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Wind Supply Curves and Location Scenarios in the West: Summary of the Clean and Diverse Energy Wind Task Force Report

Preprint

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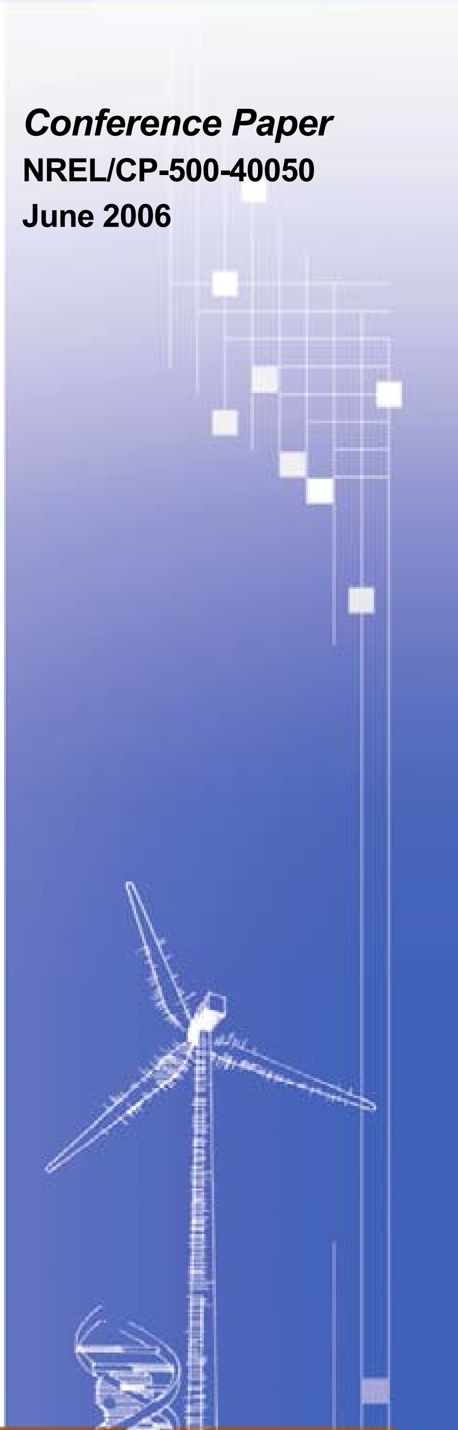

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Wind Task Force of the
Clean and Diversified Energy Advisory Committee

Abstract

In 2004, the Western Governors' Association (WGA) adopted a resolution to add 30 gigawatts (GW) of clean energy capacity in the West, with associated improvements in efficiency. To implement this proposal, the WGA formed the Clean and Diversified Energy Advisory Committee (CDEAC) and created a series of task forces that would advise the CDEAC on clean power generation technologies and develop recommendations to help achieve the Governors' goal of 30, GW of clean power. The Wind Task Force developed a set of supply curves for each WGA state under various assumptions of transmission availability. The supply curves were based on extensive wind map GIS data, paired with GIS transmission data. (The authors are all members of the Wind Task Force). The findings indicate that the wind resource in the WGA footprint can economically more than achieve the WGA target for clean energy development. The analysis also provides a first look at the cost impact of transmission availability on the supply curve that can move wind to the market. In addition to the supply curves, potential wind development in the WGA footprint was analyzed so that transmission studies could help further quantify transmission needs in the West that could help support the WGA goals.

Introduction

As part of the CDEAC effort, the Wind Task Force developed a report[1] that assessed wind supply in the WGA states. This Task Force Report developed supply curves for wind in the WGA states that were based on varying assumptions about wind technology cost and performance and transmission availability. Because wind energy is currently under development in several states in response to renewable energy requirements or utility acquisitions of wind energy, the Task Force developed a set of scenarios based on the current drivers for new wind projects.

The Wind Task Force was only one of several task forces. Task forces for solar, biomass, geothermal, clean coal, energy efficiency, and transmission all performed similar analyses that could help the Governors assess how to achieve the 30-gigawatt (GW) clean power goal in the West. Additional work was also performed by ABB Engineering, which took the existing base case representation of the Western Interconnection (as specified by the Seams Steering Group of the Western Interconnection, or SSG-WI, and the Western Electricity Coordinating Council, or WECC) and modeled several clean energy cases to evaluate the performance of the transmission system.

In this paper, we present the supply curves and scenarios that were developed by the Wind Task Force. Much of this information has been adapted from the original Wind Task Force report.

Wind energy capacity in the WGA states by the end of 2005 amounted to 6,490 MW. This is about 70% of the U.S. total.

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[1] The full Wind Task Force report can be found at http://www.westgov.org/wga/initiatives/cdeac/Wind-full.pdf.

Western Governors' Association
Footprint: Wind Installed end of 2005

Figure 1. Installed wind capacity end of 2005 (AWEA)

As the following map shows, western states have the best wind energy resources in the United States.

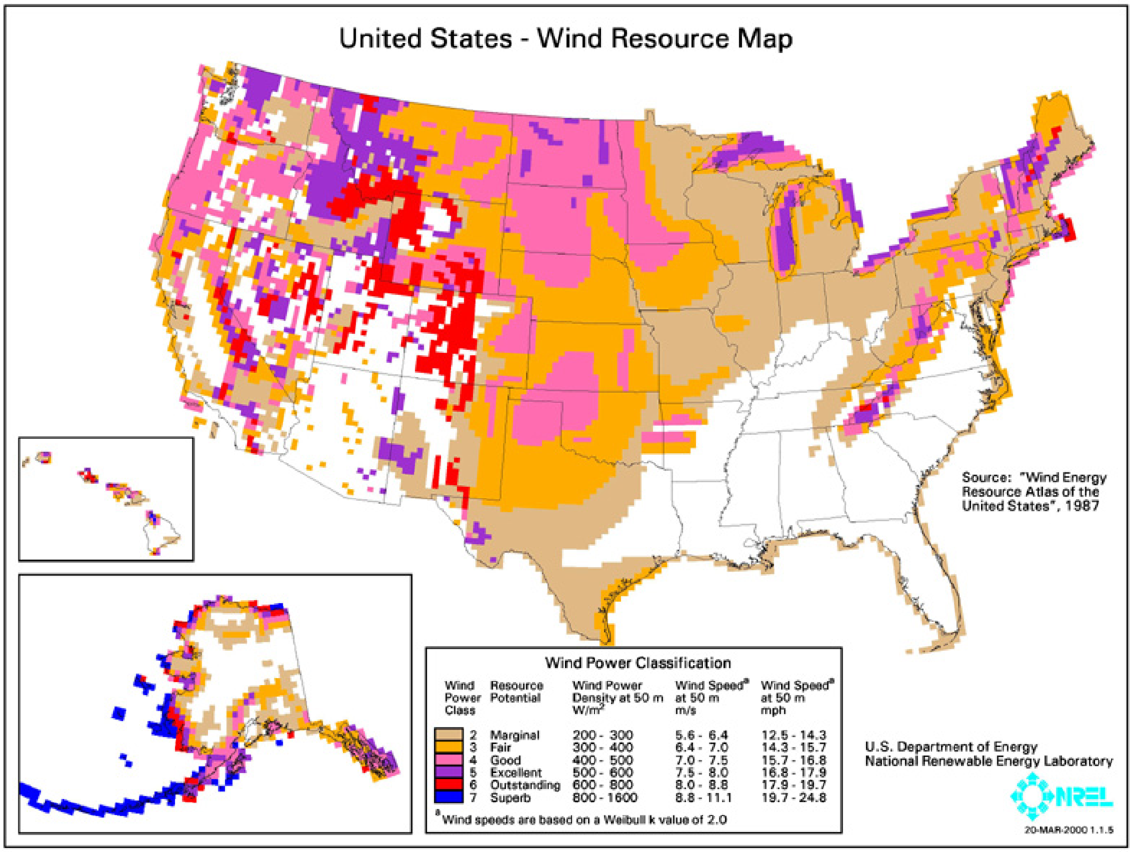


Figure 2. Wind resource map of the United States

Supply Curve Development for Wind in the WGA Footprint

The Wind Task Force developed wind energy supply curves for states in the WGA region within the continental United States. These supply curves describe the amount of wind energy that can be produced in the specified regions at alternative prices. This section describes the assumptions underlying the wind supply curves and then provides some illustrative findings. A complete collection of wind supply curves for each state is contained in the appendix.

The wind supply curve analysis is based on extensive wind resource information and key assumptions linking regional wind resources to the transmission system.

Wind resources are mapped in an extensive GIS system that contains average wind speed for grids of varying sizes, depending on the mapping location and effort. Areas with higher wind speeds can deliver energy at a lower cost than sites with low wind speeds. The analysis converts wind speed data in each grid area to derive the potential wind power based on information about modern wind turbines. Areas that are unusable for wind plants are screened out of the database.

Recently updated maps are available for most states in the WGA footprint. These maps provide detailed resolution to yield results with a high level of confidence. The wind maps for Kansas and Texas have not been fully updated. Therefore some high-quality wind resources in these two states may be overlooked by the current state maps and are not represented in the supply curves.

A second critical feature of the supply curve analysis relates to the information and assumptions about the transmission system. The supply curves represent the cost of wind energy as delivered to the transmission backbone. The supply curves were derived under two transmission system assumptions. In the first case, we assume the transmission system has no available capacity to deliver wind energy to the nearest load center. New transmission must be built to deliver wind energy, assuming a cost of $1000 per MW-mile for the new lines. In a second case, we assume the existing transmission system has 20% of its capacity available to deliver wind energy to the nearest load center. Once the 20% transmission capacity is used up, however, new transmission must be built to carry additional energy to the nearest load center. New transmission is assumed to cost $1000 per MW-mile.

A number of simplifications are involved in this aspect of the analysis. First, our database does not contain dynamic line ratings. Instead, the line capacity is based solely on voltage and length. Second, we do not know the loading patterns of the lines throughout the year, nor do we know how different operating conditions affect the line. We also do not have detailed information on specific paths that can be used to determine whether the 20% of wind capacity is available on the line. Based on the work of SSG-WI and others, we believe that this is a rough approximation that serves the purpose of developing a set of supply curves that can help us assess the overall cost and potential of wind in the WGA footprint.

In many parts of the West, transmission paths are congested during peak flow periods. Analysis by the SSG-WI showed that many transmission paths were constrained only for a very small percent of the year (e.g., less than 5%). During the rest of the year (e.g., 95%), these paths are not constrained by actual flows. Potential tariff reforms (various flexible-firm arrangements) provide the opportunity to more efficiently utilize the existing transmission system. Based on the emerging tariff reforms and efficiency gains for transmission, we believe that with the right set of policy and system operational practices that in the near term wind can obtain access to some needed transmission assets to move energy to markets. These near-term changes could yield more transmission capacity for wind without new transmission construction.

In the long term, however, the transmission system in the West will need significant upgrades to bring wind and other needed energy sources to market. The wind resource is not evenly distributed. When evaluating the economics of wind locations, one must often balance low-cost wind resource (requiring a long transmission build) against a higher-cost wind resource (requiring a shorter transmission build). The supply curves described above are valuable in assessing this tradeoff because the cost of transmission is explicitly factored into the cost calculation.

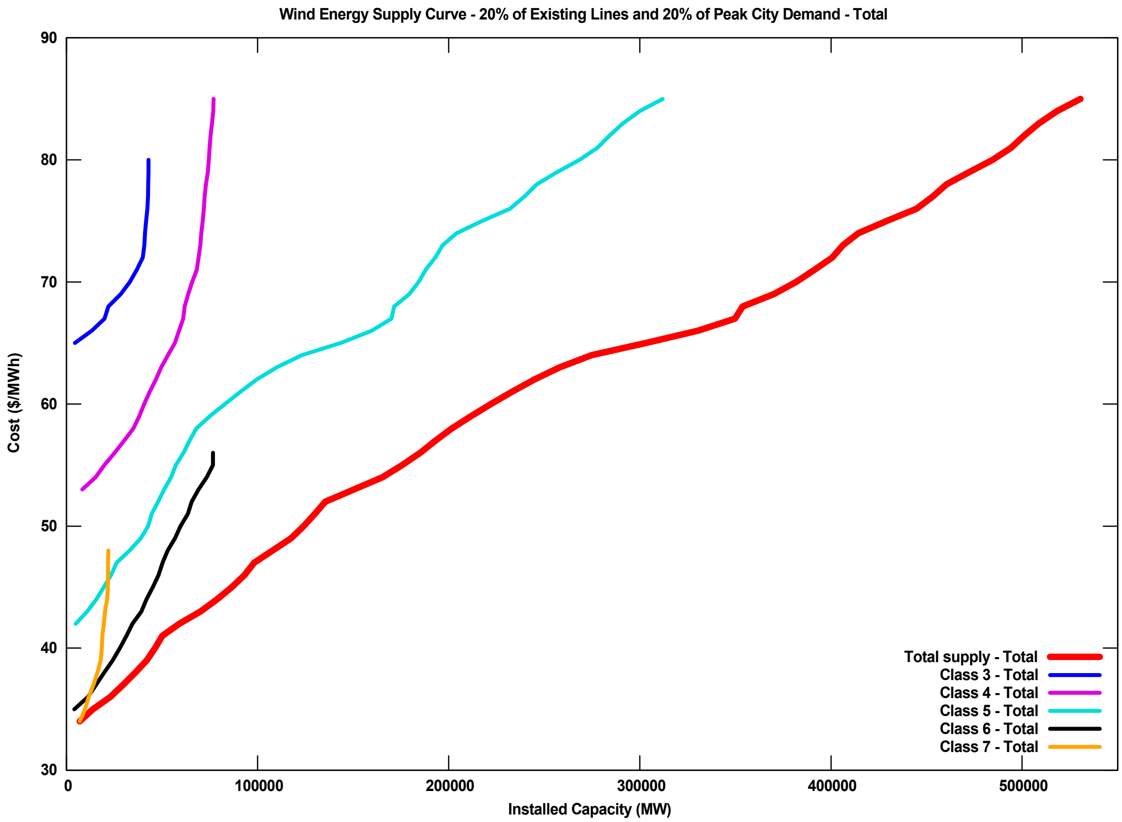
Although the best available information has been used to develop these supply curves, a number of caveats must be identified when interpreting the results. First, the supply curves were based on current wind technology. In recent years, wind energy technology has made significant advances, resulting in new turbines every 1 to 3 years. To the extent that this continues, the supply curves will overestimate the longer term future cost of wind energy. Second, the supply curve can exhibit linear step shape. Each point on a supply curve is linked to a specific location's wind power class that is used to convert wind speed to power. The step occurs when the high-class resource is exhausted and the next site is from a lower-class (higher-cost) wind resource. Each cell within the map grid is represented by the mid-point of the appropriate power density for that wind class. Third, other factors have an impact on the cost of delivered wind energy but cannot be readily captured in the supply curve (e.g., power purchase agreements, transmission access and tariffs, and ownership structure). Fourth, the cost curves do not include the cost to integrate the variable wind resource into the operating mix of generation resources. This integration cost is variable, depending on the characteristics of the generation portfolio in the region, the wind resource, and the wind penetration rate (ratio of wind energy or capacity to system energy or capacity). Recent studies estimate integration costs in the range of less than \$1/MWh to about \$5/MWh, depending on the characteristics of the mix of conventional fuels, size of load and control area, and penetration of wind relative to overall load in the specific utility system. Fifth, future policy changes are not reflected in this analysis. Finally, during the course of the work that led to these supply curves, the price of wind turbines increased substantially. The primary causes of this increase include the recent high cost of steel, the weak U.S. dollar, and pent-up demand for wind turbines that was finally released when the Production Tax Credit (PTC) was renewed. It is difficult to assess whether this cost run-up is a temporary phenomenon or part of a longer-term trend.

Wind supply curves for the WGA states are shown below. These curves illustrate the vast wind potential in the respective states. For all supply curves in this report, the cost of wheeling, integration, and distribution are not included. Costs also do not consider the PTC. The aggregate WGA supply curve shows that at a price of $50/MWh, wind can supply more than 30 GW of capacity. At $60/MWh, the quantity of wind that can be supplied is more than 100 GW. Clearly the barrier to developing significant wind generation in the West is not hindered by the resource itself. The primary barriers are related to transmission availability and other issues discussed elsewhere in this report.

Wind supply curves were derived under three cases. The first case assumes that 20% of the existing transmission capacity is available to deliver wind to load. When that transmission capacity is exhausted, new transmission is built to the nearest city, and the remaining wind energy supplies up to 20% of the city's energy.

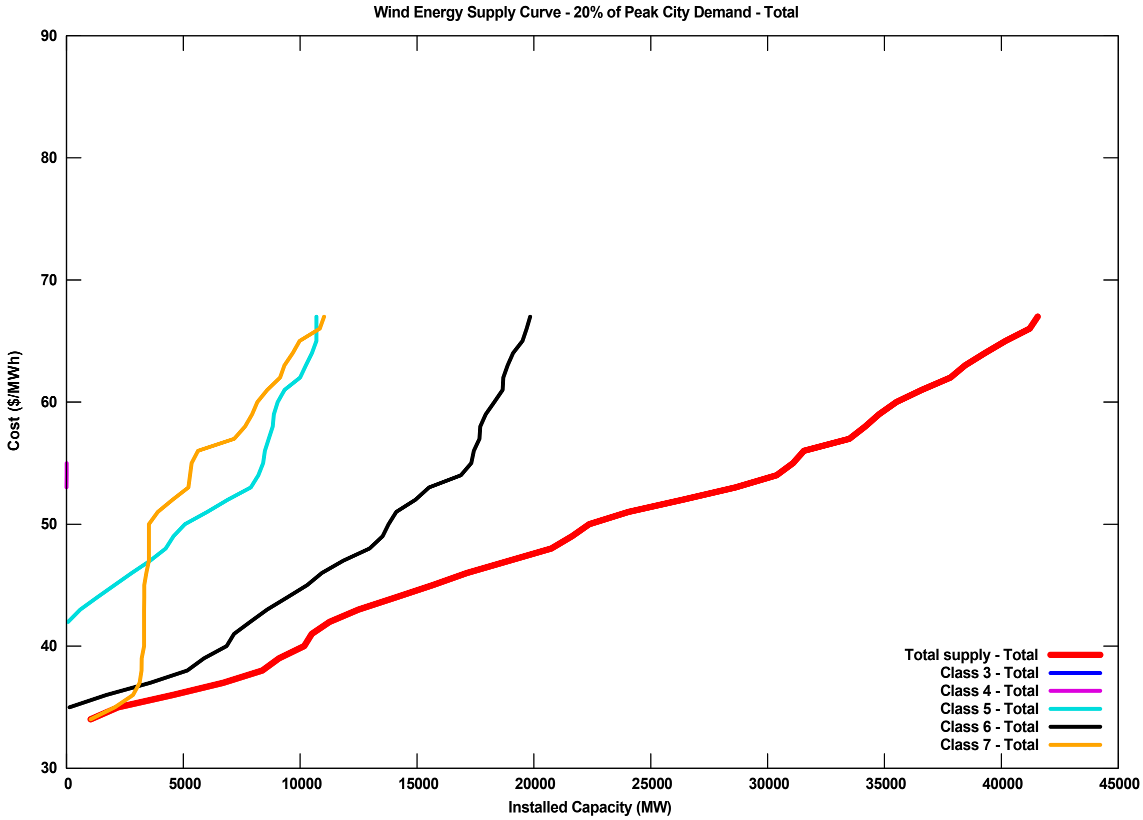
The second supply curve case assumes that there is no capability on the grid that can deliver wind. Therefore, transmission must be built to deliver all the wind energy to load.

The third supply curve case is the same as the second case, but stops once 30 GW of wind capacity has been developed. This case shows the contributions of each state and the upper bound cost of 30 GW of wind in the WGA footprint.



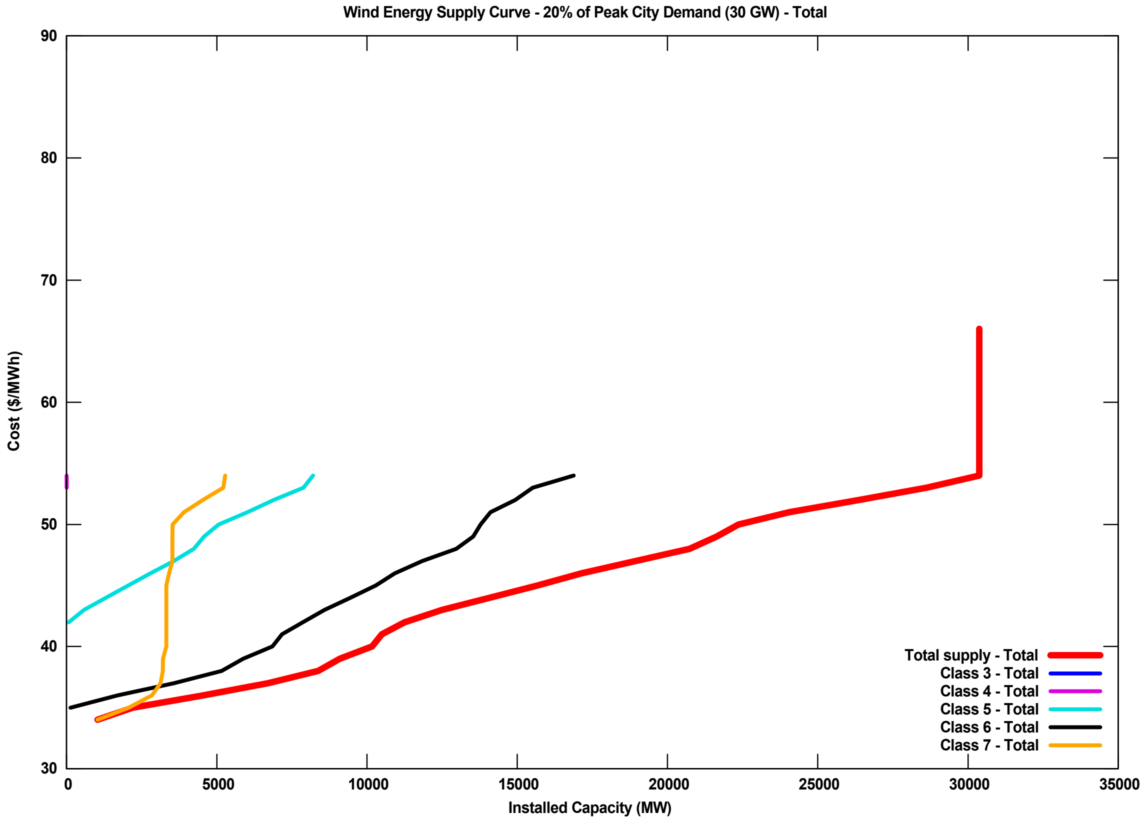
Cost does not include wheeling cost, integration cost, distribution cost or PTC

Figure 3. Wind supply curves for WGA states assuming 20% available transmission



Cost does not include wheeling cost, integration cost, distribution cost or PTC

Figure 4. Wind supply curves for WGA states assuming no available transmission; wind pays for all transmission



Cost does not include wheeling cost, integration cost, distribution cost or PTC

Figure 5. Wind supply curves for WGA states assuming no available transmission, capped at 30 GW

The impact of transmission availability is difficult to overstate. As shown in the graphs in Figure 3 and Figure 4, there is approximately five times more wind energy at $50/MWh in the first case (20% transmission capacity available) relative to the second case (zero capacity available – build-only case where wind pays for all transmission). At $60/MWh, these cases show that wind could supply more than 100 GW in the 20% transmission availability case and approximately 24 GW if new transmission is required to move all the wind energy. We believe that these two cases represent reasonable bounds on the quantities and costs of wind in the WGA footprint. We suspect that the actual costs and supplies lie in between these two cases. In the third case that caps wind energy at 30 GW, the supply curve indicates that 30 GW of wind is available in WGA at a cost of about $64/MWh or less, using the most conservative transmission assumptions.

Table 1 collects some of the key points of the supply curves presented in Figure 3 and Figure 4 so that the impact of transmission can be more clearly seen.

Table 1. Impact of Transmission on Wind Supply in WGA Footprint

Price ($/MWh)	Wind Supply (MW) at 20% Existing Transmission Availability	Wind Supply (MW) with No Existing Transmission Availability	Difference (MW)
60	115,000	25,000	90,000
70	215,000	39,000	176,000
80	320,000	40,000	280,000

Detailed supply curves for each state for the 20% existing transmission availability scenario are shown in Appendix B. Figure 6 and Figure 7 below illustrate the impact of transmission on several key states. It is evident from the supply curve development that there is an enormous wind resource potential in the WGA states that is reasonably close to the transmission infrastructure and cost competitive with other resources.

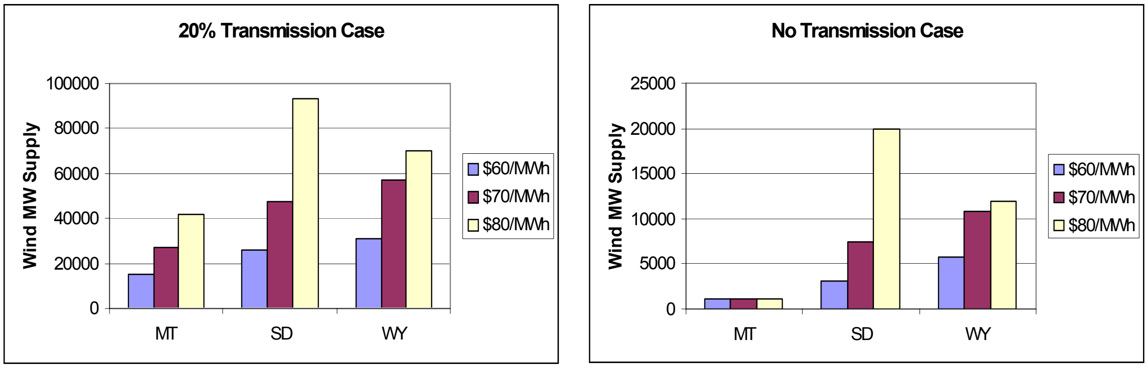


Figure 6. Transmission impact on supply, selected states

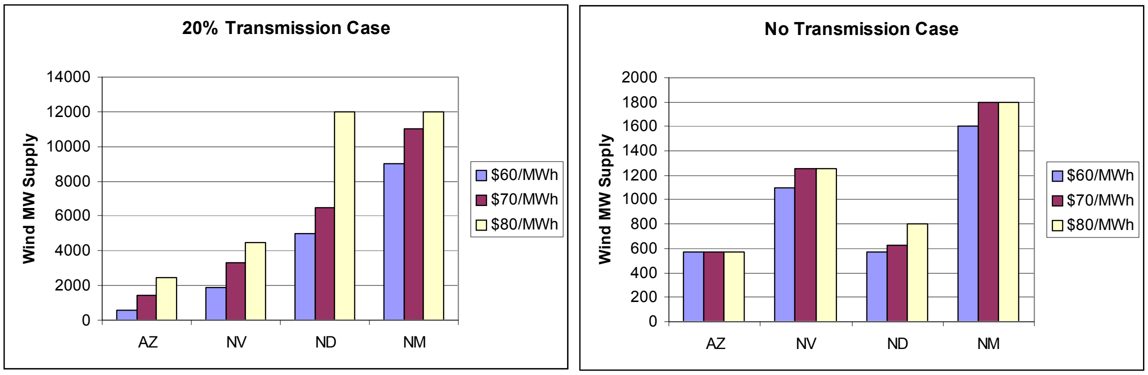
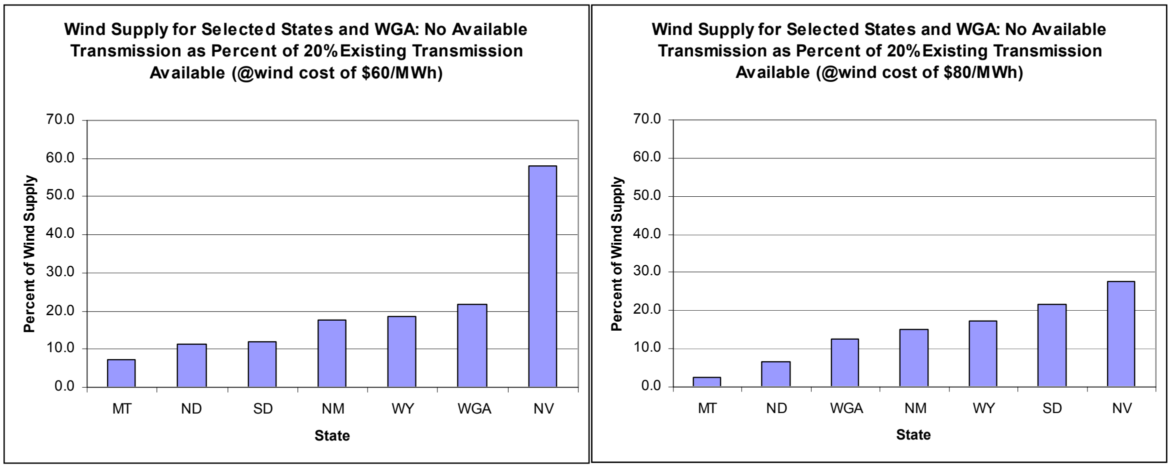


Figure 7. Transmission impact on supply, other selected states

Selected States: Availability of Transmission and Impact on Supply

Figure 8 re-arranges some of the data from some of the selected states above, and also includes the entire WGA footprint. The left panel of the graph shows the wind supply at a price of $60/MWh that would be available if no existing transmission were available, as a percentage of the wind supply if 20% of the existing transmission were available. The graph shows that across the WGA, the wind supply at $60/MWh is about 20% of the supply that could be available if 20% of the existing grid could be used to transport wind. There is clearly a large variation for individual states: in Montana less than 10% of the supply exists with no available transmission compared to the 20% transmission availability case. For the states of ND, SD, NM, and WY this percentage ranges from about 10%-20%, and for NV the percentage is about 60%.

The right side of the graph shows a similar picture at a wind cost of $80/MWh. In this case just over 10% of the WGA wind supply exists if no existing transmission is available, compared to the 20% transmission availability case. No state shows more than 30% of the supply when we compare the no existing transmission case to the 20% existing transmission case. These results show that there is not a one-size-fits-all quantity of wind that is stranded by lack of available transmission, and that for the WGA states as a whole about 20% of the supply at a $60/MWh cost can be tapped if no transmission can deliver wind to load.



Wind Supply for Selected States and WGA: No Available Transmission as Percent of 20% Existing Transmission Available (@wind cost of $60/MWh)

Wind Supply for Selected States and WGA: No Available Transmission as Percent of 20% Existing Transmission Available (@wind cost of $80/MWh)

Figure 8. Selected state transmission impacts of transmission at wind costs of $60/MWh and $80/MWh

Transmission System Availability

Existing analyses on historic flows on major transmission paths in the Western Interconnection suggest the existing transmission system could be utilized more efficiently and provide transmission capacity for new wind resources.

SSG-WI has conducted an analysis of actual flows for the years 1998-2002 using data from the WECC's Extra High Voltage database. The graph below shows summary data from SSG-WI's 2003 report on actual flows. The figure below shows the percentage of time that major transmission paths reached at least 75% of the Operating Transfer Capacity (OTC) limit during the highest summer, spring, and winter season from 1998-2002. The data suggest that many paths operate significantly below their physical capacity.

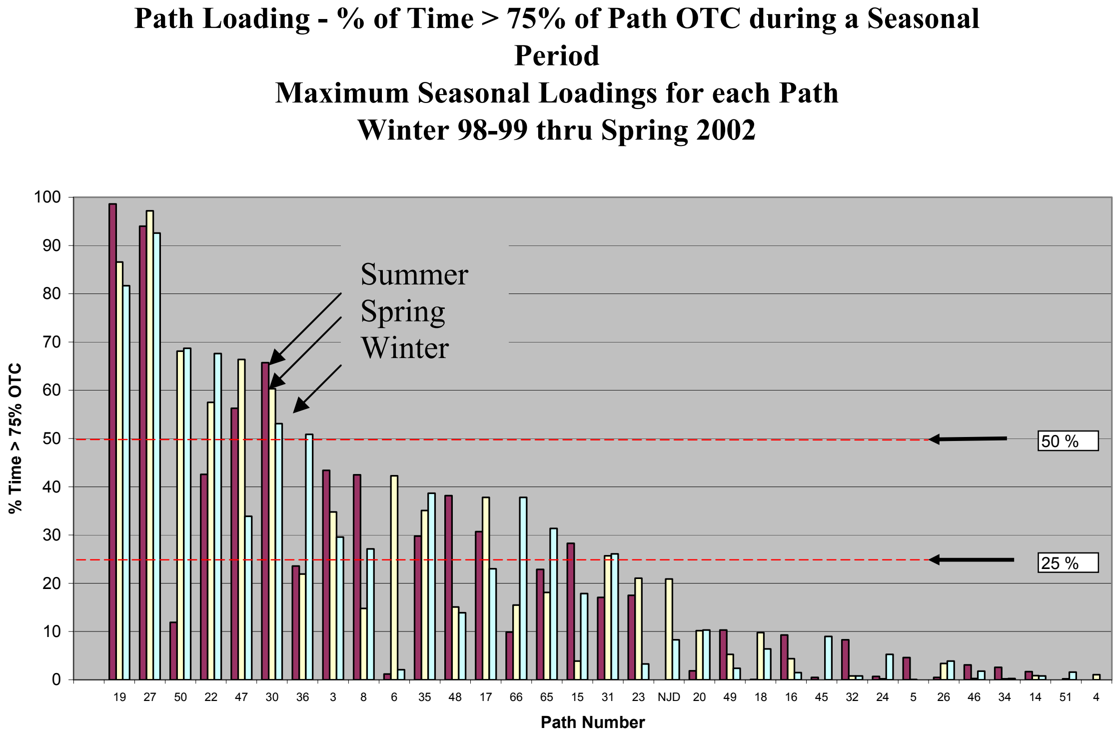

Path Loading - % of Time > 75% of Path OTC during a Seasonal Period
Maximum Seasonal Loadings for each Path
Winter 98-99 thru Spring 2002

Figure 9. Estimated transmission congestion on key paths in the west. Source: *Western Interconnection Transmission Path Flow Study*, SSG-WI, February 2003

Tapping the potential excess capacity on the existing transmission system is problematic under many existing open-access transmission tariffs. Many transmission tariffs differentiate between network service and point-to-point service. For point-to-point service, a generator can obtain firm service for a period of up to 10 years if sufficient available transmission capability (ATC) is available. Alternatively, non-firm service can be obtained for time periods up to 1 year. For ATC to be available, the transmission operator must assess whether the requested path capacity is available all year (or up to 10 years for long-term service). If the path is projected to be constrained for even a few hours during the period, firm service won't be offered and the generator must resort to obtaining non-firm service.

For wind developers, lenders providing project financing require that the proposed project must be able to deliver the energy to market long-term. Non-firm transmission service, however, is reserved and scheduled on an as-available basis and subject to curtailment and interruption. Non-firm is also offered on a stand-alone basis for a limited duration of time, generally for a period of 1 month or less. This can jeopardize the financing and ultimate success of wind projects.

These considerations have prompted a number of studies and potential policy changes. The proposals below would encourage a more efficient use of the existing transmission system and provide new transmission opportunities for wind energy generation. Follow-up studies have been proposed to further examine actual flows versus available ATC posted on transmission providers' Open Access Same Time Information Systems (OASIS) sites for highly constrained paths.

Wind Scenario Development

This section describes integrated resource plans (IRPs) and renewable portfolio standards (RPSs) in the West. IRPs and RPSs are helping drive wind development in some parts of the West, and the scenario development is based in part on this information.

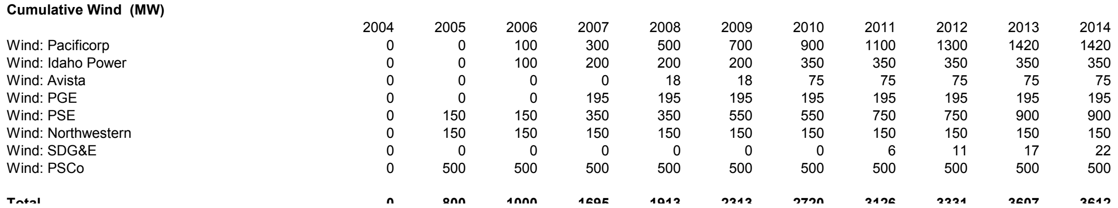
Wind in Western IRPs and RPS Requirements

A recent study by Lawrence Berkeley Laboratory (LBL) by Bolinger and Wiser (2005) examined the implications for renewable energy under existing western utility IRPs and state RPS requirements. The information from this study provided the foundation for the specification of wind development Scenario One, described in a later section of this paper.

The LBL study examined RPS states and attempted to quantify the types of renewable energy sources to be developed. But there remained a large portion of the RPS for which the type of renewable fuel is unspecified. Given the relative current prices of renewable generation, it is likely that the largest portion of this unspecified renewable source would go to wind. However, if prices of other renewable sources were to decline over the study horizon period, then we would expect relatively less wind and more generation from sources like solar.

From the group of IRPs examined by LBL, it appears that more than 3,600 MW of wind capacity could be developed by eight utilities by 2014. This development is mainly concentrated in the Northwest, although Colorado would also develop a relatively large quantity of wind in this time frame under current IRP visions.

Table 2. Wind Additions from IRPs in the West (LBL)



Cumulative Wind (MW)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Wind: Pacificorp	0	0	100	300	500	700	900	1100	1300	1420	1420
Wind: Idaho Power	0	0	100	200	200	200	350	350	350	350	350
Wind: Avista	0	0	0	0	18	18	75	75	75	75	75
Wind: PGE	0	0	0	195	195	195	195	195	195	195	195
Wind: PSE	0	150	150	350	350	550	550	750	750	900	900
Wind: Northwestern	0	150	150	150	150	150	150	150	150	150	150
Wind: SDG&E	0	0	0	0	0	0	0	6	11	17	22
Wind: PSCo	0	500	500	500	500	500	500	500	500	500	500
Total	0	800	1000	1695	1913	2313	2720	3126	3331	3607	3612

Some highlights of the IRP information are included here (Bolinger and Wiser, 2005).

1. **PacifiCorp:** 65 MW near Idaho Falls, ID (Wolverine Creek). According to a presentation given at the IRP Public Input meeting (www.pacificorp.com/File/File52811.pdf), there are a dozen projects on the short list, comprising 1800 MW of wind capacity. This is expected to be split between PacifiCorp's east and west systems, but details are not available. Based on information obtained from "Plans for PacifiCorp" (OregonLive.com, Jul 16, 2005), PacifiCorp is planning to build 100 MW of wind without the need for additional transmission. However, an additional 300 MW of planned wind will require new transmission upgrades.
2. **Idaho Power:** Assume approximately 350 MW from the Idaho region by about 2014. According to Idaho Power's plan, the wind would likely be within the control area, so transmission costs are not developed or reported.
3. **Avista:** About 75 MW of wind capacity, location to be determined according to LBL analysis. Avista has installed 35 MW of wind and is looking for a larger addition in the 2005 IRP (in process). Location will matter only relative to economics and transmission access/cost.
4. **PGE:** Most likely to add wind in the Columbia Gorge area (estimated 195 MW).
5. **Puget Sound (SE of Seattle):** about 900 MW of wind capacity is anticipated in the Columbia Gorge or central Washington.
6. **Northwestern:** Most/all additions, 150 MW total, are likely to be developed in Montana. Transmission expansion costs are not stated, but presumably the wind development would fall within Northwestern's control area.
7. **SDGE:** Beginning a study, but it is not clear where wind will be developed. SDGE has indicated that it has a 20% RPS-like goal.
8. **PSCo**: Likely wind in eastern CO, possibly near the Wyoming state line, and additional capacity near Lamar. The need for new transmission is unclear. Although the transmission system may need expansion, PSCo is apparently planning to develop wind within its control area and has not provided cost estimates for transmission.

The California utilities PG&E, SCE, and SDG&E have provided some insight regarding anticipated transmission needs for renewable energy procurement but have not communicated a plan or timetable to address these needs. SCE is evaluating potential transmission expansion in the Tehachapi region, and PG&E has estimated a potential transmission cost of $170 million to $230 million to meet its 20% renewable energy target (Bolinger and Wiser, 2005).

According to Bolinger and Wiser, "Especially as wind additions grow in the West, it will be necessary to develop and incorporate into IRPs improved assessments of the transmission costs of accessing varying quantities of wind generation. Few resource plans currently incorporate this capability, instead choosing to establish strict and sometimes-arbitrary limits on the amount of wind additions allowed."

In California there is considerable effort to determine the location of potential renewable generation to meet the RPS, and the associated transmission required to bring the energy to market. According to a consultant's report for the California Energy Commission (2005), "There is inadequate information on the extent to which the grid design is adequate for deliverability during non-peak time periods" and "There is no comprehensive region-wide peak and non-peak evaluation of the grid's performance and potential impacts on transfer capability, as a result of a changing resource mix. Such an evaluation would help California utilities and others in the WECC to better understand what, if anything, they need to do to maintain existing transmission path ratings." The report recommends that transmission studies should be improved so that appropriate decisions can be made regarding transmission expansion and renewable locations.

In these cases, transmission is an issue that the utilities are examining with varying degrees of effort and precision, although generally transmission adequacy has not been thoroughly considered relative to possible renewable development plans. In many cases, the location of the wind development could be in part determined by transmission access. In other cases, relatively short lines could potentially be built to connect the wind plant to the existing grid. Beyond these general observations, the role of the existing, constrained transmission system is not immediately apparent. By implication, it is not clear how much wind energy can be developed without improvements to transmission utilization or additional transmission or both.

Another aspect of renewable development in California is the "least cost, best fit" requirement. If the utility needs tend toward a specific type of generation, such as base load, then it is possible that renewable generation that have characteristics of base load generation (like biomass or geothermal) could be chosen, even if the energy price is higher than wind. Because this outcome is uncertain, the Wind Task Force report included several potential cases that illustrate the impact of these alternative development possibilities.

Eight WGA states have recently enacted RPS or Energy/Environmental Portfolio Standards (EPS) to encourage the development of renewable energy resources such as solar, wind, biomass, and geothermal energy. An EPS/RPS requires electric utilities in the state to generate a certain percentage of electric energy from renewable energy sources. The requirements generally only apply to investor-owned utilities; however, Colorado's applies to any utility with more than 40,000 customers. (However, rural cooperatives can opt out with a vote of their members.) Other states frequently encourage municipal and rural electric cooperatives to adopt similar requirements. The following table shows the current requirements in WGA states. Arizona and California are considering changes to their programs.

Table 3. Renewable Portfolio Standards in WGA States[2]

State	*Date Enacted*	*Requirements*
Arizona	2001	0.2% in 2001, increasing to 1.1% in 2007-2012 50% solar electric in 2001-2003; 60% solar electric in 2004-2012
California	2002 revised in 2004	20% by end of 2010 Goal for 33% by 2020
Colorado	2004	3% by 2007; 6% by 2011; 10% by 2015 4% or the renewable energy must come from solar electric generation technologies; 1/2 of this 4% located on-site at customers' facilities
Hawaii	2001 revised in 2004	7% by end of 2003; 8% by end of 2005, 10% by end of 2010, 15% by end of 2015, 20% by end of 2020 (including existing renewables)
Montana	2005	5% in 2008; 10% in 2010; 15% in 2015
Nevada	2001 revised in 2005	6% in 2005, rising to 20% by 2015 5% of the energy portfolio must be solar part of the requirement may be met by energy savings from efficiency measures
New Mexico	2002 revised in 2004	5% in 2006, rising to 10% in 2011 Some sources have a higher "value" for accumulating credits (wind 1 credit per kilowatt-hour, solar 3 credits per kilowatt-hour)
Texas	1999 revised in 2005	Renewable generation capacity of 2,280 MW in 2008 rising to 5,880 in 2015 (about 5% of state demand), 500 MW other than wind; goal of reaching 10,000 MW in 2025

Source: Database of State Incentives for Renewable Energy

Figure 10 is from Bolinger and Wiser (2005) and shows approximately 3,600 MW of wind development by 2014, according to published load serving entity resource plans.

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[2] This table shows RPS requirements in place at the time the Wind Task Force report was developed. Since that time, the Arizona Corporation Commission approved increasing the portfolio mix to 15% renewables by 2025 and an additional requirement that 30% of the renewables come from distributed generation resources. This was under review at the Arizona Attorney General's office at the time of this writing.

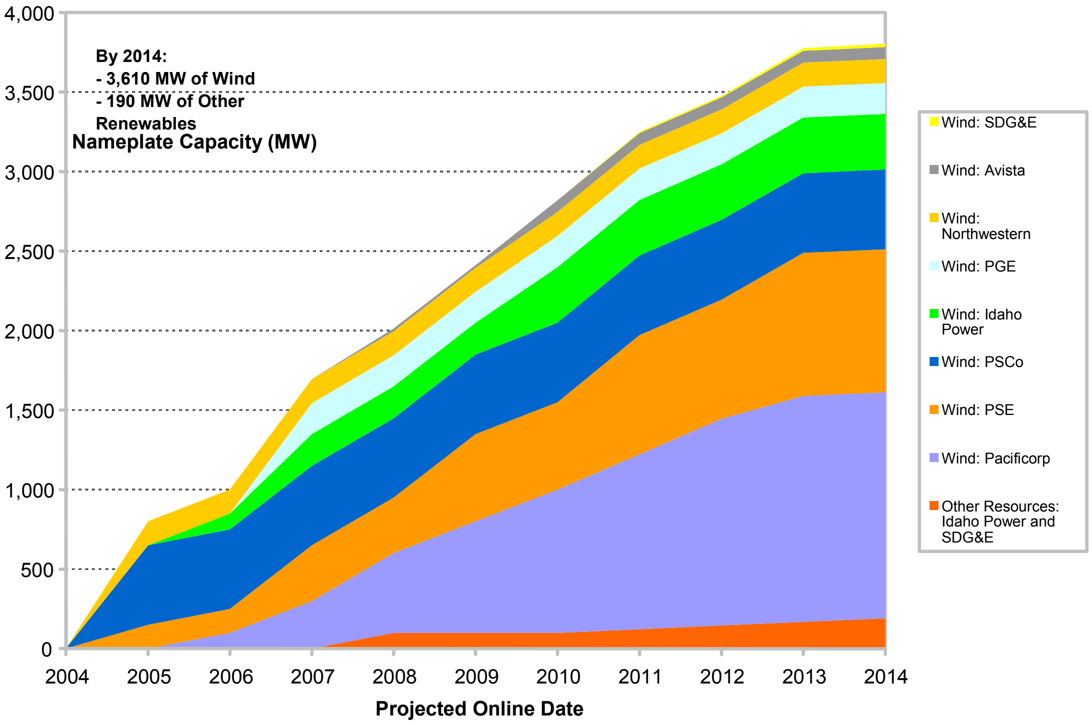

Figure 10. Wind development in IRPs analyzed by LBL

Figure 11, also from Bolinger and Wiser (2005) illustrates potential wind development from RPS requirements in the WGA region. According to this analysis, full implementation of RPS requirements in the WGA region would add nearly 10,000 MW of wind by 2015.

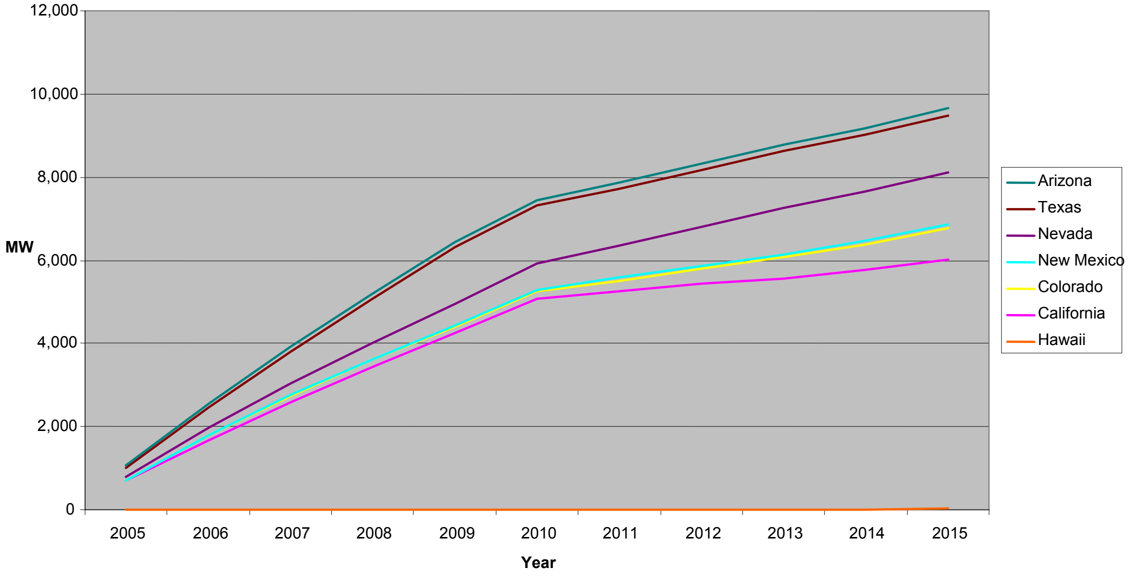

Figure 11. LBL's estimate of wind development induced by RPS requirements in the West

Wind Scenarios

Based on the supply curve analysis, RPS requirements, and IRP evidence described above, we develop three scenarios that represent alternative projections of the future under a different set of assumptions. These three scenarios are described as follows:

> **Scenario 1**. Wind development that is either in progress or can be reasonably assumed to occur based on existing plans with minimal new transmission additions. Evidence from prior work on the ability of new transmission tariffs and related policy implementation was assumed to help stimulate wind additions. This represents a near-term goal.
>
> **Scenario 2**. Wind development that would occur with additional transmission expansion as identified and analyzed in sub-regional or regional transmission studies. Some of this wind development could possibly occur with minimal transmission additions, but the additional wind in this scenario needs new transmission. Some of this transmission expansion is already under study and would not be built for wind alone. Most of this development can be located either to the individual connection point, county, transmission corridor, or other geographic location within the state. While not all of this wind capacity will be built per se, it represents a realistic path to the future if transmission availability is not a barrier. The exception is Nebraska, a state with significant potential that has not yet been subject to detailed transmission analysis.
>
> **Scenario 3**. Wind development that is harder to predict than in the previous scenarios. In some cases this wind development is under study but may depend on specific expansion of the grid or combinations of policy evolution. These also represent scenarios that have been analyzed under "high-wind" expansion scenarios. In Kansas we have identified a significant quantity of potential wind development that has not, to our knowledge, been subject to detailed transmission studies. Therefore, it is possible that additional wind development is currently under consideration in the WGA but has not yet been analyzed by subregional or regional transmission groups. The rapid recent pace of wind development suggests that the prediction offered by this scenario is imprecise.

Possible Near-Term Wind Development without Transmission Expansion

To construct a plausible reference case that does not depend on transmission expansion, we have examined preliminary rough estimates of the development path in the Northwest Transmission Assessment Committee (NTAC) area. It is important to point out that the modeling effort at NTAC has not been completed, so this information will certainly change once those results become available. The wind development that could be reasonably anticipated in the Northwest is approximately 35% of the development that is likely to occur if there is some transmission expansion.

In the Northwest region, the Bonneville Power Administration (BPA) has devoted considerable effort to developing a new transmission tariff. Although this is still in process, the objective is to offer additional transmission that is considered as conditional firm on paths that have little or no ATC. As part of the process of examining the level of conditional firm service that BPA could provide, BPA also recalculated ATC on several key transmission corridors and found several hundred megawatts of additional ATC. The "no-transmission" scenario in the Northwest therefore depends on some combination of new ATC and conditional firm transmission capacity becoming available. Therefore, the no-transmission case is not a business-as-usual scenario but instead a scenario that incorporates more efficient usage of the existing wires.

Additional non-wires alternatives would potentially include (a) the release or re-use of unused ATC, and (b) the development and use of real-time line ratings. The latter would improve the odds of uncovering additional ATC because static line ratings are used on many paths. There is a need to study and identify, in a comprehensive way, grid locations that are favorable for near-term generation additions that require no or minimal grid upgrades.

Because utilities have not thoroughly evaluated transmission needs relative to renewable requirements, it is not possible to predict with confidence a level of wind generation that would be stranded by the lack of transmission. If we assume that other areas within the WGA footprint are similar to the Northwest, with new transmission tariffs and additional ATC resulting from more detailed analysis, then it might be reasonable to predict that approximately 35% of the low-end 2015 wind scenario (developed in a later section of this report) would occur. This would represent approximately 9 GW of wind. Without the development of new transmission tariffs and revised ATC calculations, perhaps 20% of the wind scenario would be developed (approximately 5 GW). These numbers have not been confirmed by detailed transmission modeling, which would increase our confidence in the estimates.

Scenario 1 assumes an additional wind capacity of 5,000-9,175 MW by 2015. As discussed below, the lower end of this range, 5,000 MW of wind capacity, is likely if there is no significant increase in the usage efficiency of the existing transmission system, such as re-evaluation of ATC or flexible-firm transmission service. If these and other institutional improvements can increase the grid efficiency, it is possible that about 9,000 MW of wind can be accommodated with no significant transmission additions.

Figure 12. WGA Scenario 1

Other Analyses of Wind and Transmission

One primary goal of the CDEAC Wind Task Force is to identify the possible locations and sizes of wind development in the WGA region in the 2015 time frame. The primary source of information for this material is the large and growing body of work undertaken by regional and subregional transmission planning groups in the west. In Texas we used information developed by ERCOT and incorporated recent and ongoing work from the Midwest Independent System Operator (MISO) and the Southwest Power Pool (SPP). The Kansas Energy Council has developed detailed information about possible wind development in that state, including locations, capacity, and the wind developer that is anticipated to build the wind plants. In addition, we consulted recent work by the BLM, which utilized a GIS database and modeling from NREL to analyze wind development relative to BLM lands in the west. The GIS and modeling used by the BLM work is the same as that used by the CDEAC Wind Task Force to develop the supply curves for wind.

All the data we examined are not equally solid. For example, the Northwest Transmission Assessment Committee (www.nwpp.org/ntac/) has developed a detailed set of scenarios of likely wind development in the Northwest. Many of the projects are in process, or have obtained, permits required for construction.

The Rocky Mountain Area Transmission Study (RMATS) analyzed several scenarios for generation expansion trajectories in the West. Some of these scenarios included significant wind generation, but much of that wind generation would be stranded under the current transmission configuration (although this difficulty is shared by other generation fuels also). SSG-WI developed a similar set of scenarios in the transmission study undertaken in 2003 and was updating that work while the Wind Task Force report was in process.

The Kansas Energy Council has a detailed wind scenario that describes potential wind development in that state. The SPP has performed a transmission study examining parts of Texas, Oklahoma, and Kansas (those portions in the Eastern Interconnection). Because the SPP work did not cover the entire state of Kansas, we used only the Kansas Energy Council information in developing the single scenario for Kansas.

MISO is in the advanced stages of the Northwest Exploratory Study, which examines the congested transmission paths moving from the Dakotas to the load centers in Minnesota. The study examines the impact of more than 1,000 MW of wind in the Dakotas. In its previous transmission planning effort known as MTEP 2003 (MISO Transmission Expansion Plan), MISO analyzed 4,500 MW of wind capacity in the Dakotas.

Of the states we analyzed, Arizona and Nebraska were the most difficult. Although Arizona has an excellent solar resource, its wind resource is less than what is found in many other WGA states. Although this can be confirmed by examining wind resource maps, these maps do not always recognize high-quality wind sites that may be too small or too difficult to capture by the GIS mapping processes. Many wind capacity trajectories for Arizona are null. However, we received information from the Arizona Wind Working Group that between 2,800 and 3,300 MW of wind capacity is currently under pre-development consideration. It is hard to know the likelihood of so much wind in Arizona, and these estimates are higher than what we expected. One factor that favors wind development in Arizona is that the state has a significant load, even though transmission from wind regions to load centers would be an issue. But compared to high-resource/low-load states such as Wyoming and Montana, which would both require longer lines to deliver wind energy to load, the required transmission in Arizona would be less by comparison.

In Nebraska, utilities and utility customers have not expressed an interest in wind energy. As a result, wind development plans in Nebraska are essentially non-existent. A deliberative poll was carried out in Nebraska that indicated a high level of consumer interest in developing wind generation. If the deliberative poll accurately represents consumer preference in Nebraska, and if this preference is translated into policy or utility action, it is possible that significant wind development could take place. But under the business-as-usual scenario, and given the 73 MW of existing wind capacity in Nebraska, it is difficult to project likely outcomes over the 10-year horizon. The result is that we have a very large range of plausible wind development in Nebraska and little useful information to help determine the likely path that this development will take.

Scenario 2 postulates 25,266 MW of new wind development as shown below. Scenario 3 is the high case scenario with 54,724 MW of additional wind capacity. Some of the Scenario 3 capacity may be intended for import to California markets that could be displaced by in-state wind development in California. This potential inconsistency is discussed later in this report.


Western Governors' Association
Wind Additions: Scenario 2

Total: 25,266 MW

Figure 13. WGA Scenario 2


Western Governors' Association
Wind Additions: Scenario 3

Total: 54,724 MW

Figure 14. WGA Scenario 3

Discussion of Selected Key States

In this section, we examine some key points that relate the supply curves with various elements of the wind scenarios found in transmission studies. Some interesting observations can be made by looking at South Dakota, a state with an enormous wind resource. Of the transmission planning efforts that we are aware of, the highest wind scenario for South Dakota is 3,150 MW. The results of the supply curve for South Dakota (using the assumptions that 20% of existing transmission is available for wind and new lines are built when that is exceeded) indicate that there is more than 3,500 MW of wind in South Dakota at a price of $50/MWh or less. At $60/MWh, the quantity of wind increases to almost 24,000 MW. When this is compared to our supply curve Scenario 3 that builds up to 30,000 MW in the WGA footprint by building all transmission, South Dakota shows about 200 MW of wind at a price of $50/MWh or less and about 3,000 MW of wind at a price of $60/MWh or less. Clearly, transmission constraints strand a very large portion of wind in South Dakota. This is also true in other states, although to a lesser extent, in the WGA footprint.

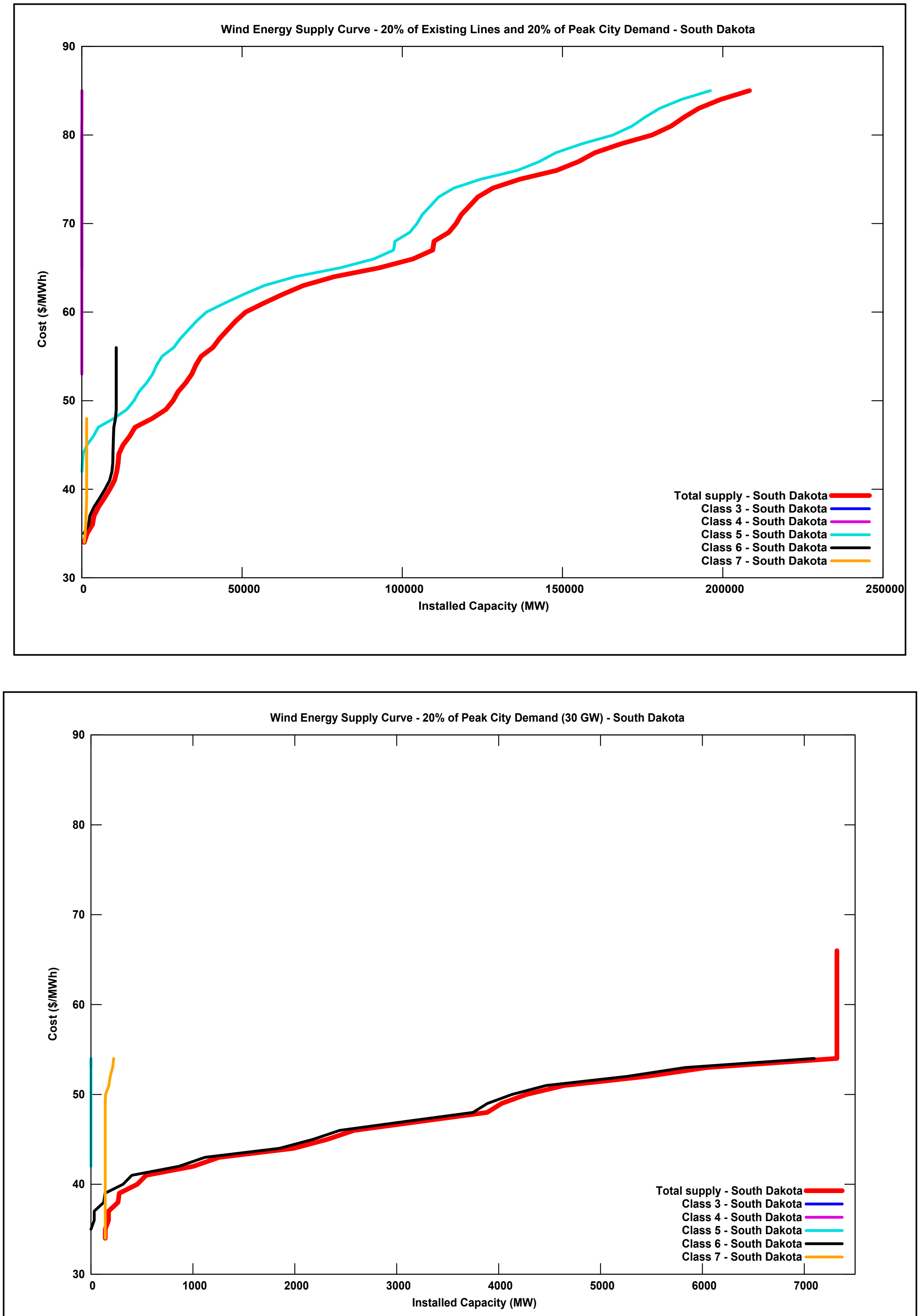

Figure 15. South Dakota wind supply curves with (a) 20% availability of existing transmission and (b) no available existing transmission.

It is also worth noting that the capacity that appears in the tables is not always consistent. The New Mexico Wind Task Force (not part of CDEAC) has developed a wind export scenario that would provide for approximately 4,000 MW to 6,000 MW of wind capacity in New Mexico that would deliver energy to load centers in Arizona or California, possibly using a high-voltage DC line. Examination of the California supply curve (20% of Existing Lines and 20% of Peak City Demand) shows approximately 9,000 MW of wind in California at a cost of $60/MWh or less. On the New Mexico supply curve, we see approximately 6,000 MW of wind supply at just over $55/MWh. Given the cost-competitiveness of the wind resource in California with the resource in New Mexico, it is not clear that a New Mexico export case would be the preferred way to deliver wind energy to California. Further analysis and refinement would be necessary to answer this question. However, unless the New Mexico wind is used to export to Arizona load centers, a scenario with 6,000 MW to 8,000 MW of wind in California *and* 4,000 MW to 6,000 MW of wind in New Mexico may not be consistent.

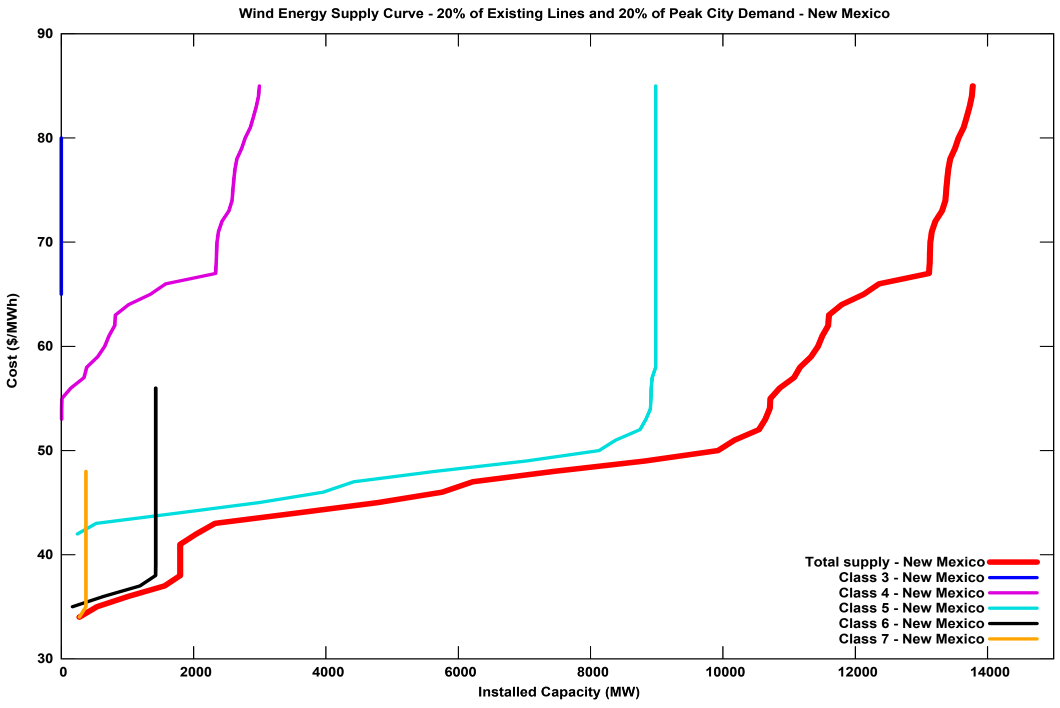

Figure 16. New Mexico wind supply curve assuming 20% of existing transmission is available for wind.

Conclusions and Summary

The supply curves developed for the Wind Task Force illustrate that a very significant wind potential exists in the WGA states. It is also clear that transmission is a potential barrier to much of this wind development, and the no-transmission supply case illustrates the magnitude of this impact. However, although these supply curves have been developed with the best information available, there are several caveats. Most of the wind-speed data are from 50 meters, significantly lower than the hub height of modern wind turbines. We were unable to represent advances in turbine technology. In addition, our transmission availability assumptions, along with static line ratings, will compromise these results. However, we believe that these supply curves and scenario developments represent valuable information that can be used to help analyze future wind development in the WGA states.

This work also highlights the need for map/GIS data that is at hub-heights that are representative of current and future wind developments. However, states such as TX and NB do not even have data that correspond to the other states within the WGA footprint, which significantly clouds our ability to assess potential wind development in those states (although TX appears to be off to an ambitious start).

Conceptual plans to build large wind plants so that the energy can be exported to large power markets are not necessarily coordinated with plans to serve the load. This is apparent in looking at the NM export plan. Although this plan appears plausible and may indeed unfold, it is not clear that CA would be interested in purchasing this wind energy. Further work is required to evaluate the possibilities related to this scenario.

It is also clear that increasing the utilization of the existing transmission grid may offer the ability to transport wind and other sources of electricity to markets. In the absence of incentives or tariff reform however, some power sources may be required to pay for new transmission which may not be the least-cost solution.

Acknowledgements

We thank Donna Heimiller and George Scott of NREL for their significant contributions to the supply curve development effort.

Appendix A
Western Governors' Association
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Wind Task Force Members

Chair: Rachel Shimshak, Renewable Northwest Project

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Acknowledgement:
Bill Schroeder of Intermountain Rural Electric Association participated in the Wind Task Force but did not support the report's final conclusions.

Appendix B
State Wind Supply Curves Assuming 20% Existing Transmission Availability

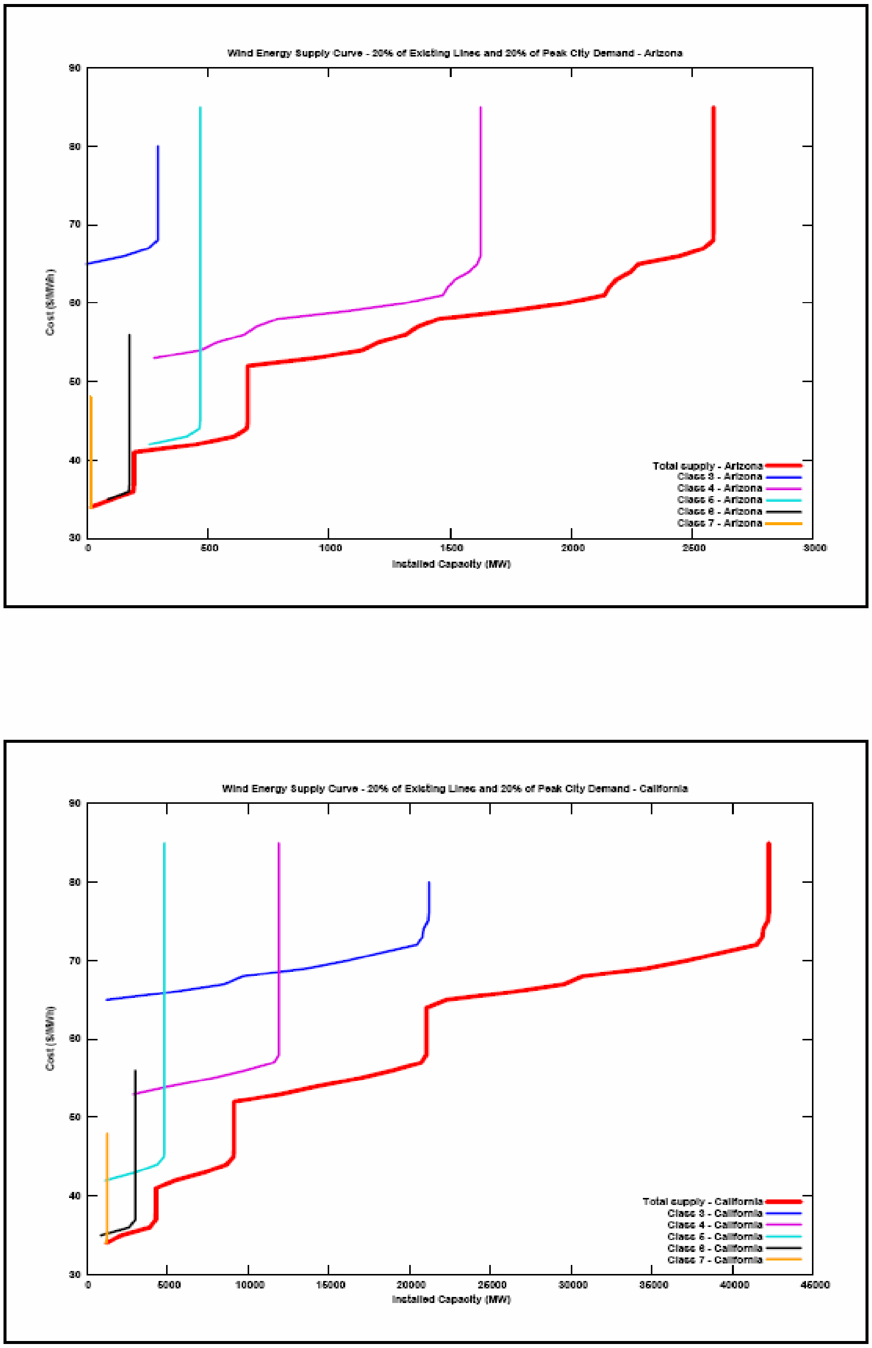


Figure 17. Arizona and California wind supply curves assuming 20% of existing transmission is available for wind.

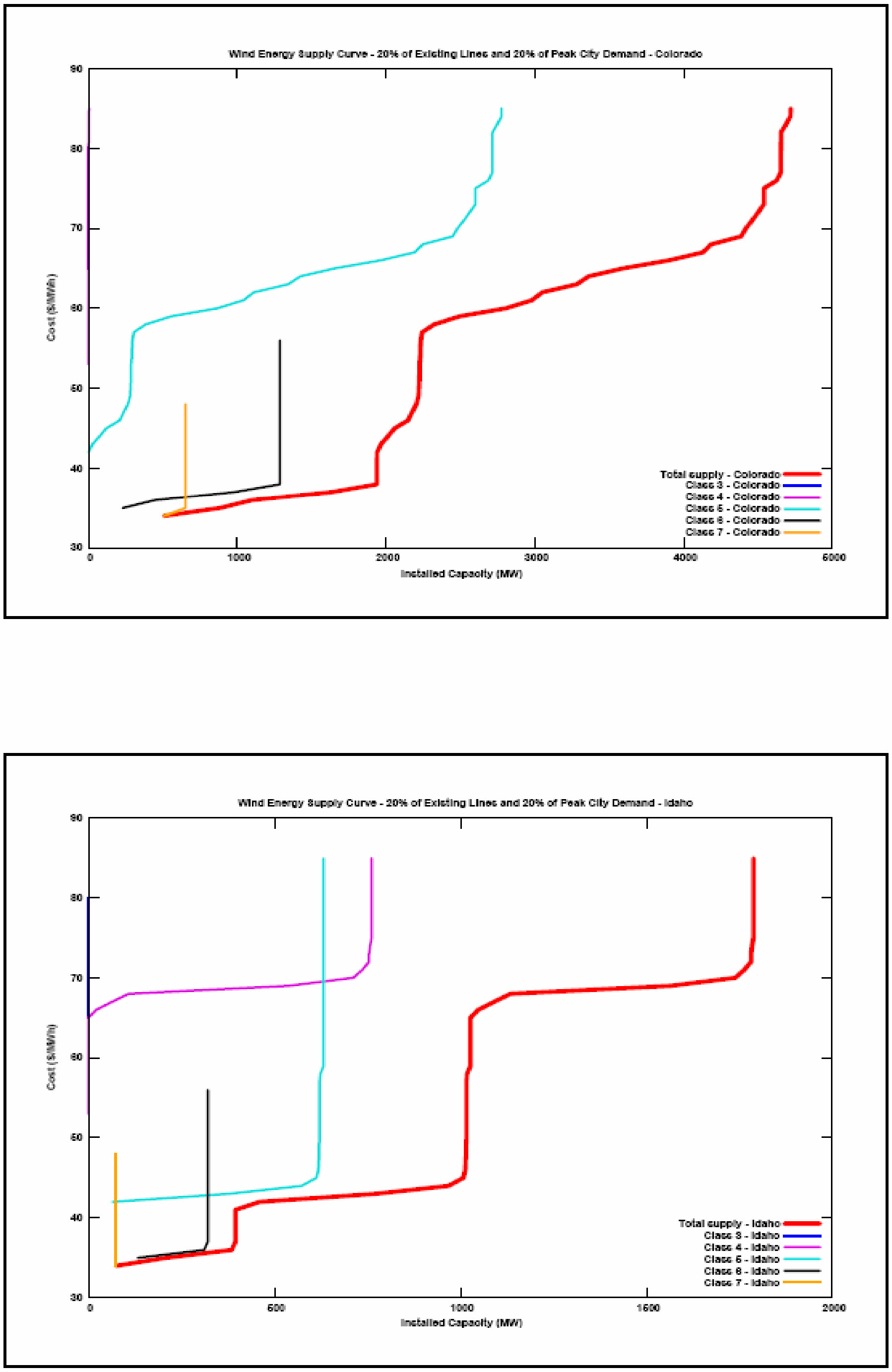


Figure 18. Colorado and Idaho wind supply curves assuming 20% of existing transmission is available for wind.

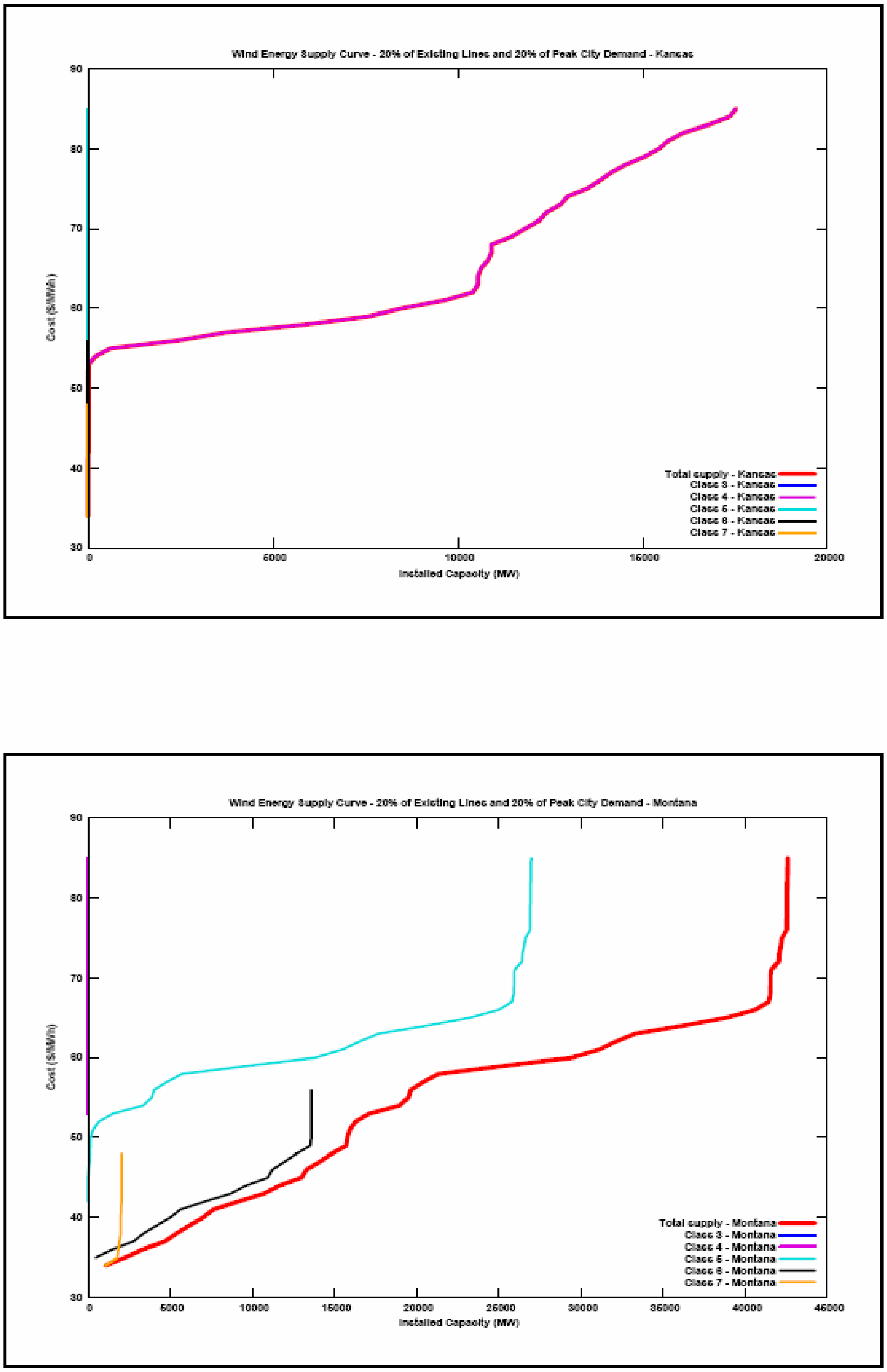


Figure 19. Kansas and Montana wind supply curves assuming 20% of existing transmission is available for wind.

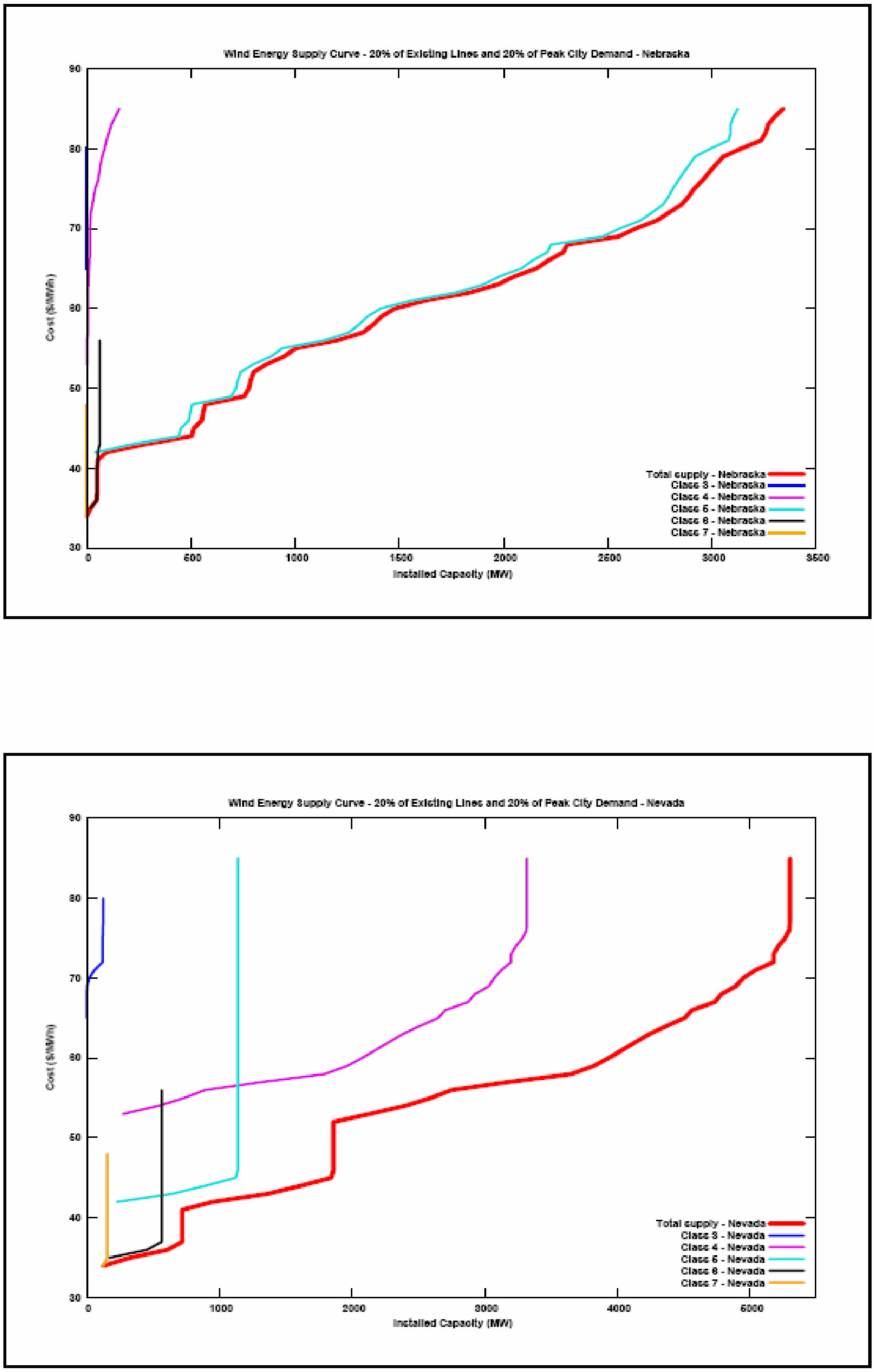


Figure 20. Nebraska and Nevada wind supply curves assuming 20% of existing transmission is available for wind.

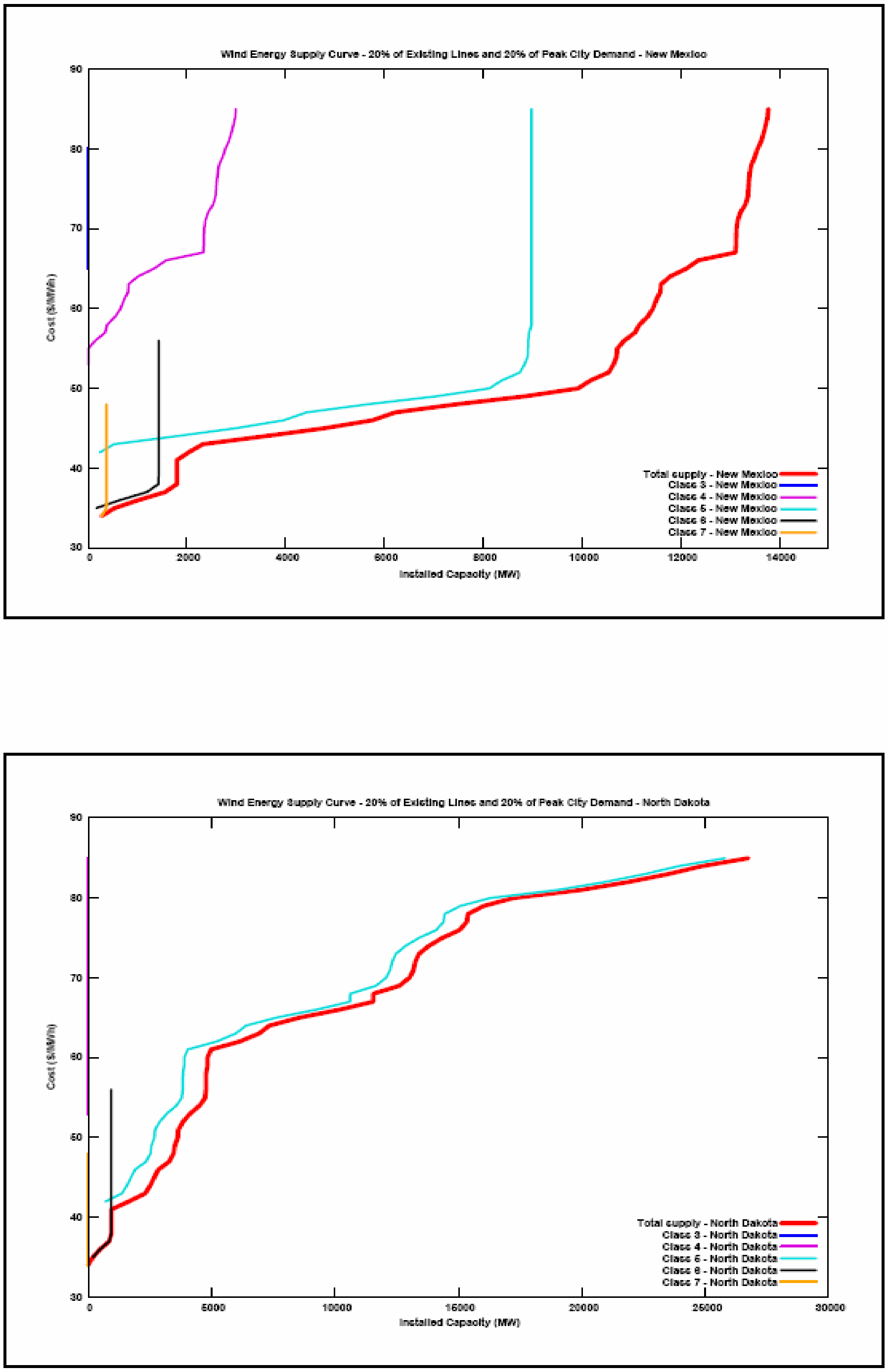


Figure 21. New Mexico and North Dakota wind supply curves assuming 20% of existing transmission is available for wind.

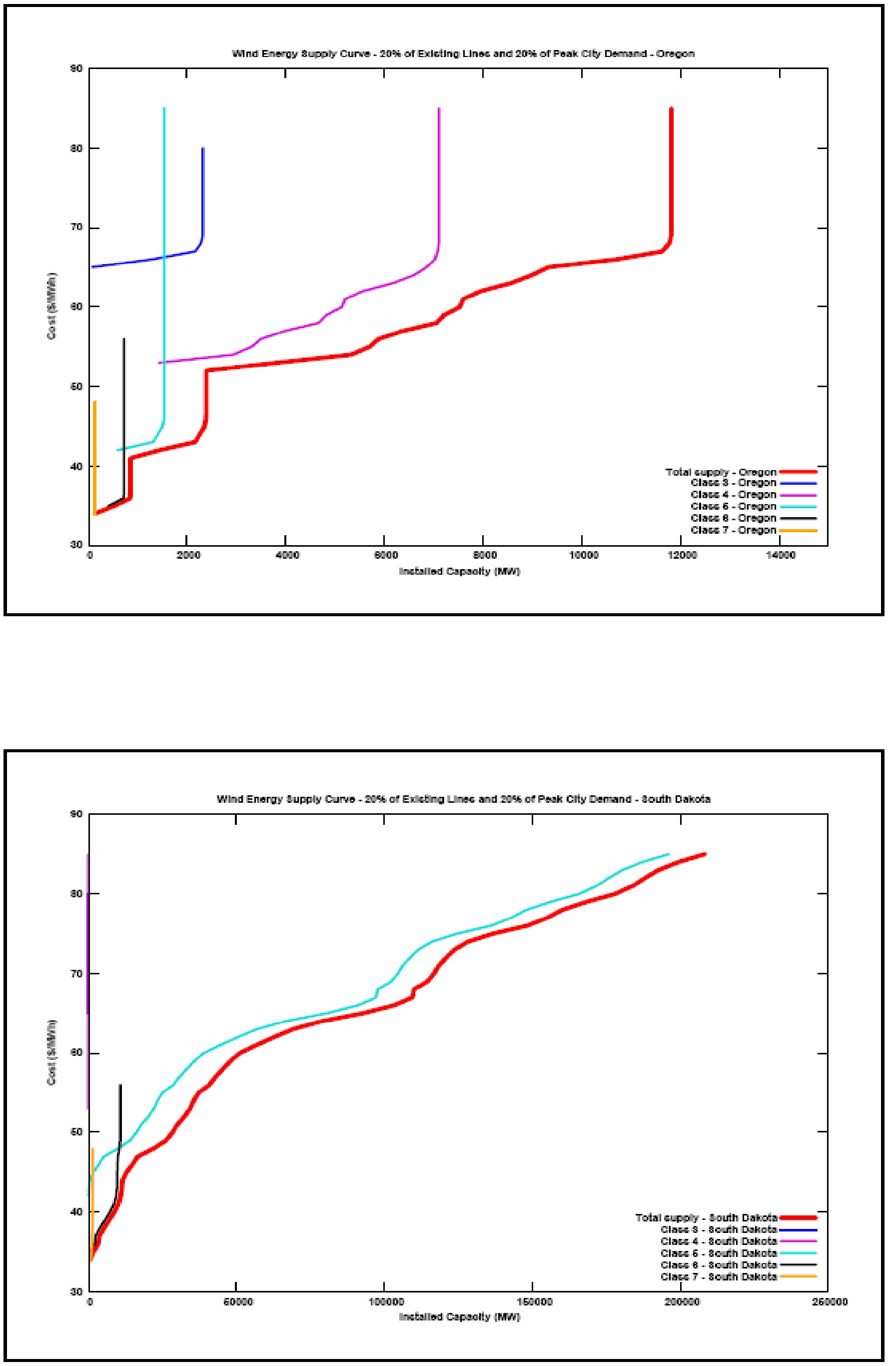


Figure 22. Oregon and South Dakota wind supply curves assuming 20% of existing transmission is available for wind.

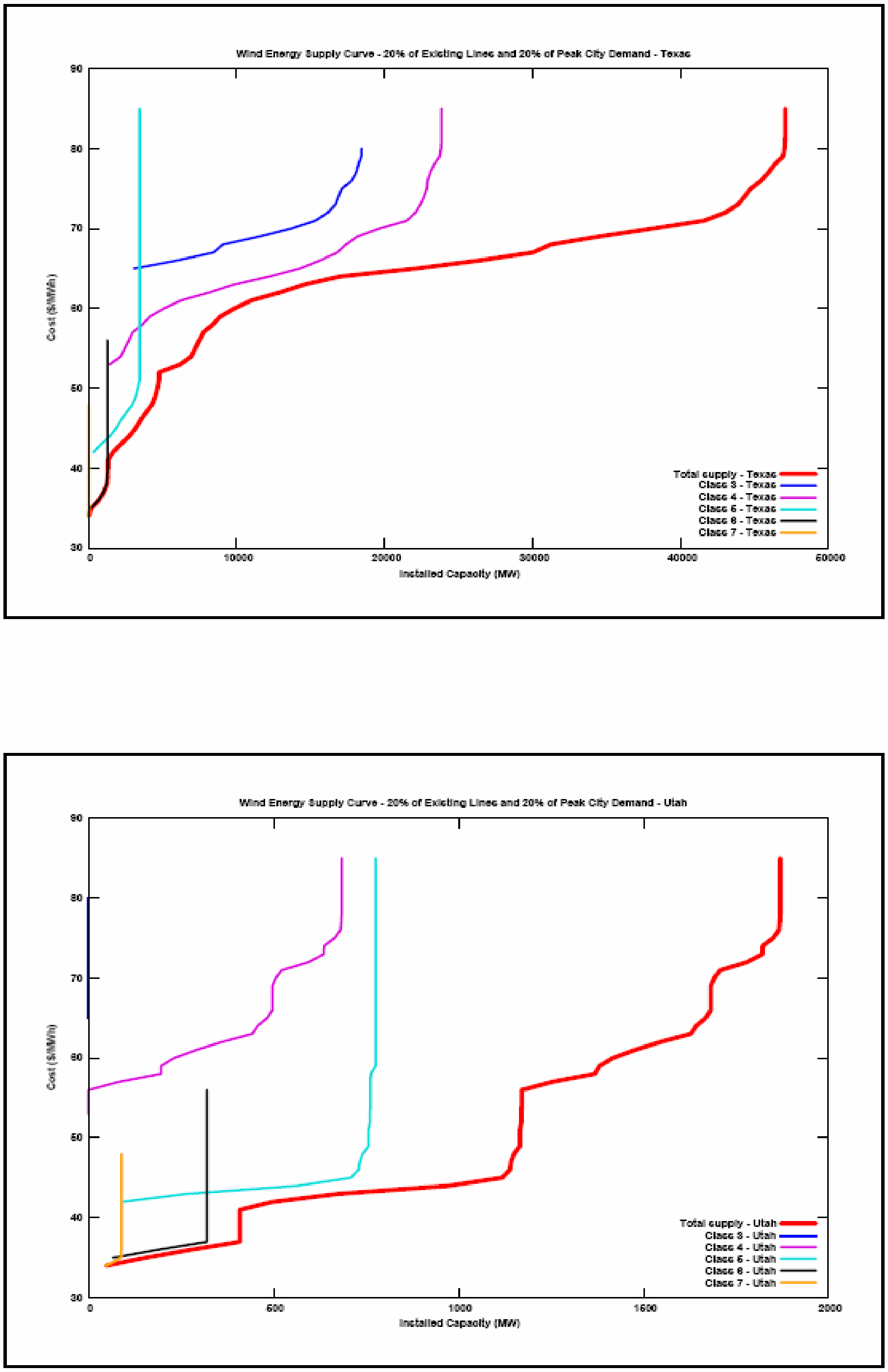


Figure 23. Texas and Utah wind supply curves assuming 20% of existing transmission is available for wind.

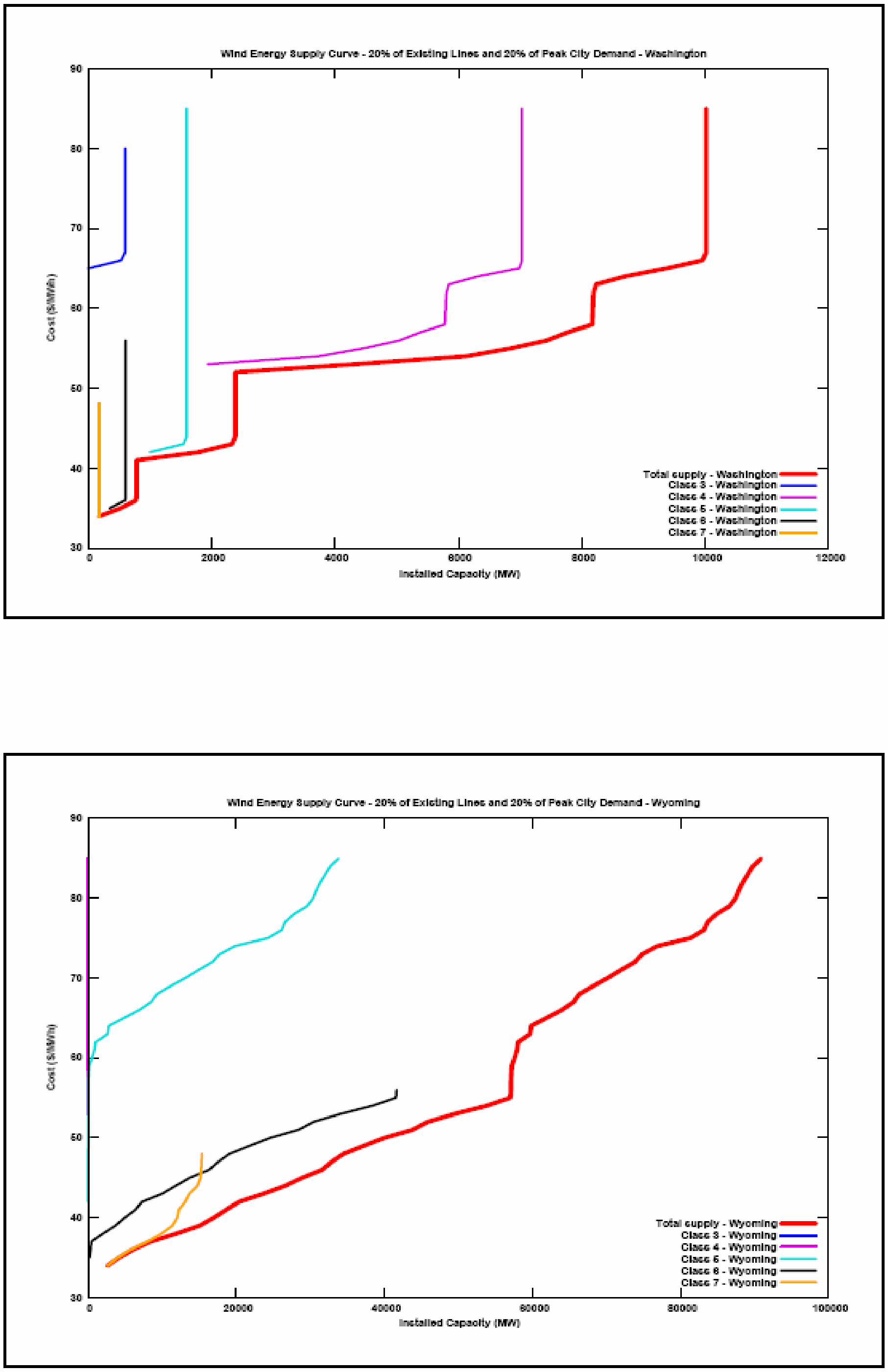


Figure 24. Washington and Wyoming wind supply curves assuming 20% of existing transmission is available for wind.

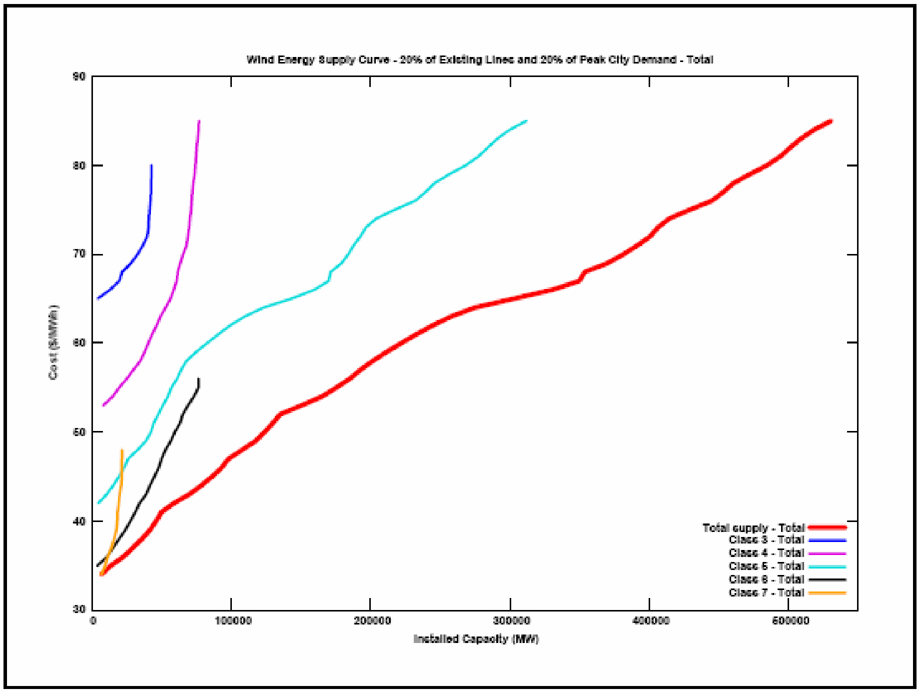


Figure 25. Total WGA area wind supply curves assuming 20% of existing transmission is available for wind.

Appendix C
Detailed Wind Scenarios

The tables and maps on the following pages illustrate the amount and location of potential wind development under the three scenarios developed from existing transmission studies and from the California Energy Commission.

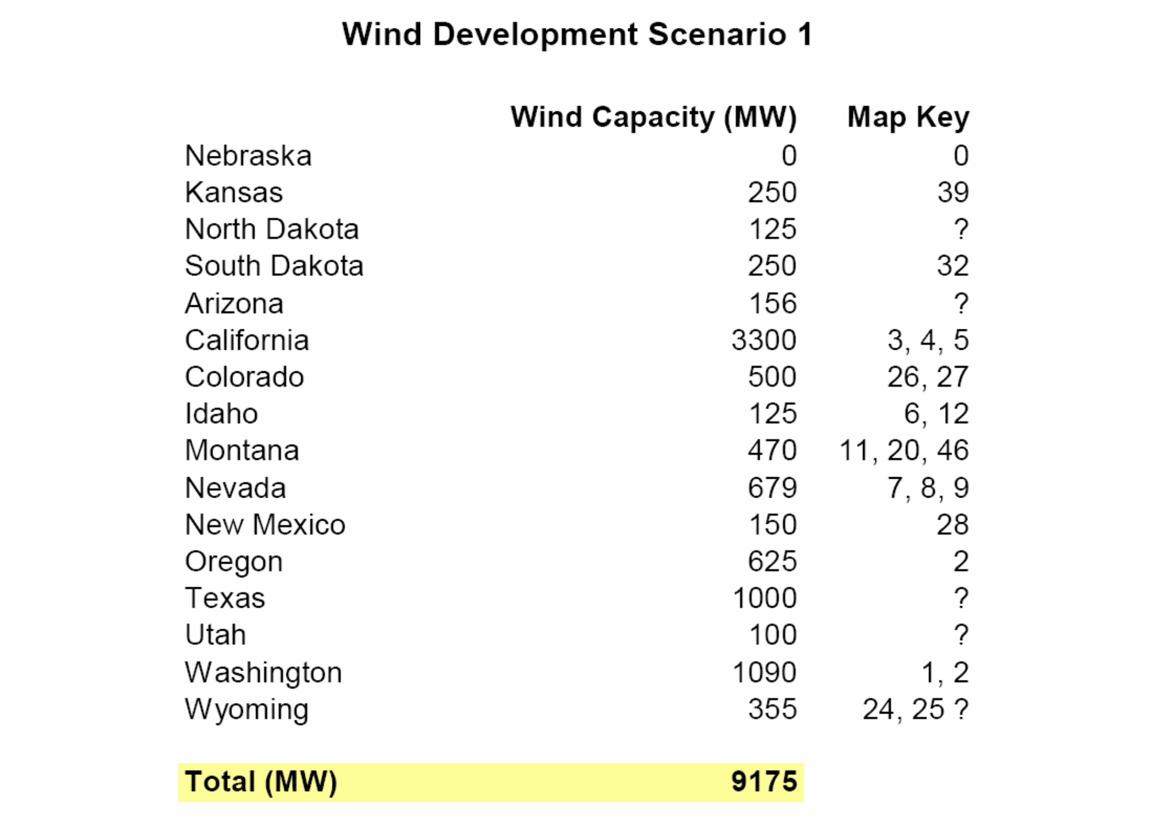
In the tables, the columns labeled 2015 Range of Installed Capacity do not represent maximum and minimum wind capacities; they illustrate *plausible ranges of development based on existing information, assuming that the required grid expansion takes place*. The list that follows should provide a rich set of locations and capacities for the CDEAC Integration and Transmission Task Forces for the next steps of the CDEAC process. As with the previous work in SSG-WI and RMATS, it is likely that some new transmission would be required regardless of the specific scenario and its resource mix.

Each table shows the location and capacity estimate of wind generation, a numbered key to the maps that appear in Figure 26 and Figure 27 (both maps are the same – one shows transmission and the other doesn't), and the CEC estimates (the CEC estimates cover only the WECC) for comparison.

Table Keys:

- NTAC = Northwest Transmission Assessment Committee
- RMATS = Rocky Mountain Area Transmission Study. The number after the "RMATS" designates the RMATS scenario number (i.e., RMATS/4 is Scenario 4 from RMATS)
- CEC/SVA = California Energy Commission Strategic Value Analysis
- MISO/NW = Midwest Independent System Operator Northwest Exploratory Study
- MTEP 2003 = MISO Transmission Expansion Plan, 2003

Table 4. Wind Development Scenario 1: No Transmission Upgrades



Wind Development Scenario 1

	Wind Capacity (MW)	**Map Key**
Nebraska	0	0
Kansas	250	39
North Dakota	125	?
South Dakota	250	32
Arizona	156	?
California	3300	3, 4, 5
Colorado	500	26, 27
Idaho	125	6, 12
Montana	470	11, 20, 46
Nevada	679	7, 8, 9
New Mexico	150	28
Oregon	625	2
Texas	1000	?
Utah	100	?
Washington	1090	1, 2
Wyoming	355	24, 25 ?
Total (MW)	**9175**	

Table 5. Wind Development Scenarios 2 and 3. Note that Map Key refers to Figure 26 and Figure 27

Wind Development Scenarios 2 and 3

	Substation/Location	**2015 Range of Installed Capacity**		**Map Key**	**CEC**
Washington		NTAC	NTAC		
Hopkins Ridge	Walla Walla 115 kV	150	150	2	
Wild Horse	Vantage 230 kV	240	240	1	
Wild Horse 2	Vantage 230 kV	120	120	1	
Big Horn	Big Eddy 230 kV	250	250	2	
Last Mile Co-op	Big Eddy 230 kV	200	200	2	
Saddleback			70	2	
Columbia Wind			80	2	
Columbia Hills			125	2	
Goodnoe Hills			150	2	
Kittitas Valley			236	1	
Desert Claim			159	1	
Roosevelt			100	2	
Nine Canyon II			33	2	
Stateline (Sacajawea)			100	2	
Other	Big Eddy 230 kV	130	130	2	
Unspecified			104		
Subtotal Washington		**1090**	**2247**		**899**

	Substation/Location	**2015 Range of Installed Capacity**		**Map Key**	**CEC**
Oregon		NTAC	NTAC		
Klondike 2	Big Eddy 230 kV	75	75	2	
Klodike 3/Orion	John Day 500 kV	300	300	2	
Klodike 3/Orion	John Day 500 kV	600	600	2	
Arlington/Leaning J.	Dalreed 230 kV	100	100	2	
Arlington/Leaning J.	Dalreed 230 kV	200	200	2	
Willow Creek			180	2	
Shepherds Flat			1000	2	
Combine Hills			63	2	
Other	Dalreed 230 kV	130	130	2	
Unspecified			105		
Subtotal Oregon		**1405**	**2753**		**899**

	Substation/Location	**2015 Range of Installed Capacity**		**Map Key**	**CEC**
Idaho		RMATS	NTAC		
Ridgeline	Goshen 161 kV	125	65	12	
Hagerman	Upper Salmon 138 kV		50		
Cotterel Mountain	Minidoka 138 kV		200	6	
Burley	Minidoka 138 kV		20	6	
Other ID	Goshen 161 kV		150	12	
Other ID	Midpoint		150		
Subtotal Idaho		**125**	**635**		**18**

Montana NTAC		NTAC	
Judith Gap	Judith Gap 230 kV	150	150
Gore Hill	Great Falls 230 kv	10	10
Other MT	Great Falls 230 kv (?)	310	310
Subtotal Montana		**470**	**470**

	2015 Range of Installed Capacity		**Map Key**	**CEC**
California	CEC/SVA	(4GW Tehachapi)		
Solano Vaca-Dixon	100	100	3	
Solano Vaca-Dixon-Contra Costa	275	275	3	
Alameda Contra Costa-Tesla	132	132	3	
Los Angeles - Kern Pardee-Vincent	2376	2376	4	
Los Angeles-Kern Tehachapi	500	500	4	
San Diego Los Coches-Miguel	700	700	4	
Imperial	82	82	5	
San Diego Glencliff	50	50	5	
Riverside	1416	1416	5	
San Bernardino Etiwanda	280	280	4	
Additional Tehachapi	1624	3392	4	
Subtotal California	**7535**	**9303**		**4800**

Nevada	2015 Range of Installed Capacity Dracker	 NV State Office of Energy	Map Key	CEC
Northern NV/Pacific DC Intertie	1150	1150	8	
Northern NV		1620	7	
Subtotal Nevada	**1150**	**2770**		**442**

Colorado (RMATS)	2015 Range of Installed Capacity RMATS/3 and CEC	 RMATS/4	Map Key	CEC
Colorado East	800	1500	27	
Colorado West	200	250	26	
Subtotal Colorado	**1000**	**1750**		**1006**

Wyoming RMATS	2015 Range of Installed Capacity RMATS/2	 RMATS/4	Map Key	CEC
WY-Big Horn Basin	250	250	21	
WY-Jim Bridger	0	230	23	
Wy-Central	0	800	24	
WY-Southwest	1150	2450	23	
WY-Black Hills	0	125	22	
WY-Laramie River	500	1500	25	
Subtotal Wyoming	**1900**	**5355**		**698**

Utah RMATS	2015 Range of Installed Capacity RMATS/2	 RMATS/4	Map Key	CEC
UT-North	100	320	13-14	
UT-South	0	250	15-16	
Subtotal Utah	**100**	**570**		**413**

Montana RMATS	2015 Range of Installed Capacity NTAC	 RMATS/4	Map Key	CEC
MT-West	150	1000	11	
MT-Broadview	310	1000	20	
MT-Colstrip	10	100	40	
Subtotal Montana	**470**	**2100**		**767**

	2015 Range of Installed Capacity		Map Key	CEC
	CEC	Task Force, Governor's Office		
New Mexico Task Force	**200**	**6000**	28-29	**200**

	2015 Range of Installed Capacity		Map Key
North Dakota MISO	MISO/NW	MTEP 2003	
Central/Antelope Valley	250	250	30
Near Ellendale	250	250	31
Unspecified		2400	
Subtotal North Dakota	**500**	**2900**	

	2015 Range of Installed Capacity		Map Key
South Dakota MISO	MISO/NW	MTEP 2003	
Near Ellendale	250	250	31
Huron	250	250	33
Watertown/Blair	250	250	32
Unspecified		2150	
Subtotal South Dakota	**750**	**2900**	

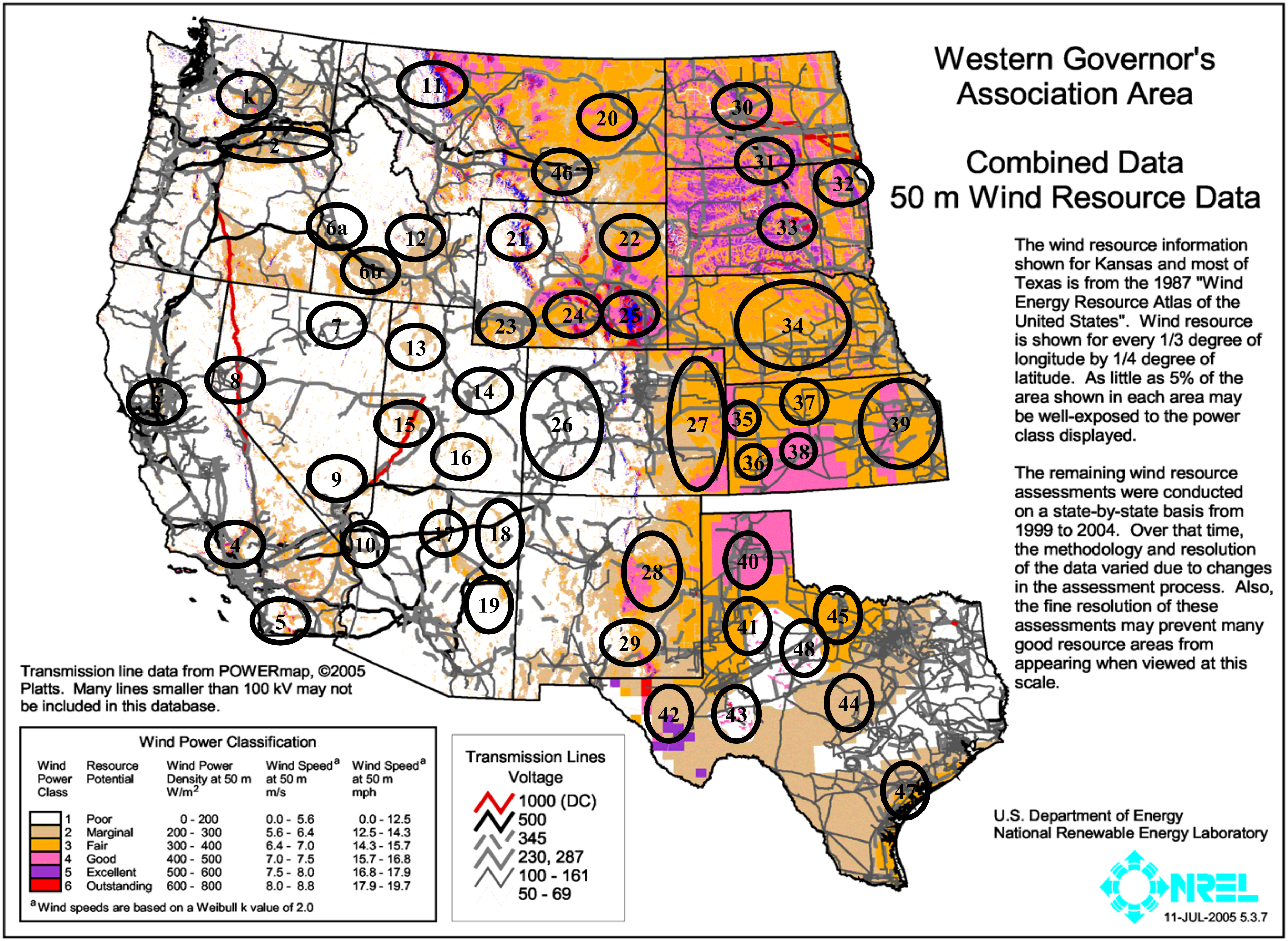
	Substation/Location	2015 Range of Installed Capacity		Map Key
Subtotal Nebraska Potential		**100**	**1000**	34

	Substation/Location	2015 Range of Installed Capacity		Map Key
Kansas - KS Energy Council				
RES-W Central	(From Energy Council map)	30	30	35
HMH Energy SW		200	200	36
Zilkha SE		100	100	39
Clipper SW		100	100	38
EnXco SW		100	100	38
TradeWind N Central		250	250	37
Zilkha N Central		250	250	37
Orion NE		100	100	39
DisGen E		150	150	39
JW Prairie E		120	120	39
TradeWind E		201	201	39
Greenlight/HMH SE		150	150	39
Greenlight SE		300	300	39
TradeWind SE		200	200	39
Unspecified		249	249	
Subtotal Kansas		**2500**	**2500**	

Substation/Location	2015 Range of Installed Capacity		Map Key
Texas ERCOT/Legislature Brief			
Panhandle (Amarillo)	236	2236	40
South Plains (Lubbock)	80	1080	41
Far West (Guadalupe)	0	200	42
McCamey	750	1250	43
Morgan/Sweetwater	1100	1400	44
Abilene	1175	1475	48
Vernon	0	200	45
South Coast	300	800	47
Subtotal Texas	**3641**	**8641**	

	2015 Range of Installed Capacity		Map Key
Arizona WWG			
Mohave County (NW)	700	800	10
Coconino County (N Central)	900	1100	17
Navajo/Apache Counties (NE)	1000	1100	18
Cochise/Graham Counties (SE)	200	300	19
Subtotal Arizona	**2800**	**3300**	

WGA Total	**25,266**	**54,724**



Western Governor's Association Area

Combined Data
50 m Wind Resource Data

The wind resource information shown for Kansas and most of Texas is from the 1987 "Wind Energy Resource Atlas of the United States". Wind resource is shown for every 1/3 degree of longitude by 1/4 degree of latitude. As little as 5% of the area shown in each area may be well-exposed to the power class displayed.

The remaining wind resource assessments were conducted on a state-by-state basis from 1999 to 2004. Over that time, the methodology and resolution of the data varied due to changes in the assessment process. Also, the fine resolution of these assessments may prevent many good resource areas from appearing when viewed at this scale.

Transmission line data from POWERmap, ©2005 Platts. Many lines smaller than 100 kV may not be included in this database.

Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7

[a] Wind speeds are based on a Weibull k value of 2.0

Transmission Lines
Voltage
1000 (DC)
500
345
230, 287
100 - 161
50 - 69

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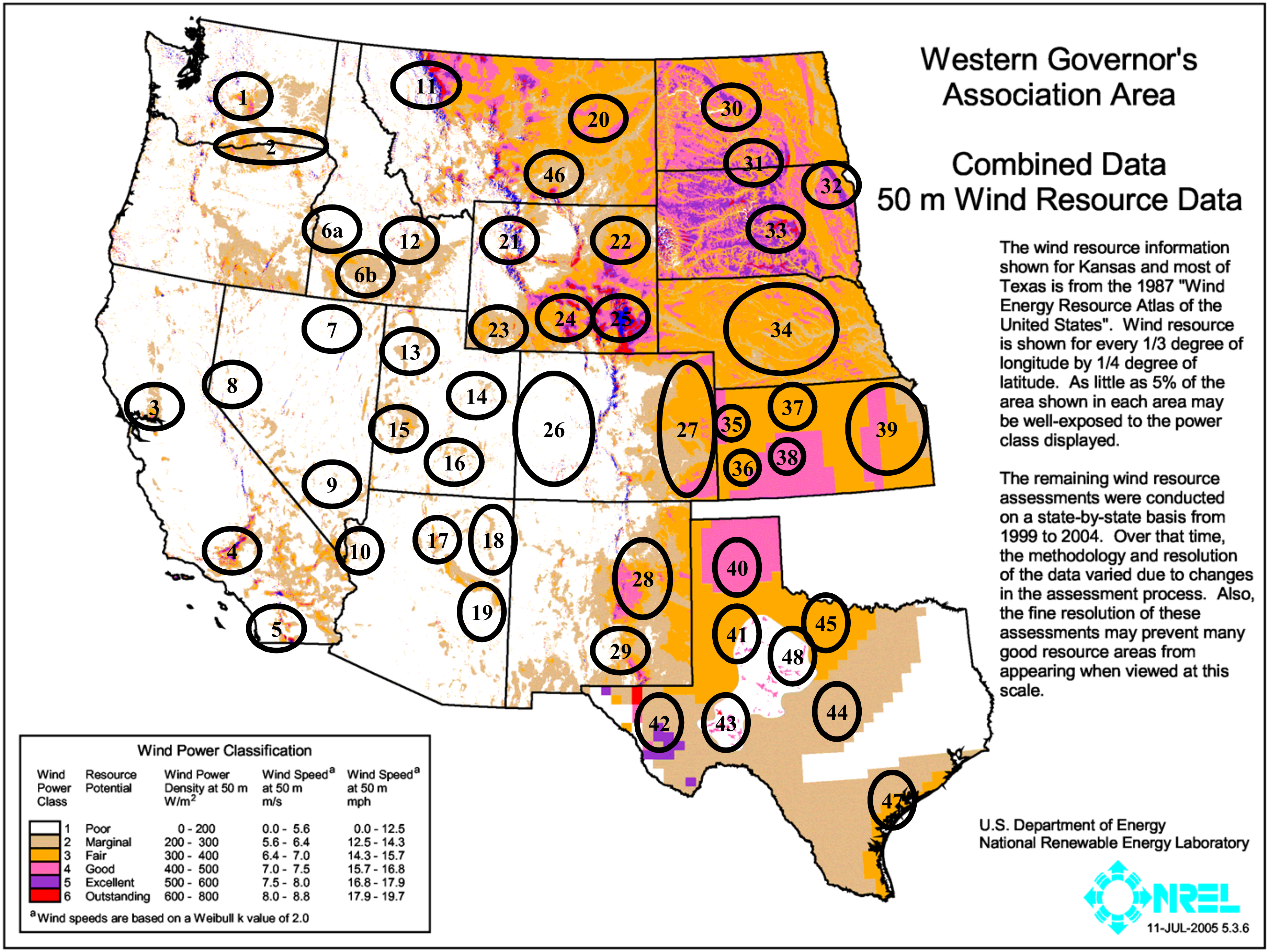
Figure 26. Location of wind scenarios showing transmission grid



The wind resource information shown for Kansas and most of Texas is from the 1987 "Wind Energy Resource Atlas of the United States". Wind resource is shown for every 1/3 degree of longitude by 1/4 degree of latitude. As little as 5% of the area shown in each area may be well-exposed to the power class displayed.

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^{a}Wind speeds are based on a Weibull k value of 2.0

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Figure 27. Location of wind scenarios without showing transmission grid

Appendix D: Data Sources and Wind Capacity Estimates

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MTEP 2003, MISO Transmission Expansion Project

Nebraska Energy Office

Kansas Energy Council

ERCOT White Paper to the Texas Legislature

Arizona Wind Working Group

State Incentives Web site www.dsireusa.org/

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Montana RPS www.dsireusa.org/documents/Incentives/MT08R.htm

Nevada RPS www.dsireusa.org/documents/Incentives/NV01R.htm

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SPP Expansion Plan

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