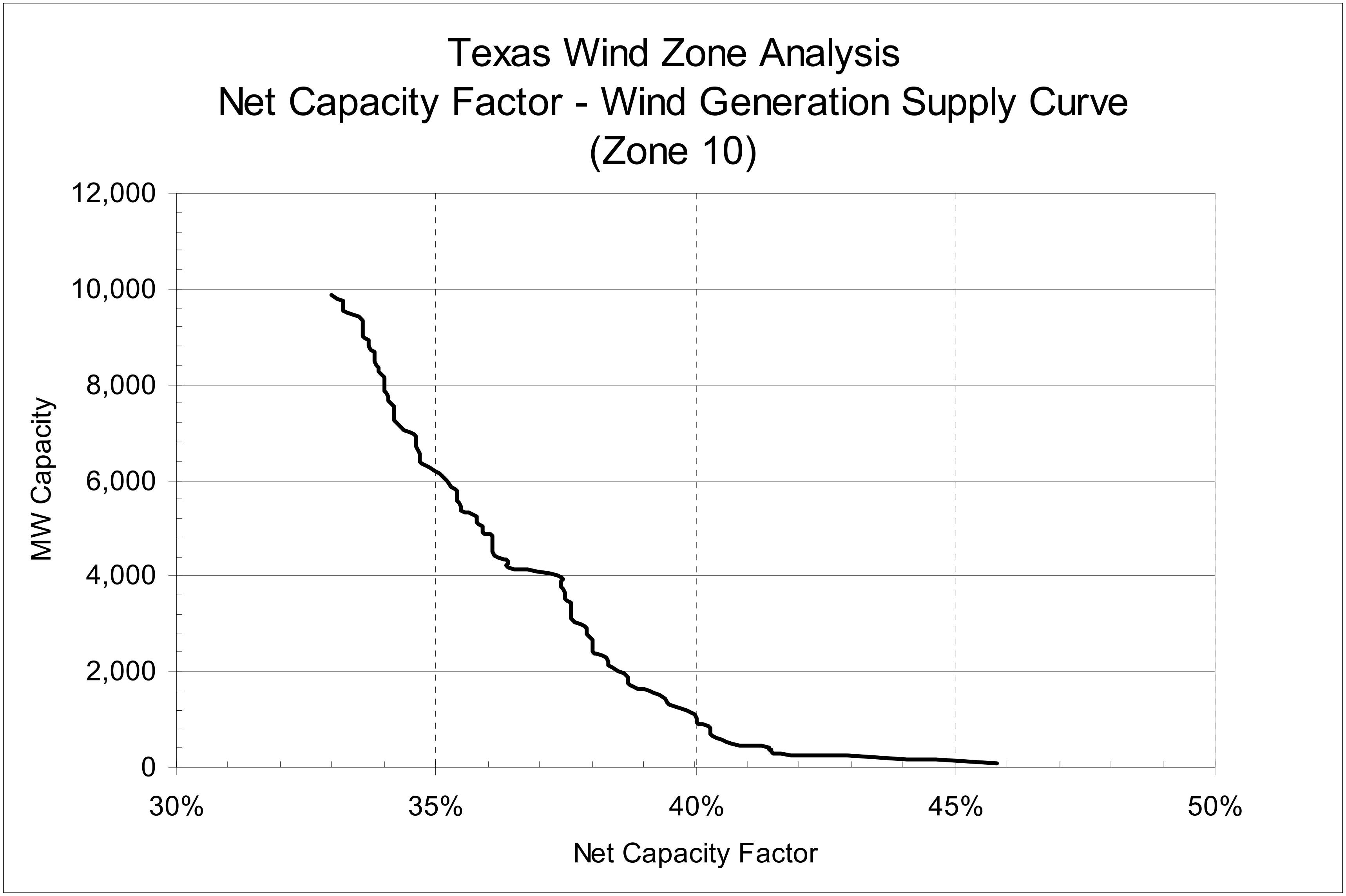

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 6)
MW Capacity
10,000
8,000
6,000
4,000
2,000
0
30%
35%
40%
45%
50%
Net Capacity Factor

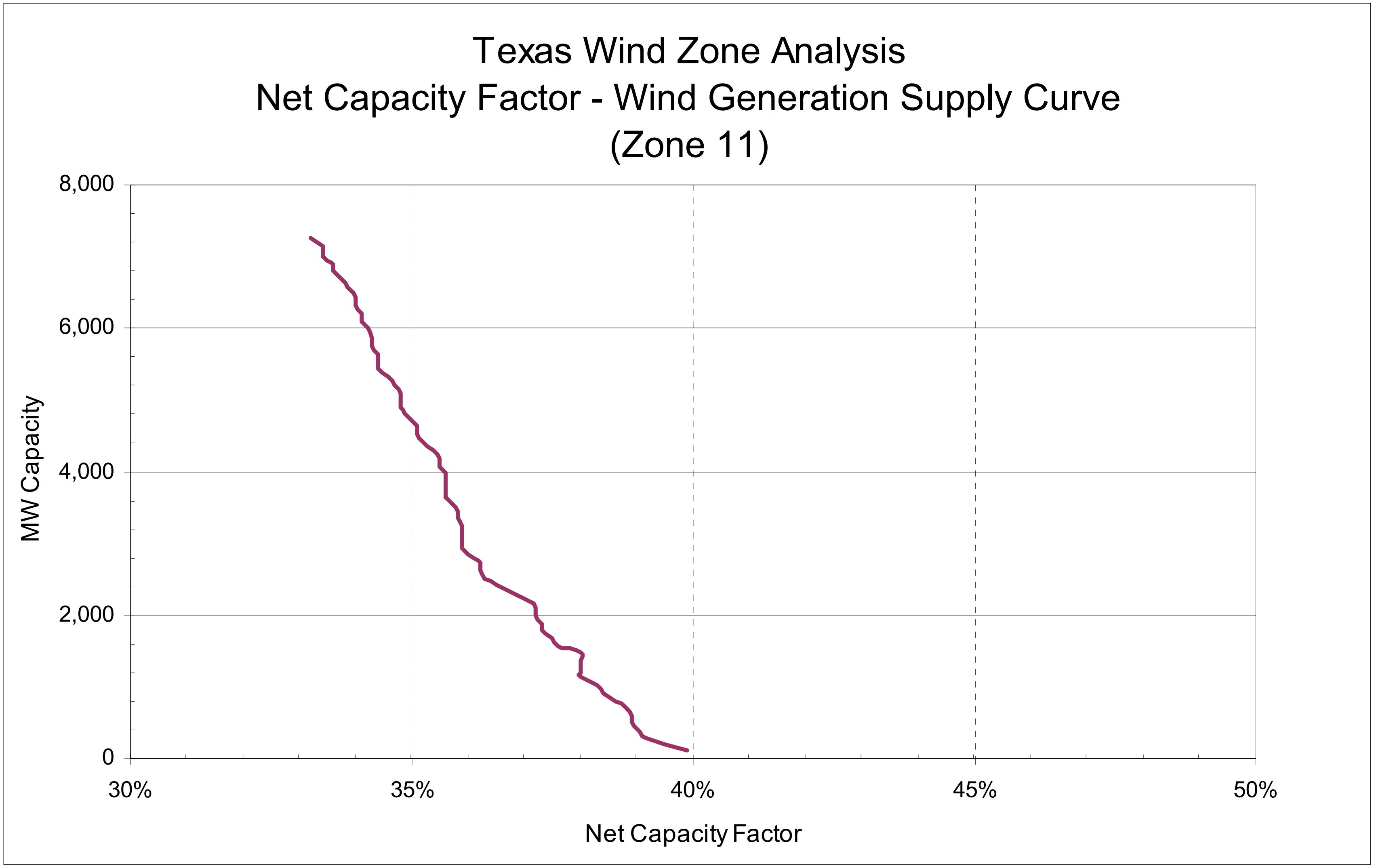


Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 7)
MW Capacity
2,000
1,600
1,200
800
400
0
30%
35%
40%
45%
50%
Net Capacity Factor

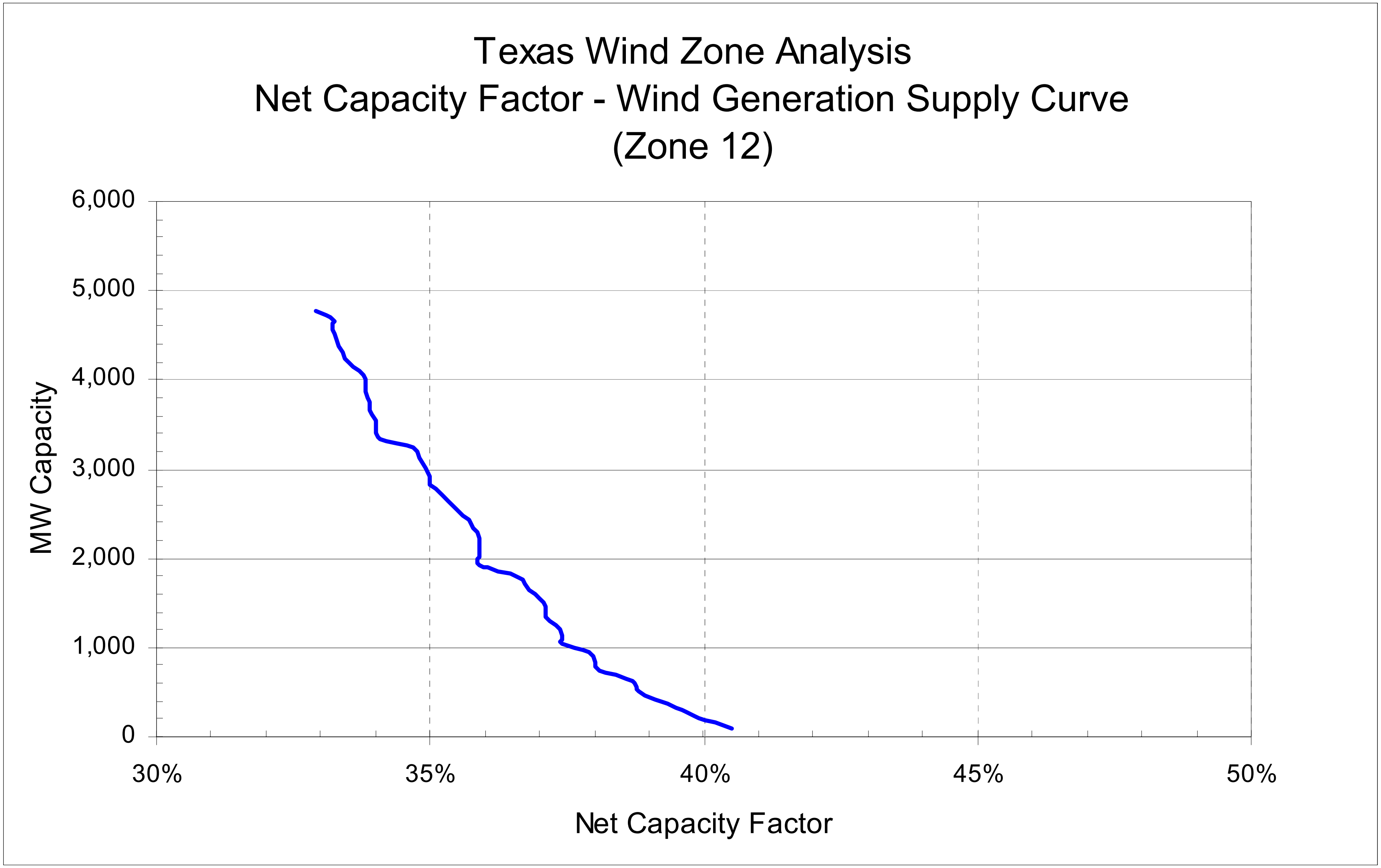

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 8)
2,000
1,600
1,200
800
400
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

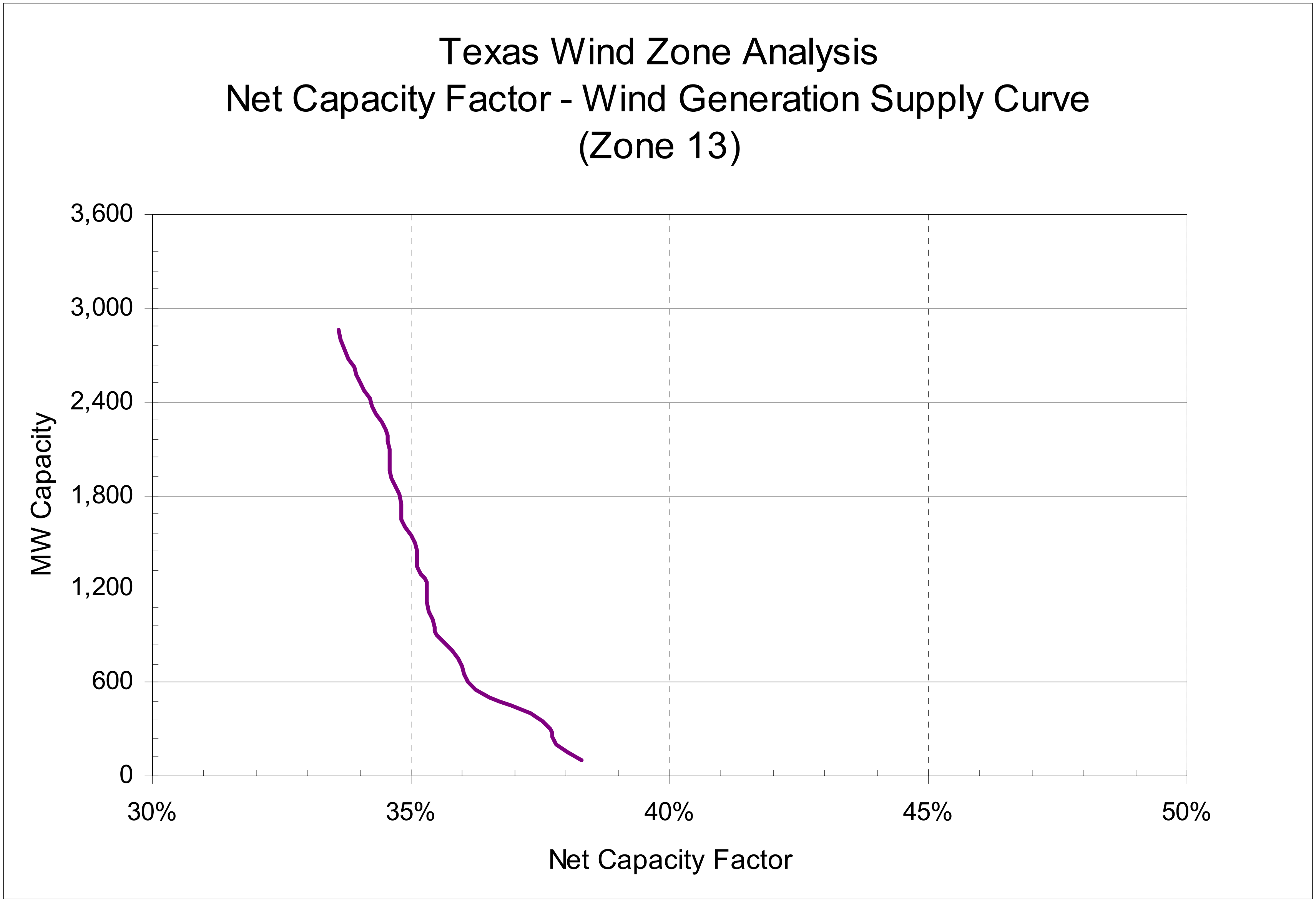

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 9)
10,000
8,000
6,000
4,000
2,000
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

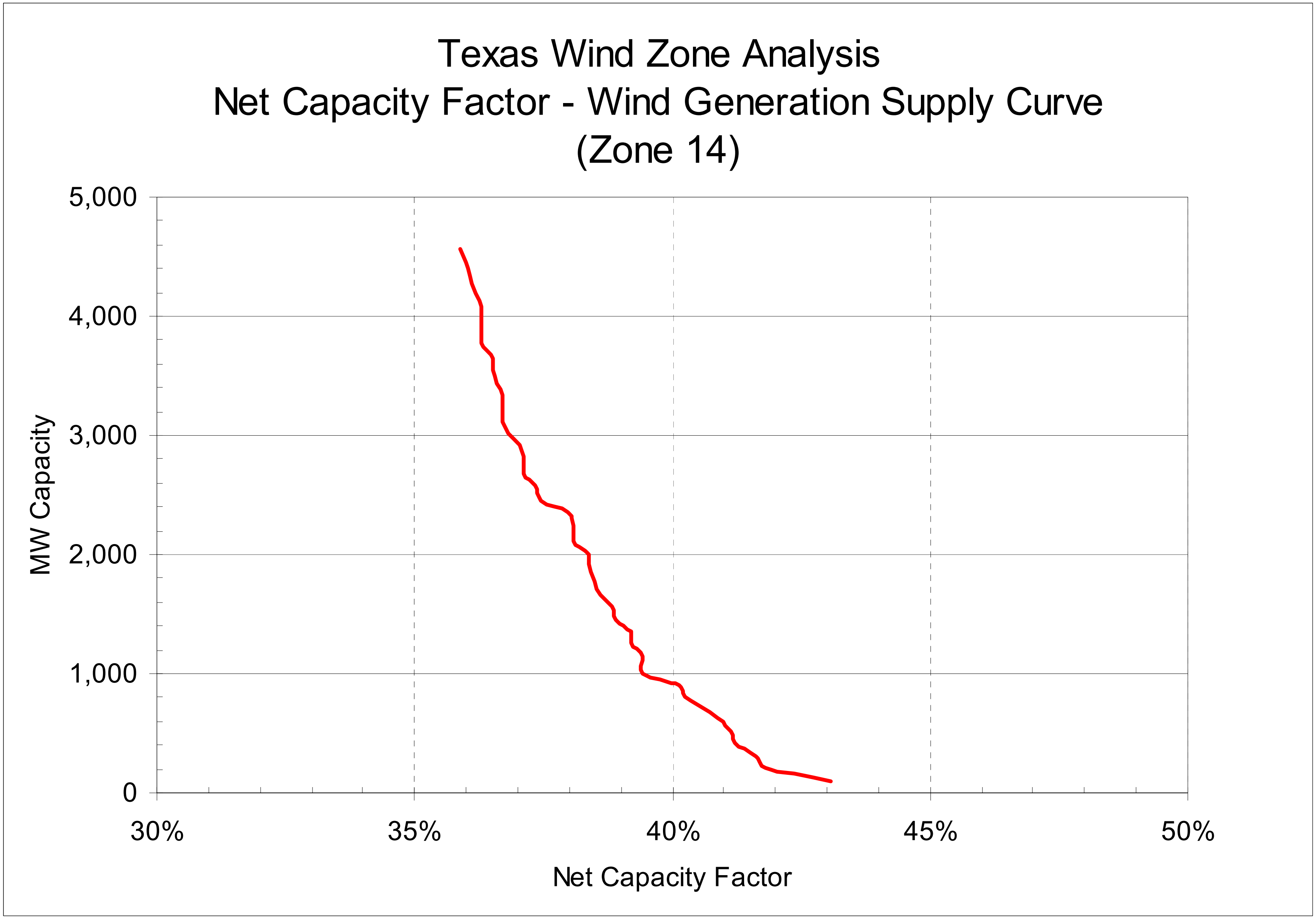

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 10)
12,000
10,000
8,000
6,000
4,000
2,000
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

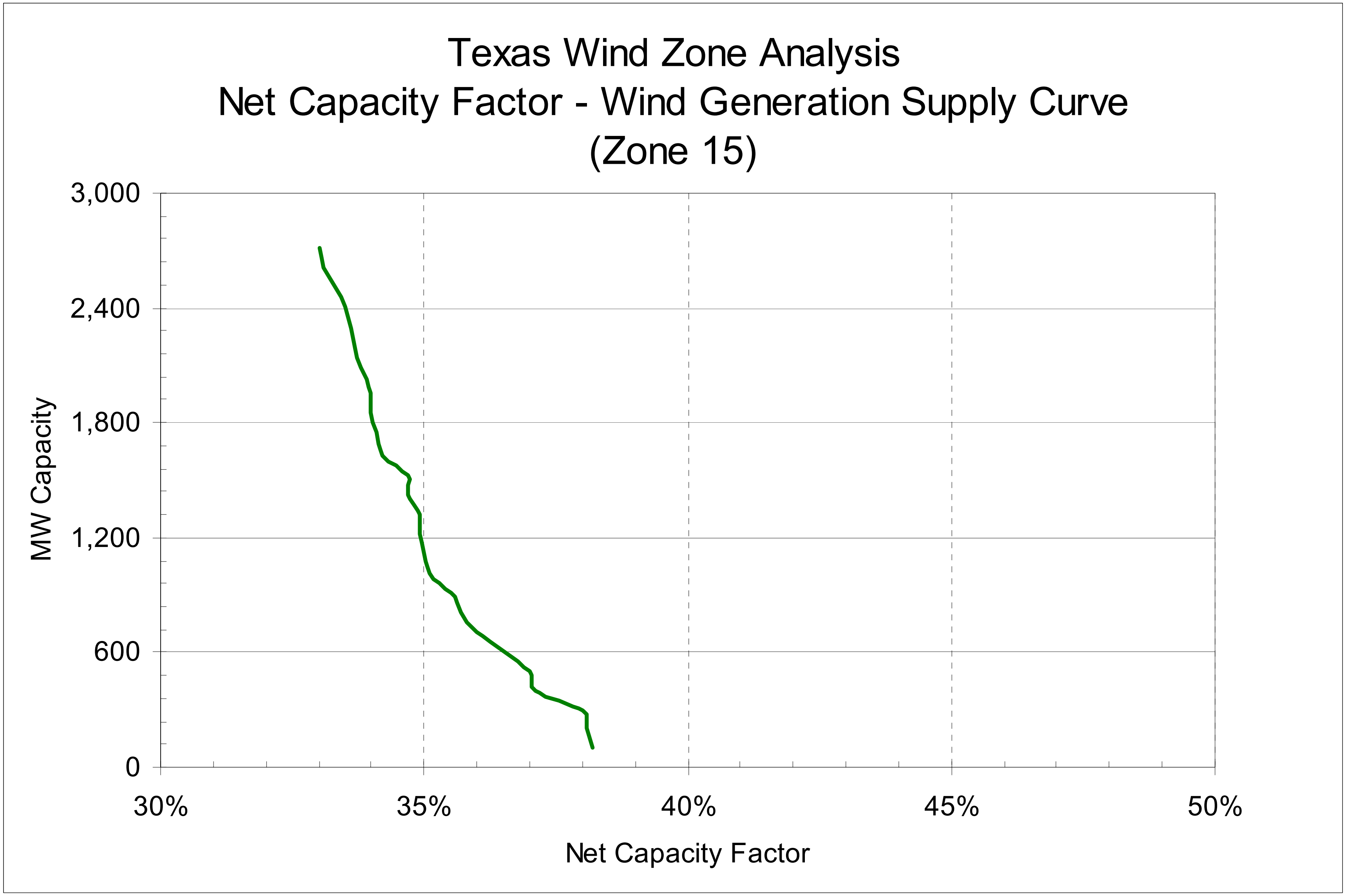


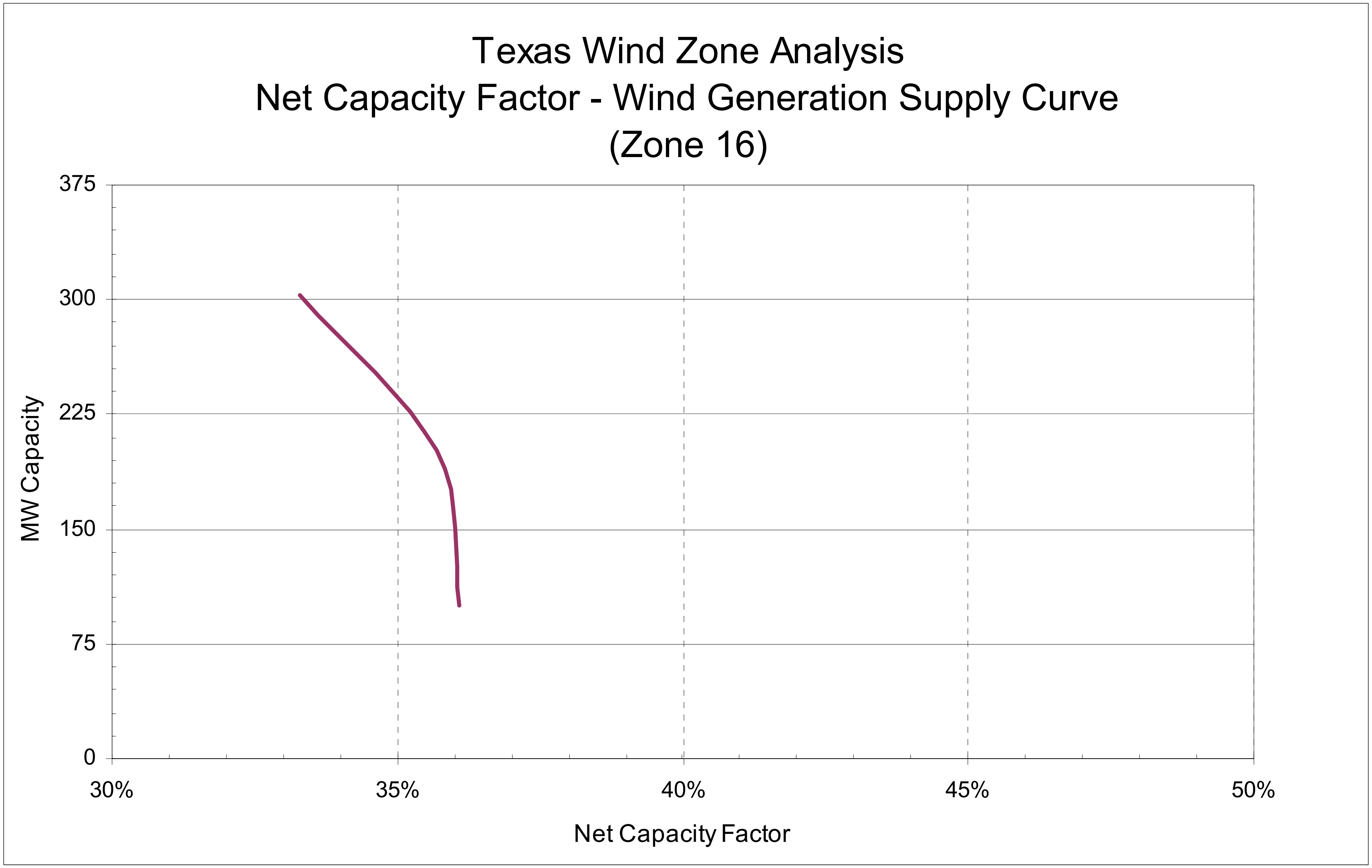
Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 11)
8,000
6,000
4,000
2,000
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

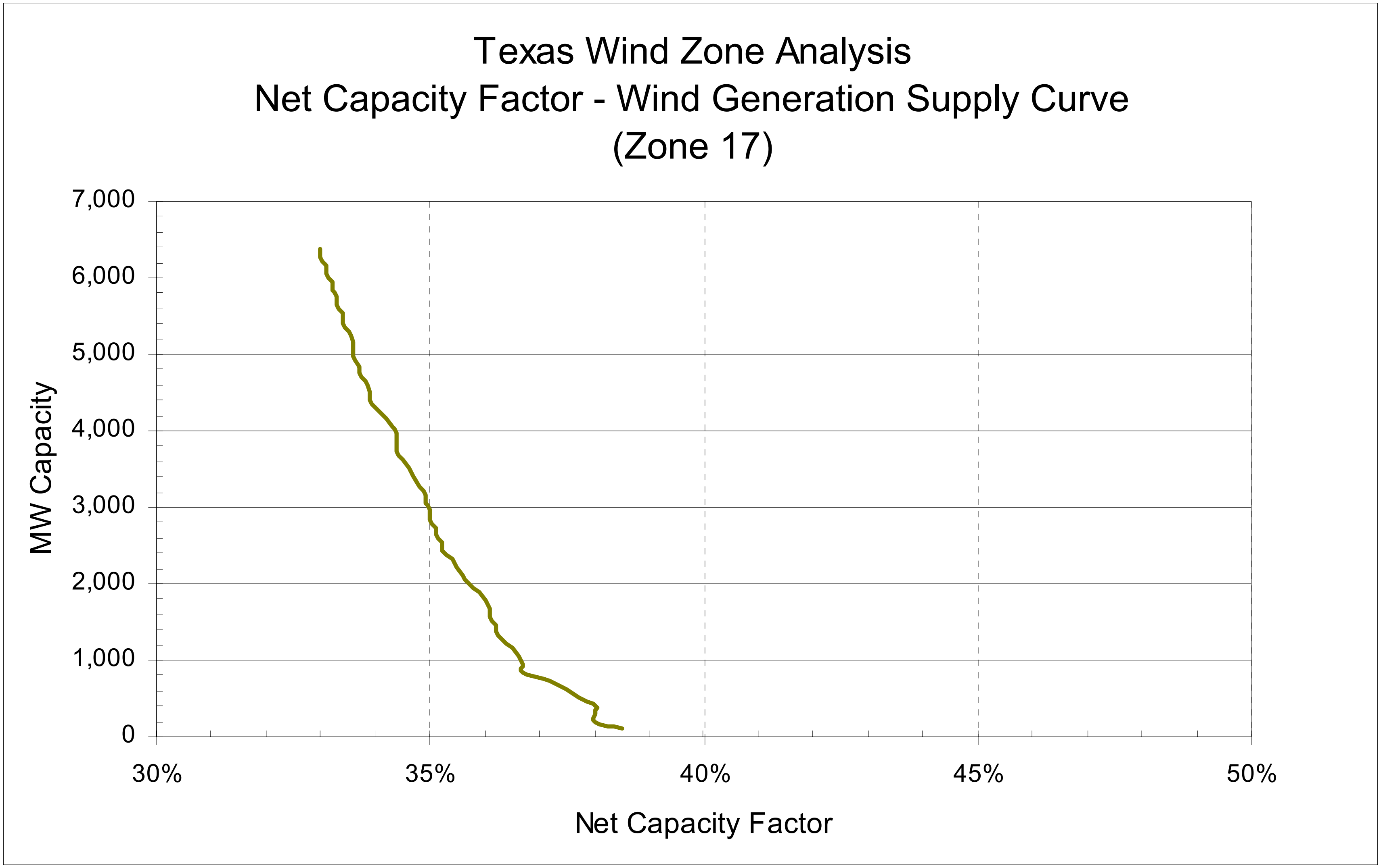

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 12)
6,000
5,000
4,000
3,000
2,000
1,000
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

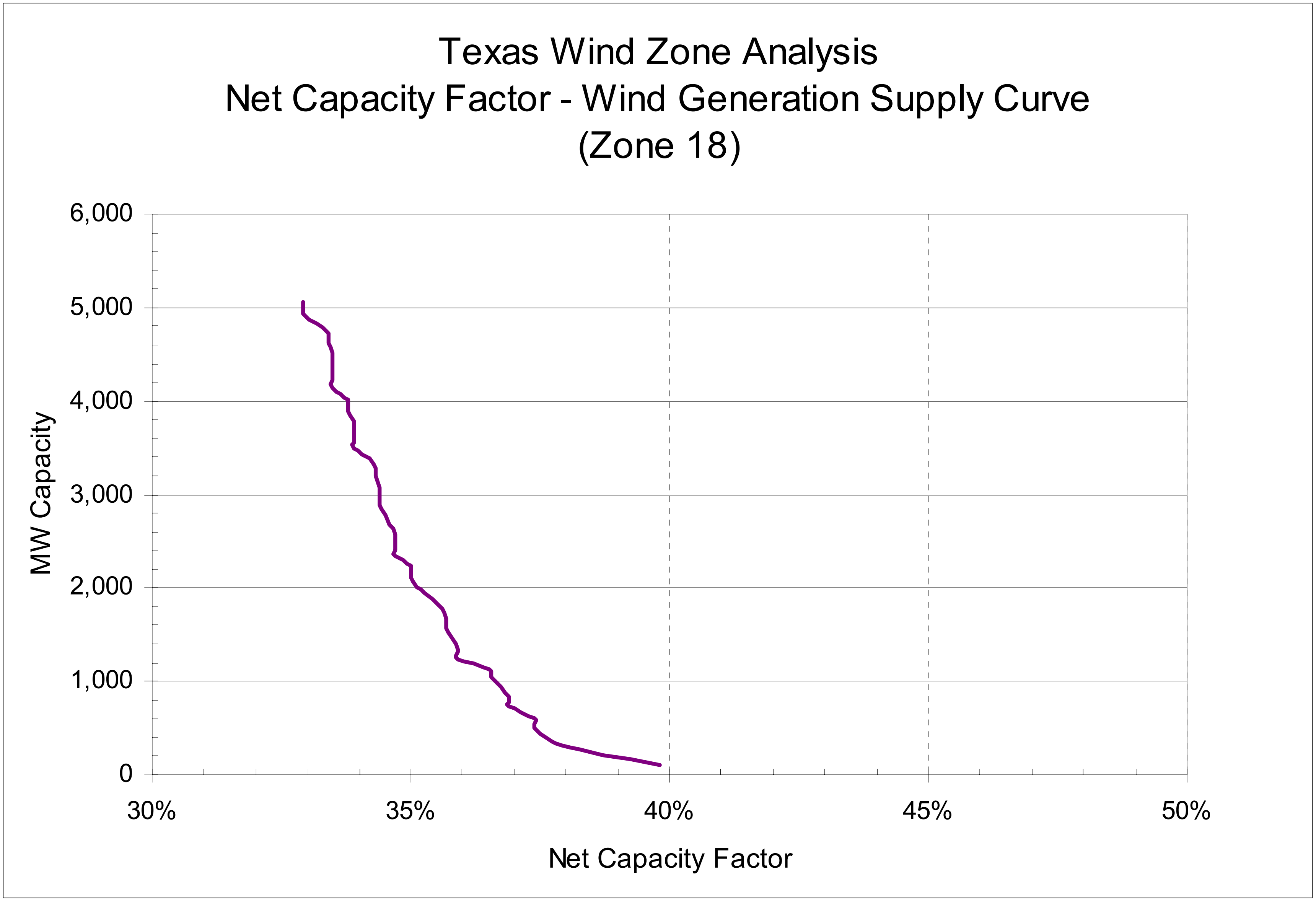

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 13)
MW Capacity
3,600
3,000
2,400
1,800
1,200
600
0
30%
35%
40%
45%
50%
Net Capacity Factor

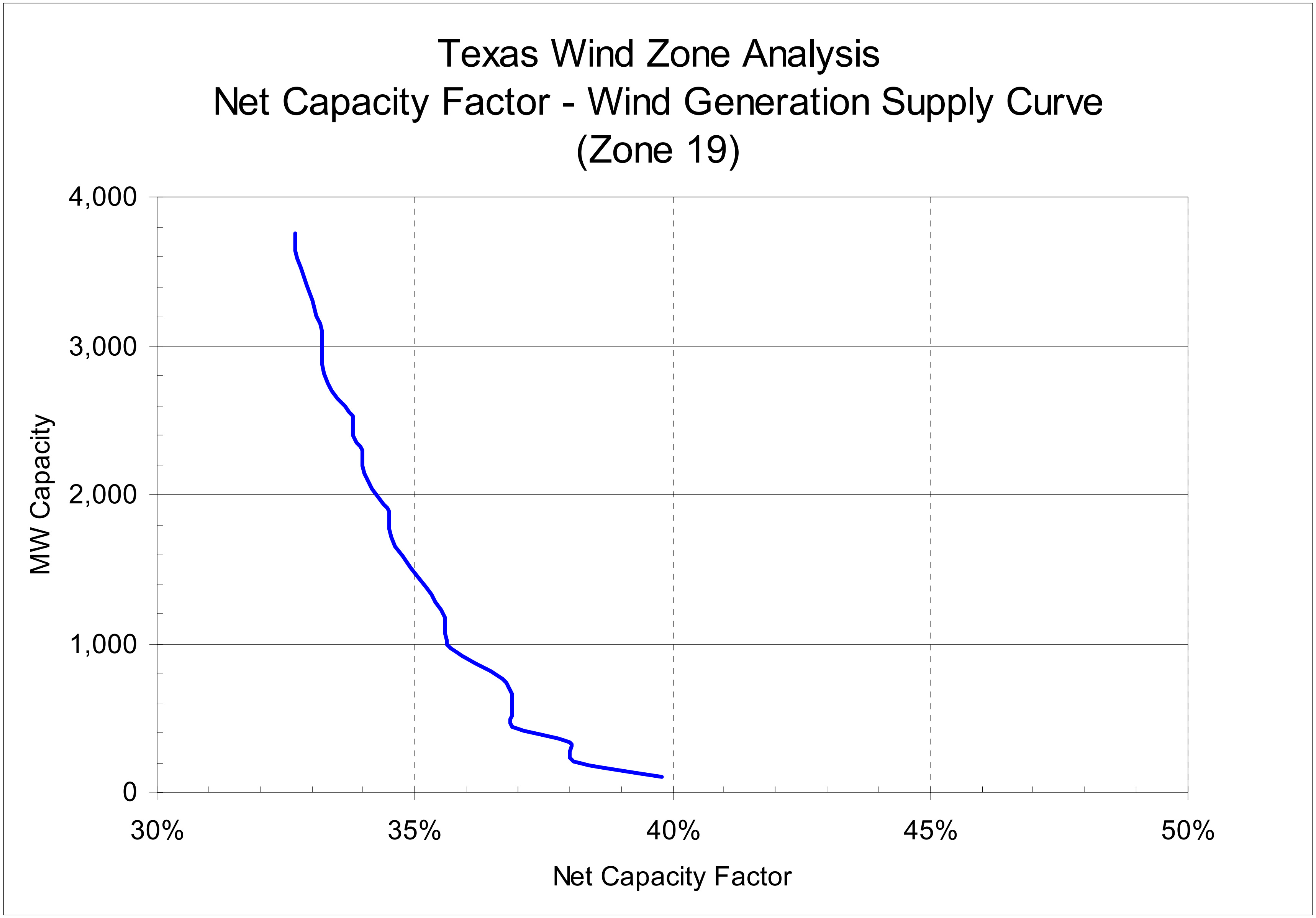

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 14)
MW Capacity
5,000
4,000
3,000
2,000
1,000
0
30%
35%
40%
45%
50%
Net Capacity Factor


Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 15)
3,000
2,400
1,800
1,200
600
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

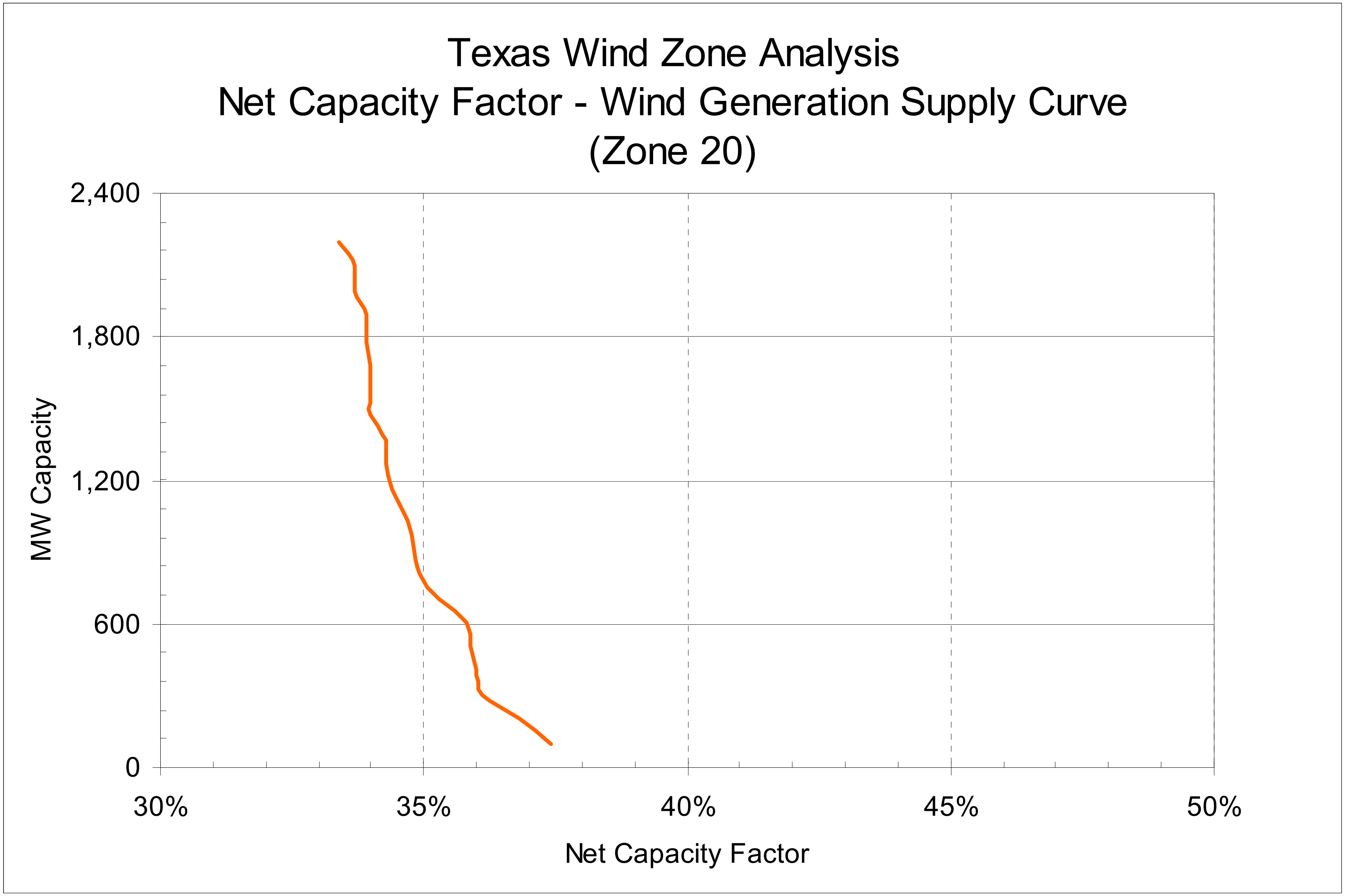

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 16)
MW Capacity
375
300
225
150
75
0
30%
35%
40%
45%
50%
Net Capacity Factor


Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 17)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

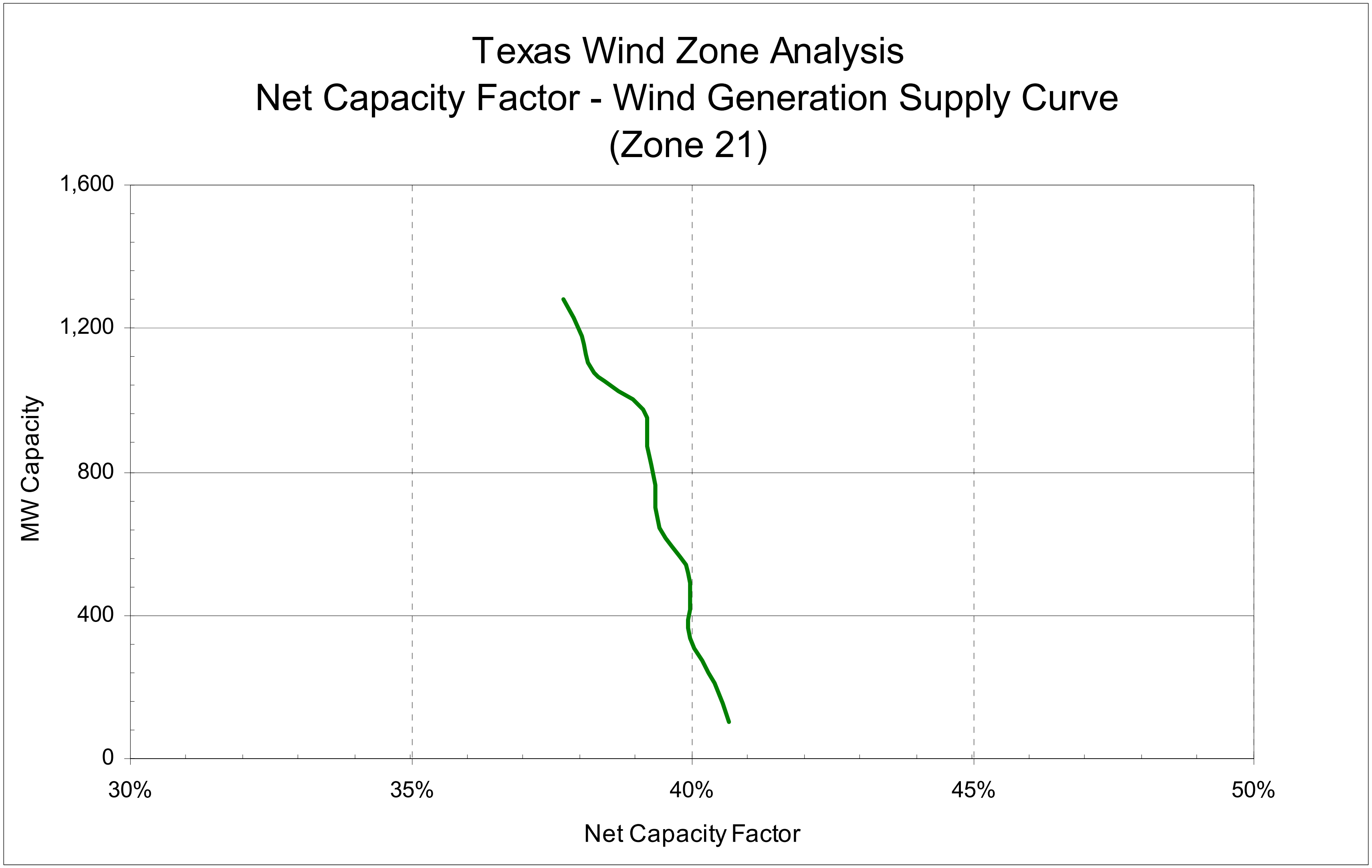

Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 18)
6,000
5,000
4,000
3,000
2,000
1,000
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor



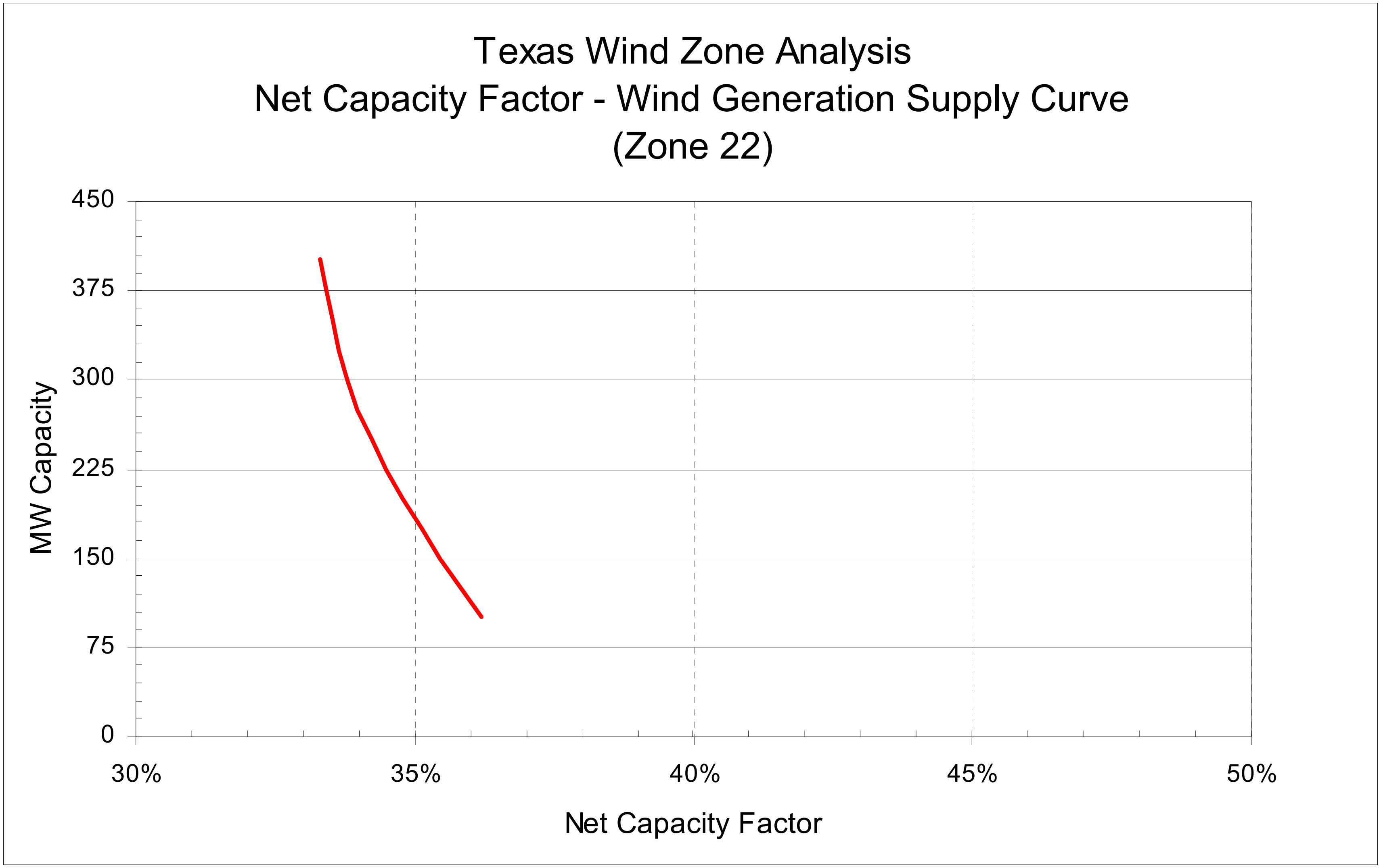
Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 19)
4,000
3,000
2,000
1,000
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor

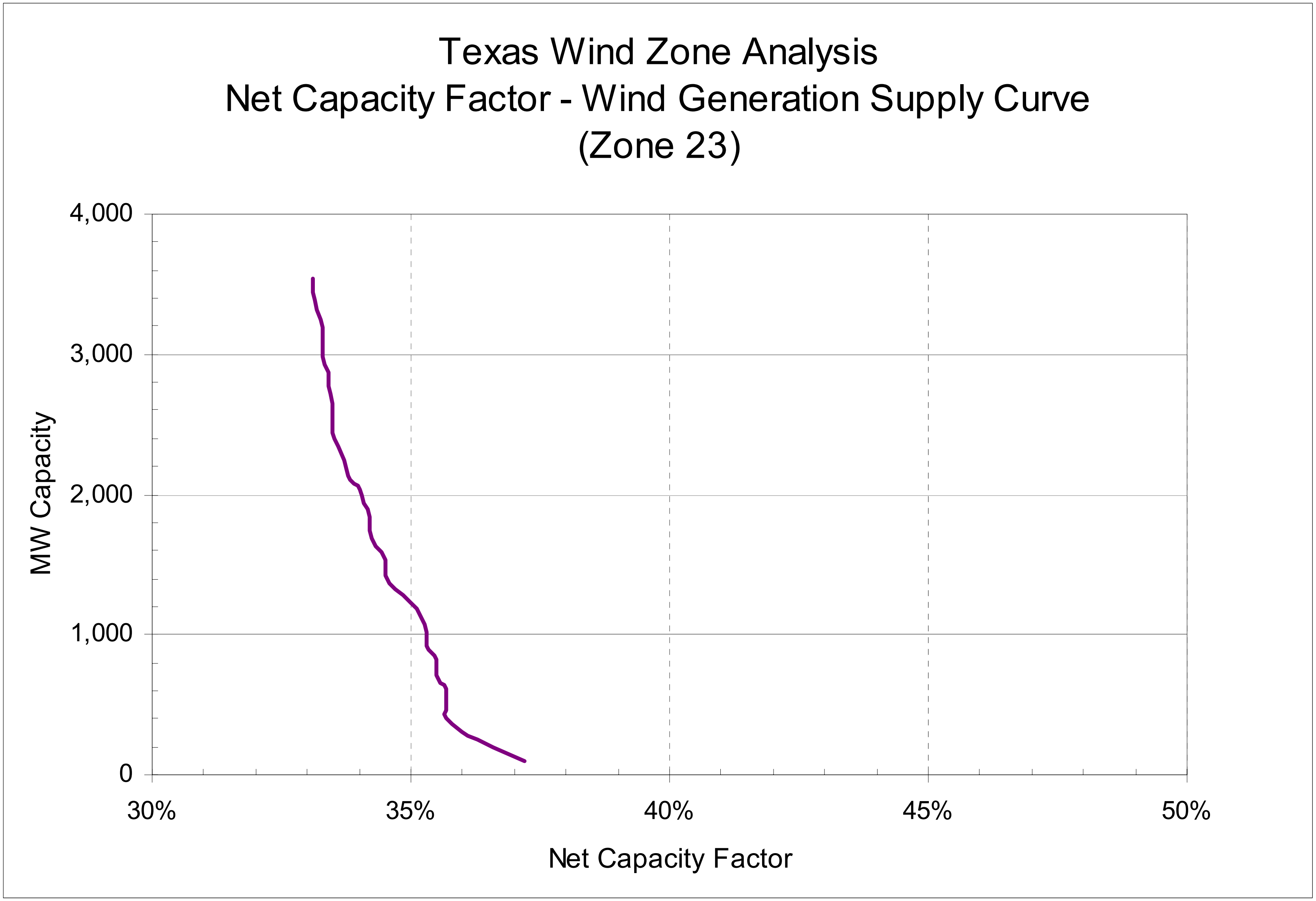


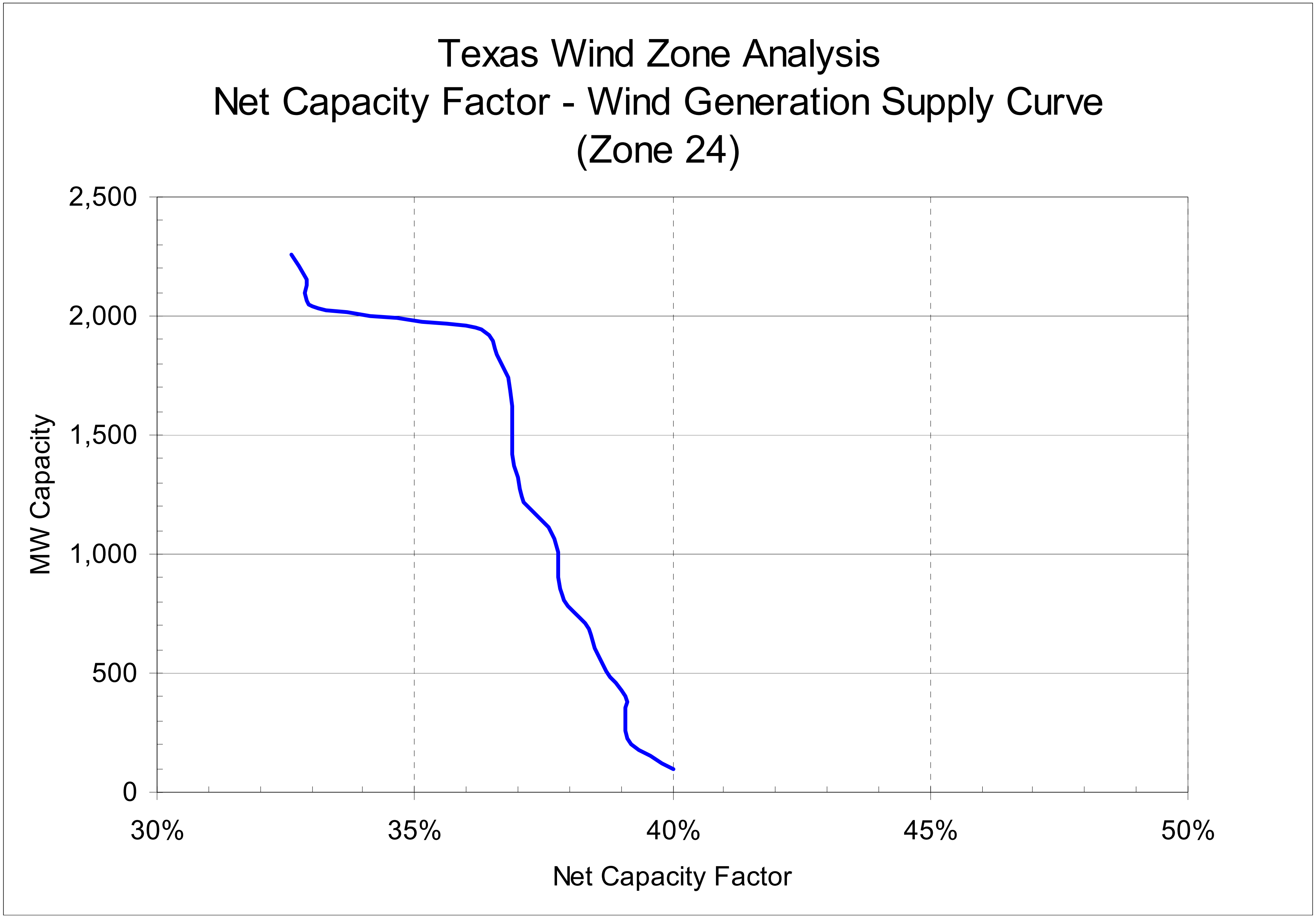
Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 20)
2,400
1,800
1,200
600
0
30%
35%
40%
45%
50%
MW Capacity
Net Capacity Factor

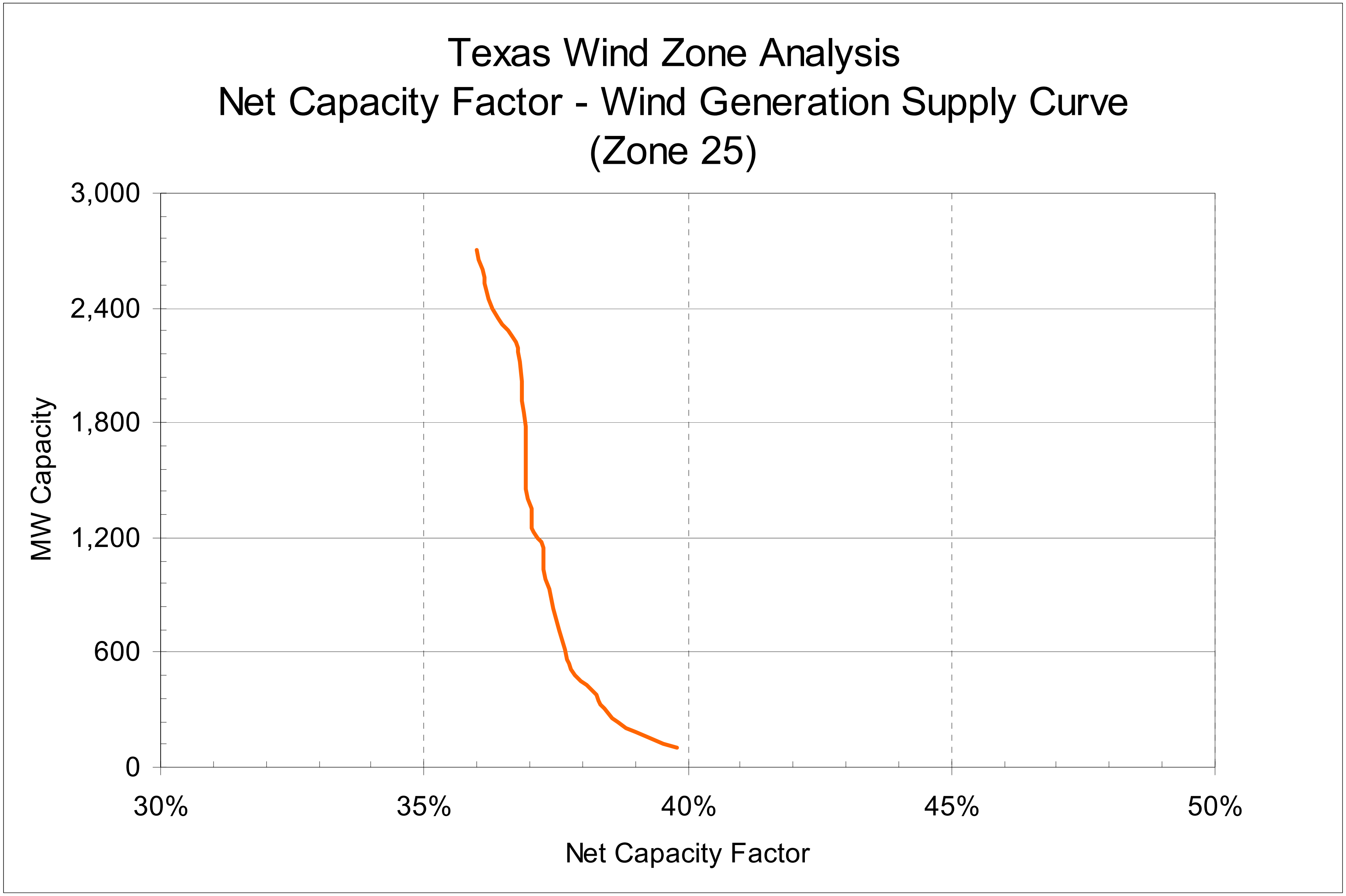


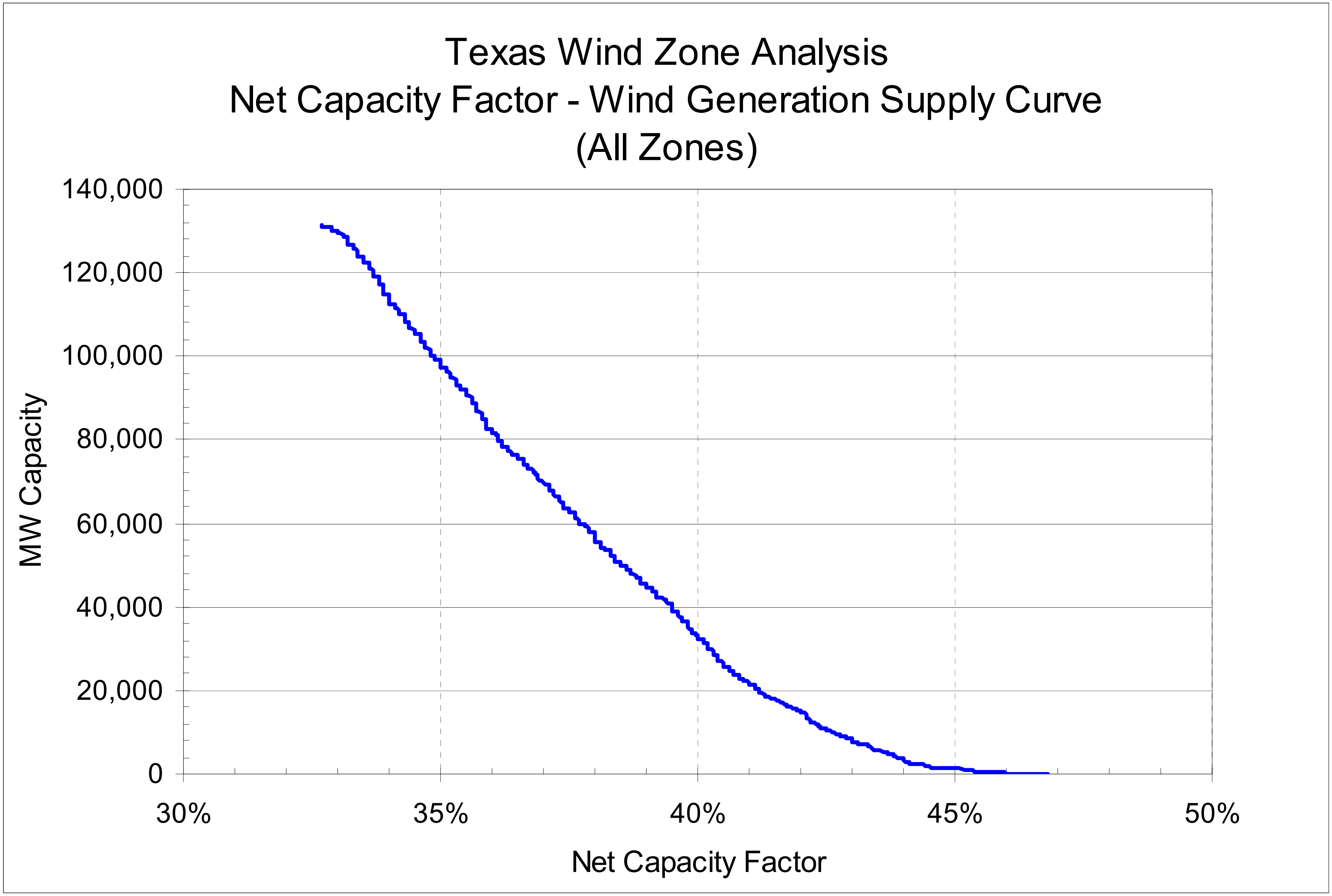
Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 21)
1,600
1,200
800
400
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor


Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 22)
450
375
300
225
150
75
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor


Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 23)
MW Capacity
4,000
3,000
2,000
1,000
0
30%
35%
40%
45%
50%
Net Capacity Factor


Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 24)
2,500
2,000
1,500
1,000
500
0
MW Capacity
30%
35%
40%
45%
50%
Net Capacity Factor


Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(Zone 25)
MW Capacity
3,000
2,400
1,800
1,200
600
0
30%
35%
40%
45%
50%
Net Capacity Factor



Texas Wind Zone Analysis
Net Capacity Factor - Wind Generation Supply Curve
(All Zones)
MW Capacity
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
30%
35%
40%
45%
50%
Net Capacity Factor

APPENDIX B

List of Common Transmission Projects

The following common projects were included in many of the scenarios of this study:

1. Build a 345-kV ring-bus at the Long Creek substation to tie in both existing lines.
2. Build a new substation and 345-kV ring-bus near Paint Creek where the Mulberry Creek - Oklaunion and Morgan Creek – Graham lines cross. This project has been shown to be economically cost-justified in the Five-Year Plan.
3. Build a new 345-kV Oklaunion – Bowman line on separate right-of-way from the existing Oklaunion – Fisher Road – Bowman 345-kV line. This project also has been shown to be economically cost-justified in the Five-Year Plan.
4. Build a 345-kV ring-bus at Bittercreek substation to tie in both existing lines.
5. Upgrade the existing 345-kV Bluff Creek – Mulberry Creek line.
6. Build a new 345-kV Willow Creek – Eagle Mt line. The transmission owner has confirmed that the Willow Creek substation is arranged for additional lines, but that the Eagle Mountain endpoint may not have sufficient room for the necessary additional equipment. One possible alternative would be to build a new substation slightly east of Eagle Mountain in the existing right-of-way. Eagle Mountain is a good site for an additional 345-kV connection into the Fort Worth area because a significant amount of 138-kV infrastructure exists to distribute the output of the now inactive Eagle Mountain power plant.
7. Install a second 345/138-kV autotransformer at Eagle Mountain. The transmission owner has confirmed that the switching substation is big enough to accommodate an additional autotransformer.
8. Upgrade the existing 345-kV Willow Creek – Jacksboro line.
9. Build a new 138-kV line from Forsan tap or McDonald Rd to Cedar Hill.
10. Upgrade the existing 138-kV Cedar Hill – Oak Creek line.
11. Install a Special Protection Scheme to open the 69-kV Fort Stockton – Barrilla line if the 138-kV Fort Stockton – Barrilla line goes out of service.
12. Open the 69-kV switch at Camp Wood
13. Establish a methodology to protect the Bluff Creek autotransformers, such as a Special Protection Scheme to disconnect a nearby windfarm whenever one of the autotransformers goes out of service.
14. Evaluate the current operations of the 138-kV Sonora – Corinthian line. The phase-shifting transformer in service at Hamilton may already by sufficient to mitigate the effects of contingencies noted in the planning models, but its effectiveness and impact on production costs to relieve system congestion require further detailed study.
15. Upgrade the rate A of many 69-kV lines from their current thermal rating (often less than 20 MVA) to their rate B.

APPENDIX C

Economic Modeling Results

Table C1(A): Modeling Results for Transmission Solutions for Coastal Texas (Zone 24)

Transmission Option	New CREZ Installed Wind Capacity (MW)	New CREZ Wind Energy Curtailed (%)	New CREZ Wind Capacity Factor (%)	Total Wind Energy Curtailed (%)	Total Wind Capacity Factor (%)	New CREZ Wind Generation (GWh)	Total Wind Generation (GWh)
Level 1	800	0.00	38.44	2.56	38.71	2,694	19,174
	1,000	0.00	38.27	2.47	38.67	3,353	19,835
	1,200	0.05	38.01	2.39	38.61	3,996	20,479
	1,400	0.20	37.74	2.35	38.53	4,629	21,114
Level 2	1,800	0.00	37.54	2.18	38.43	5,920	22,405
	2,000	0.05	37.05	2.12	38.27	6,491	22,980
	2,200	0.29	37.14	2.14	38.26	7,157	23,645
Level 3	2,600	0.09	37.41	1.99	38.29	8,520	25,003
	2,800	0.45	37.29	2.08	38.22	9,147	25,627
	3,000	1.26	37.00	2.33	38.08	9,724	26,206
	3,200	2.46	36.51	2.77	37.86	10,234	26,713

Table C1(B): Modeling Results for Transmission Solutions for Coastal Texas (Zone 24)

Transmission Option	New CREZ Installed Wind Capacity (MW)	Total Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Energy Revenue ($/MWh)	Total Wind Generator Annual Revenue ($M/Yr)	Total Wind Generator Energy Revenue ($/MWh)	Total Annual System Production Costs ($M/Yr)
Level 1	800	17,262	117	43.39	686	35.77	13,276
	1,000	17,228	145	43.10	712	35.92	13,249
	1,200	17,184	170	42.66	737	35.99	13,221
	1,400	17,143	194	41.87	760	35.98	13,194
Level 2	1,800	17,043	246	41.58	807	36.02	13,139
	2,000	17,012	264	40.69	823	35.83	13,116
	2,200	16,984	280	39.12	838	35.44	13,096
Level 3	2,600	16,864	324	37.97	876	35.03	13,038
	2,800	16,800	326	35.66	878	34.25	13,015
	3,000	16,736	324	33.31	873	33.33	12,995
	3,200	16,676	315	30.77	863	32.32	12,976

Table C1(C): Modeling Results for Transmission Solutions for Central Western Texas (Zone 24)

Transmission Option	New CREZ Installed Wind Capacity (MW)	SO2 Emissions (K Tons)	NOX Emissions (K Tons)	CO2 Emissions (M Tons)
Level 1	800	220.134	87.178	226.930
	1,000	220.022	87.052	226.617
	1,200	219.900	86.930	226.300
	1,400	219.785	86.838	226.015
Level 2	1,800	219.488	86.580	225.371
	2,000	219.346	86.490	225.094
	2,200	219.145	86.475	224.799
Level 3	2,600	218.722	86.312	224.096
	2,800	218.472	86.231	223.799
	3,000	218.225	86.188	223.530
	3,200	218.039	86.130	223.271

Table C2(A): Modeling Results for Transmission Solutions for Central Western Texas

Transmission Option	New CREZ Installed Wind Capacity (MW)	New CREZ Wind Energy Curtailed (%)	New CREZ Wind Capacity Factor (%)	Total Wind Energy Curtailed (%)	Total Wind Capacity Factor (%)	New CREZ Wind Generation (GWh)	Total Wind Generation (GWh)
Red Creek to Hill Country	1,800	0.0	40.09	1.5	39.35	6,322	22,945
	2,000	0.0	40.05	2.1	39.12	7,017	23,492
	2,200	0.0	40.03	2.8	38.85	7,715	24,014
Paint Creek to Fort Worth	1,400	0.0	39.74	1.3	39.35	4,874	21,567
	1,800	0.2	39.49	2.1	38.98	6,227	22,728
	2,000	0.8	39.11	2.6	38.73	6,852	23,262
Bluff Creek to Bosque	1,000	0.0	39.78	0.4	39.73	3,485	20,379
	1,400	0.0	39.99	1.5	39.36	4,905	21,569
	1,600	0.0	40.06	2.3	39.06	5,615	22,087

Table C2(B): Modeling Results for Transmission Solutions for Central Western Texas

Transmission Option	New CREZ Installed Wind Capacity (MW)	Total Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Energy Revenue ($/MWh)	Total Wind Generator Annual Revenue ($M/Yr)	Total Wind Generator Energy Revenue ($/MWh)	Total Annual System Production Costs ($M/Yr)
Red Creek to Hill Country	1,800	17,052	200	31.21	740	32.23	13,120
	2,000	16,995	210	29.85	730	31.12	13,100
	2,200	16,932	220	28.82	730	30.27	13,070
Paint Creek to Fort Worth	1,400	17,201	160	33.31	720	33.28	13,180
	1,800	17,071	190	30.99	710	31.19	13,140
	2,000	17,011	200	29.59	700	30.23	13,120
Bluff Creek to Bosque	1,000	17,304	130	35.97	740	36.51	13,200
	1,400	17,180	150	30.13	720	33.46	13,160
	1,600	17,125	160	28.17	720	32.47	13,140

Table C2(C): Modeling Results for Transmission Solutions for Central Western Texas

Transmission Option	New CREZ Installed Wind Capacity (MW)	SO2 Emissions (K Tons)	NOX Emissions (K Tons)	CO2 Emissions (M Tons)
Red Creek to Hill Country	1,800	218.071	86.458	224.569
	2,000	217.821	86.374	224.268
	2,200	217.676	86.299	224.034
Paint Creek to Fort Worth	1,400	218.062	87.009	225.392
	1,800	217.620	86.924	224.844
	2,000	217.415	86.859	224.577
Bluff Creek to Bosque	1,000	218.900	86.899	225.739
	1,400	218.345	86.767	225.239
	1,600	218.153	86.721	224.99

Table C3(A): Modeling Results for Transmission Solutions for McCamey Area (Zones 5 and 6)

Transmission Option	New CREZ Installed Wind Capacity (MW)	New CREZ Wind Energy Curtailed (%)	New CREZ Wind Capacity Factor (%)	Total Wind Energy Curtailed (%)	Total Wind Capacity Factor (%)	New CREZ Wind Generation (GWh)	Total Wind Generation (GWh)
Level 1	1,250	0.2	40.82	1.4	39.57	4470	21,162
	1,500	0.5	40.51	2.0	39.30	5324	21,881
	1,750	1.1	40.05	2.8	38.96	6140	22,542
Level 2	3,600	0.02	41.07	1.82	39.68	12,953	29,393
	3,800	0.04	41.04	2.18	39.54	13,660	29,980
	4,000	0.12	40.94	2.57	39.37	14,346	30,540

Table C3(B): Modeling Results for Transmission Solutions for McCamey Area (Zones 5 and 6)

Transmission Option	New CREZ Installed Wind Capacity (MW)	Total Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Energy Revenue ($/MWh)	Total Wind Generator Annual Revenue ($M/Yr)	Total Wind Generator Energy Revenue ($/MWh)	Total Annual System Production Costs ($M/Yr)
Level 1	1,250	17,146	155	34.75	733	34.66	13,204
	1,500	17,053	172	32.26	720	32.89	13,178
	1,750	16,977	184	29.97	710	31.49	13,149
Level 2	3,600	16,453	401	30.96	924	31.43	12,889
	3,800	16,390	412	30.17	924	30.84	12,870
	4,000	16,314	419	29.21	918	30.07	12,850

Table C3(C): Modeling Results for Transmission Solutions for McCamey Area (Zones 5 and 6)

Transmission Option	New CREZ Installed Wind Capacity (MW)	SO2 Emissions (K Tons)	NOX Emissions (K Tons)	CO2 Emissions (M Tons)
Level 1	1,250	218.809	86.779	225.712
	1,500	218.471	86.696	225.386
	1,750	218.225	86.627	225.069
Level 2	3,600	215.312	84.858	220.961
	3,800	215.014	84.748	220.635
	4,000	214.690	84.632	220.344

Table C4(A): Modeling Results for Transmission Solutions for Culberson County (Zone 7)

Transmission Option	New CREZ Installed Wind Capacity (MW)	New CREZ Wind Energy Curtailed (%)	New CREZ Wind Capacity Factor (%)	Total Wind Energy Curtailed (%)	Total Wind Capacity Factor (%)	New CREZ Wind Generation (GWh)	Total Wind Generation (GWh)
Level 1	1,200	0.0	38.79	0.52	39.50	4078	20,953
	1,400	0.0	37.88	0.91	39.11	4645	21,433
	1,600	0.0	37.15	1.40	38.70	5207	21,880

Table C4(B): Modeling Results for Transmission Solutions for Culberson County (Zone 7)

Transmission Option	New CREZ Installed Wind Capacity (MW)	Total Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Energy Revenue ($/MWh)	Total Wind Generator Annual Revenue ($M/Yr)	Total Wind Generator Energy Revenue ($/MWh)	Total Annual System Production Costs ($M/Yr)
Level 1	1,200	17,293	148	36.18	763	36.41	13,177
	1,400	17,245	159	34.25	761	35.50	13,158
	1,600	17,208	168	32.32	759	34.68	13,143

Table C4(C): Modeling Results for Transmission Solutions for Culberson County (Zone 7)

Transmission Option	New CREZ Installed Wind Capacity (MW)	SO2 Emissions (K Tons)	NOX Emissions (K Tons)	CO2 Emissions (M Tons)
Level 1	1,200	218.889	86.844	225.528
	1,400	218.699	86.770	225.294
	1,600	218.558	86.707	225.118

Table C5(A): Modeling Results for Transmission Solutions for the Panhandle Region (Zones 2 and 4)

Transmission Option	New CREZ Installed Wind Capacity (MW)	New CREZ Wind Energy Curtailed (%)	New CREZ Wind Capacity Factor (%)	Total Wind Energy Curtailed (%)	Total Wind Capacity Factor (%)	New CREZ Wind Generation (GWh)	Total Wind Generation (GWh)
Level 1	600	1.22	43.00	1.88	39.57	2,260	18,910
	800	2.12	43.24	2.46	39.53	3,030	19,585
Level 2	1,600	0.14	43.55	1.72	40.14	6,104	22,699
	1,800	0.18	43.26	2.04	40.02	6,822	23,332
	2,000	0.25	43.14	2.55	39.86	7,558	23,935
Level 3	2,000	0.00	43.2%	1.78	40.2%	7577	24,123
	2,400	0.22	42.8%	2.14	40.0%	8998	25,444
	2,800	1.63	41.9%	2.89	39.7%	10283	26,644
Level 4	4,400	0.40	42.70	1.60	40.67	16,459	32,973
	4,600	0.70	42.50	1.90	40.54	17,124	33,577
	4,800	1.02	42.27	2.20	40.83	17,774	34,173

Table C5(B): Modeling Results for Transmission Solutions for the Panhandle Region (Zones 2 and 4)

Transmission Option	New CREZ Installed Wind Capacity (MW)	Total Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Energy Revenue ($/MWh)	Total Wind Generator Annual Revenue ($M/Yr)	Total Wind Generator Energy Revenue ($/MWh)	Total Annual System Production Costs ($M/Yr)
Level 1	600	17,276	80	35.54	643	33.98	13,293
	800	17,202	101	33.24	640	32.66	13,266
Level 2	1,600	17,048	210	34.45	750	33.02	13,153
	1,800	16,975	224	32.84	747	32.01	13,129
	2,000	16,902	234	31.00	740	30.93	13,110
Level 3	2,000	16,935	215	28.39	760	31.49	13,107
	2,400	16,839	235	26.17	762	29.95	13,079
	2,800	16,767	252	24.47	763	28.63	13,057
Level 4	4,400	16,261	460	27.94	974	29.54	12,803
	4,600	16,209	465	27.13	970	28.90	12,789
	4,800	16,147	466	26.20	963	28.19	12,774

Table C5(C): Modeling Results for Transmission Solutions for the Panhandle Region (Zones 2 and 4)

Transmission Option	New CREZ Installed Wind Capacity (MW)	SO2 Emissions (K Tons)	NOX Emissions (K Tons)	CO2 Emissions (M Tons)
Level 1	600	219.596	87.369	226.875
	800	219.431	87.307	226.588
Level 2	1,600	217.697	86.818	224.889
	1,800	217.434	86.709	224.542
	2,000	217.123	86.601	224.260
Level 3	2,000	217.449	86.488	224.138
	2,400	216.629	86.216	223.148
	2,800	215.864	86.021	222.253
Level 4	4,400	212.756	84.355	218.709
	4,600	212.356	84.222	218.300
	4,800	211.892	84.083	217.840

Table C6(A): Modeling Results for Transmission Solutions for Combination Scenarios

Transmission Option	New CREZ Installed Wind Capacity (MW)	New CREZ Wind Energy Curtailed (%)	New CREZ Wind Capacity Factor (%)	Total Wind Energy Curtailed (%)	Total Wind Capacity Factor (%)	New CREZ Wind Generation (GWh)	Total Wind Generation (GWh)
Red Creek and Bluff Creek Options – Wind from Zones 10 and 14	2,800	0.0	39.34	1.6	39.09	9,648	26,214
	3,000	0.2	38.98	2.0	38.80	10,244	26,699
	3,200	1.1	38.68	2.6	38.58	10,841	27,229
Red Creek and Paint Creek Options – Wind from Zones 10 and 14	2,000	0.0	38.43	0.5	39.29	6,733	23,596
	2,800	0.1	38.87	1.8	38.83	9,534	26,042
	3,000	0.4	38.51	2.3	38.52	10,121	26,511
Paint Creek and Bluff Creek Options – Wind from Zones 10 and 14	2,000	0.0	38.43	0.9	39.15	6,733	23,512
	2,600	0.0	38.04	1.9	38.54	8,663	25,170
	3,000	0.2	38.57	2.8	38.32	10,137	26,369

Table C6(B): Modeling Results for Transmission Solutions for Combination Scenarios

Transmission Option	New CREZ Installed Wind Capacity (MW)	Total Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Energy Revenue ($/MWh)	Total Wind Generator Annual Revenue ($M/Yr)	Total Wind Generator Energy Revenue ($/MWh)	Total Annual System Production Costs ($M/Yr)
Red Creek and Bluff Creek Options – Wind from Zones 10 and 14	2,800	16,798	296	30.70	822	31.37	12,990
	3,000	16,732	303	29.61	816	30.55	12,970
	3,200	16,676	310	28.63	810	29.73	12,949
Red Creek and Paint Creek Options – Wind from Zones 10 and 14	2,000	17,089	235	34.84	824	34.94	13,089
	2,800	16,788	289	30.35	804	30.88	13,006
	3,000	16,752	296	29.27	797	30.06	12,989
Paint Creek and Bluff Creek Options – Wind from Zones 10 and 14	2,000	17,068	229	34.01	802	34.09	13,093
	2,600	16,896	269	31.08	792	31.47	13,037
	3,000	16,751	292	28.80	780	29.60	12,994

Table C6(C): Modeling Results for Transmission Solutions for Combination Scenarios

Transmission Option	New CREZ Installed Wind Capacity (MW)	SO2 Emissions (K Tons)	NOX Emissions (K Tons)	CO2 Emissions (M Tons)
Red Creek and Bluff Creek Options – Wind from Zones 10 and 14	2,800	216.655	85.665	222.694
	3,000	216.456	85.574	222.443
	3,200	216.231	85.463	222.158
Red Creek and Paint Creek Options – Wind from Zones 10 and 14	2,000	217.537	86.387	224.111
	2,800	216.294	86.028	222.984
	3,000	216.055	85.954	222.716
Paint Creek and Bluff Creek Options – Wind from Zones 10 and 14	2,000	217.340	86.487	224.152
	2,600	216.579	86.286	223.384
	3,000	215.959	86.133	222.780

Table C7(A): Modeling Results for Transmission Solutions for Combination Scenarios

Transmission Option	New CREZ Installed Wind Capacity (MW)	New CREZ Wind Energy Curtailed (%)	New CREZ Wind Capacity Factor (%)	Total Wind Energy Curtailed (%)	Total Wind Capacity Factor (%)	New CREZ Wind Generation (GWh)	Total Wind Generation (GWh)
Red Creek and Bluff Creek Options – Wind from Zones 5, 10, and 14	3,000	0.3	39.87	1.6	39.32	10,479	27,061
	3,250	0.4	39.84	2.1	39.13	11,343	27,784
	3,500	0.7	39.71	2.8	38.85	12,174	28,437
Red Creek and Paint Creek Options – Wind from Zones 5, 10, and 14	2,500	0.4	39.67	1.3	39.38	8,687	25,376
	2,750	0.6	39.66	1.7	39.23	9,555	26,141
	3,000	1.0	39.58	2.3	39.02	10,400	26,852
Paint Creek and Bluff Creek Options – Wind from Zones 5, 10, and 14	1,950	1.2	39.85	1.5	39.44	6,808	23,516
	2,000	1.7	39.73	1.9	39.31	6,960	23,608
	2,750	4.7	38.05	3.6	38.47	9,166	25,629

Table C7(B): Modeling Results for Transmission Solutions for Combination Scenarios

Transmission Option	New CREZ Installed Wind Capacity (MW)	Total Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Energy Revenue ($/MWh)	Total Wind Generator Annual Revenue ($M/Yr)	Total Wind Generator Energy Revenue ($/MWh)	Total Annual System Production Costs ($M/Yr)
Red Creek and Bluff Creek Options – Wind from Zones 5, 10, and 14	3,000	16,746	327	31.25	851	31.45	12,960
	3,250	16,663	340	29.98	844	30.38	12,933
	3,500	16,592	349	28.64	835	29.37	12,910
Red Creek and Paint Creek Options – Wind from Zones 5, 10, and 14	2,500	16,902	280	32.20	820	32.32	13,027
	2,750	16,816	297	31.07	816	31.23	13,005
	3,000	16,737	311	29.91	810	30.15	12,979
Paint Creek and Bluff Creek Options – Wind from Zones 5, 10, and 14	1,950	17,041	223	32.69	775	32.95	13,092
	2,000	17,024	222	31.89	765	32.39	13,088
	2,750	16,838	281	30.69	785	30.62	13,018

Table C7(C): Modeling Results for Transmission Solutions for Combination Scenarios

Transmission Option	New CREZ Installed Wind Capacity (MW)	SO2 Emissions (K Tons)	NOX Emissions (K Tons)	CO2 Emissions (M Tons)
Red Creek and Bluff Creek Options – Wind from Zones 5, 10, and 14	3,000	216.084	85.581	222.277
	3,250	215.575	85.407	221.820
	3,500	215.287	85.336	221.510
Red Creek and Paint Creek Options – Wind from Zones 5, 10, and 14	2,500	216.561	86.152	223.292
	2,750	216.173	86.081	222.922
	3,000	215.784	85.998	222.552
Paint Creek and Bluff Creek Options – Wind from Zones 5, 10, and 14	1,950	217.371	86.462	224.237
	2,000	217.324	86.477	224.202
	2,750	216.347	86.241	223.193

Table C8(A): Modeling Results for Transmission Solutions for Combination Scenarios

Transmission Option	New CREZ Installed Wind Capacity (MW)	New CREZ Wind Energy Curtailed (%)	New CREZ Wind Capacity Factor (%)	Total Wind Energy Curtailed (%)	Total Wind Capacity Factor (%)	New CREZ Wind Generation (GWh)	Total Wind Generation (GWh)
Red Creek, Bluff Creek and Paint Creek Options – Wind from Zones 10 and 14	3,600	0.0	39.40	1.6	39.05	12,425	28,928
	3,800	0.1	39.25	2.0	38.85	13,065	29,459
	4,000	0.3	38.97	2.4	38.61	13,653	29,950
Red Creek, Bluff Creek and Paint Creek Options – Wind from Zones 5, 10, and 14	3,750	0.5	38.95	1.7	38.93	12,794	29,352
	4,000	0.8	38.95	2.1	38.78	13,647	30,088
	4,200	1.0	38.94	2.5	38.65	14,325	30,661
Red Creek, Bluff Creek and Coastal Level 2 Options – Wind from Zones 5, 10, 14, and 24	5,000	0.12%	38.8%	1.34%	38.84%	16,981	33,529
	5,250	0.18%	38.8%	1.77%	38.69%	17,851	34,248
	5,500	0.30%	38.8%	2.35%	38.47%	18,697	34,897

Table C8(B): Modeling Results for Transmission Solutions for Combination Scenarios

Transmission Option	New CREZ Installed Wind Capacity (MW)	Total Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Annual Revenue ($M/Yr)	New CREZ Wind Generator Energy Revenue ($/MWh)	Total Wind Generator Annual Revenue ($M/Yr)	Total Wind Generator Energy Revenue ($/MWh)	Total Annual System Production Costs ($M/Yr)
Red Creek, Bluff Creek and Paint Creek Options – Wind from Zones 10 and 14	3,600	16,565	370	29.74	875	30.26	12,899
	3,800	16,496	377	28.89	869	29.51	12,881
	4,000	16,453	385	28.18	867	28.96	12,864
Red Creek, Bluff Creek and Paint Creek Options – Wind from Zones 5, 10, and 14	3,750	16,535	381	29.81	887	30.20	12,884
	4,000	16,467	397	29.09	887	29.48	12,856
	4,200	16,399	405	28.30	881	28.72	12,837
Red Creek, Bluff Creek and Coastal Level 2 Options – Wind from Zones 5, 10, 14, and 24	5,000	16,257	556	32.77	1059	31.59	12,695
	5,250	16,181	570	31.92	1056	30.85	12,671
	5,500	16,102	577	30.87	1046	29.99	12,649

Table C8(C): Modeling Results for Transmission Solutions for Combination Scenarios

Transmission Option	New CREZ Installed Wind Capacity (MW)	SO2 Emissions (K Tons)	NOX Emissions (K Tons)	CO2 Emissions (M Tons)
Red Creek, Bluff Creek and Paint Creek Options – Wind from Zones 10 and 14	3,600	214.817	85.162	221.186
	3,800	214.513	85.085	220.852
	4,000	214.275	84.988	220.600
Red Creek, Bluff Creek and Paint Creek Options – Wind from Zones 5, 10, and 14	3,750	214.525	85.113	220.944
	4,000	214.052	84.986	220.494
	4,200	213.670	84.861	220.178
Red Creek, Bluff Creek and Coastal Level 2 Options – Wind from Zones 5, 10, 14, and 24	5,000	214.038	84.084	218.792
	5,250	213.626	83.940	218.405
	5,500	213.214	83.807	218.047