NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

Reduced Form of Detailed Modeling of Wind Transmission and Intermittency for Use in Other Models

BACKGROUND/OVERVIEW

The Wind Deployment Systems Model (WinDS) is a computer model, which shows expansion of generation and transmission capacity in the U.S. electric sector during the next 50 years. It minimizes system-wide costs of meeting loads, reserve requirements, and emission constraints by building and operating new generators and transmission in 25 two-year periods from 2000 to 2050.

Figure 1 shows the 358 regions in the United States represented by WinDS. As shown in **Figure 2**, WinDS disaggregates the wind resource into five classes ranging from Class 3 (5.4 meters/second at 10 meters above ground) to Class 7 (>7.0 m/s). WinDS also includes offshore wind resources.

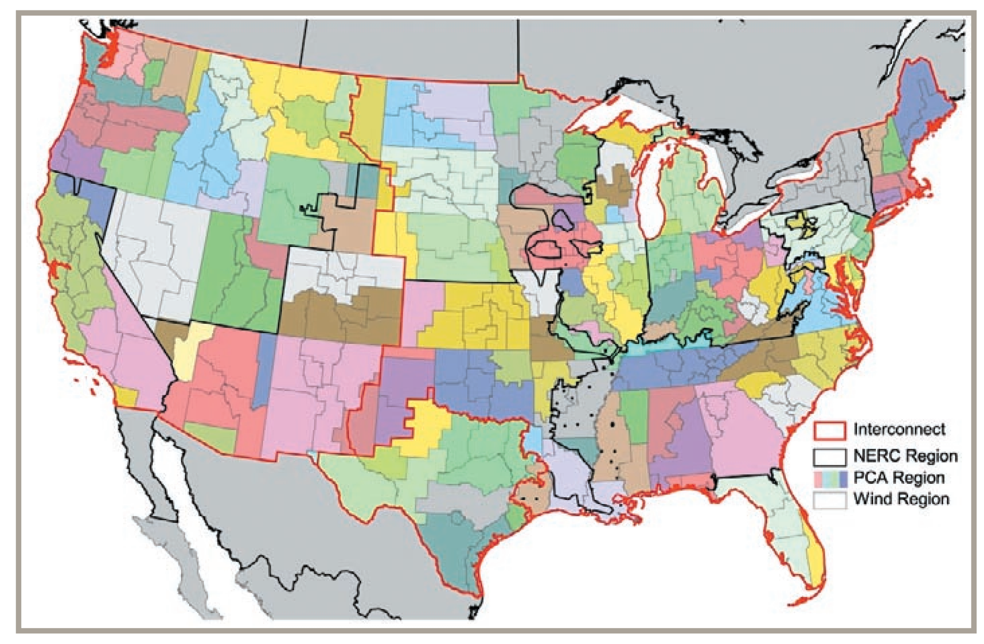

Figure 1. Regions within WinDS

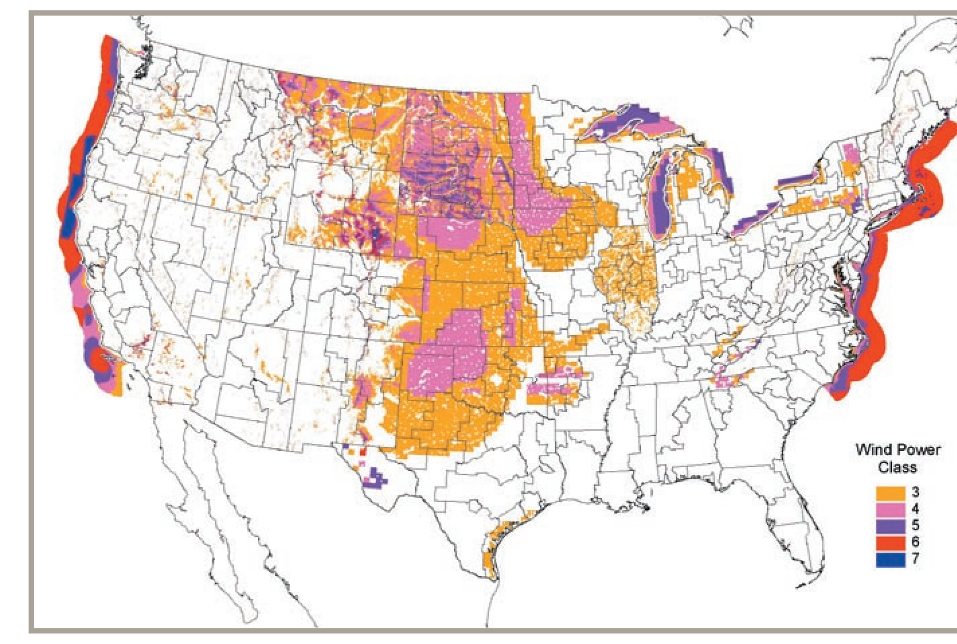

Figure 2. Wind Resources in WinDS

BASE CASE ASSUMPTIONS/RESULTS

In this analysis, the Base Case is a business-as-usual case that relies heavily on the Reference Case scenario of the U.S. Energy Information Agency (EIA) Annual Energy Outlook, using it for inputs that fall outside the scope of WinDS. This includes electricity demand, fossil-fuel prices, existing federal energy policies, and the cost and performance of non-wind electric-generating technologies (see **Figure 3**).

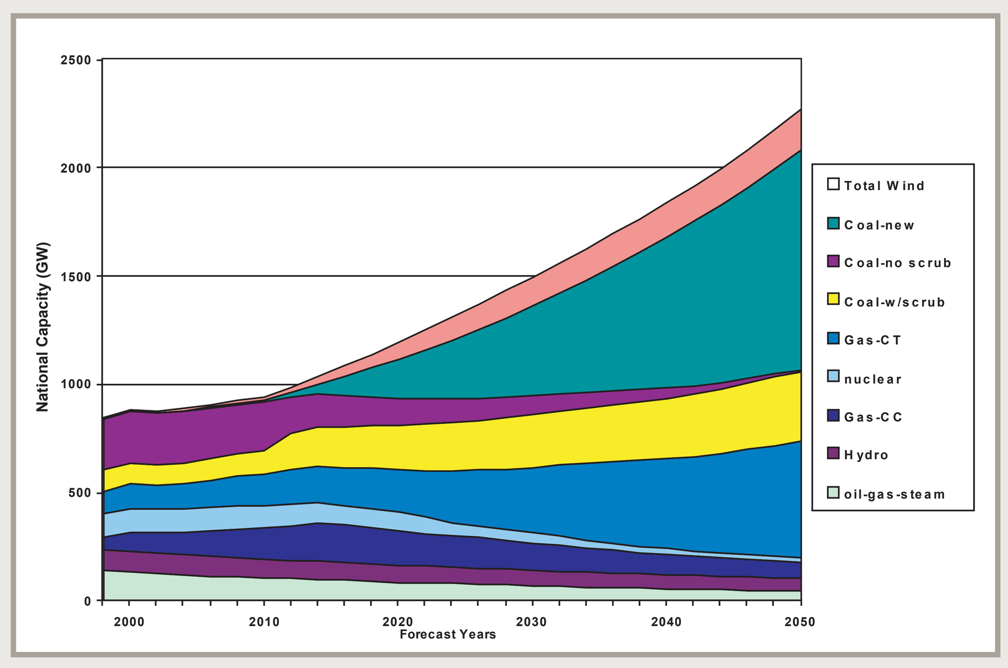

Figure 3. National Capacity Projections for the WinDS Base Case

LOCATION OF WIND CAPACITY

Figure 4 shows the location of the cumulative wind-power installations in 2050 in the Base Case scenario. As one might expect, most are located in areas with excellent wind resource — but other areas are close to load centers (such as southern California). Note also that offshore wind is represented in the closest onshore wind region on the map. Most of the wind on the East Coast is offshore wind power.

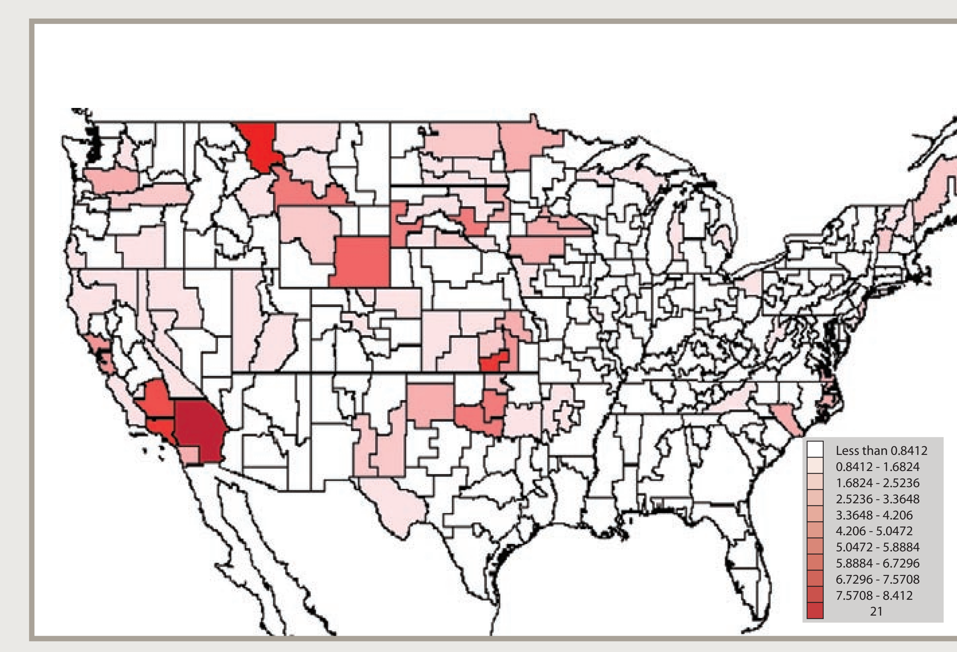

Figure 4. Location of Cumulative Wind-Power Installations in 2050 in GW

MOTIVATION AND METHOD

Unlike WinDS, most capacity expansion models do not have significant geographic disaggregation. These models cannot track the geographic dispersion of the installed wind and cannot estimate the transmission and intermittency cost as the penetration level increases. One solution is to develop supply curves (see **Figure 5**) that capture the additional system costs associated with intermittency and transmission as the amount of installed wind increases. The other model developers could modify their models to add this cost to the base capital cost of the wind supply. Specifically, the additional system costs measured in the supply curve will include:

- the transmission cost for the distance from the wind resource to the load
- the cost of decreasing capacity value of wind, due to penetration within the region
- the cost of providing operating reserve for the wind

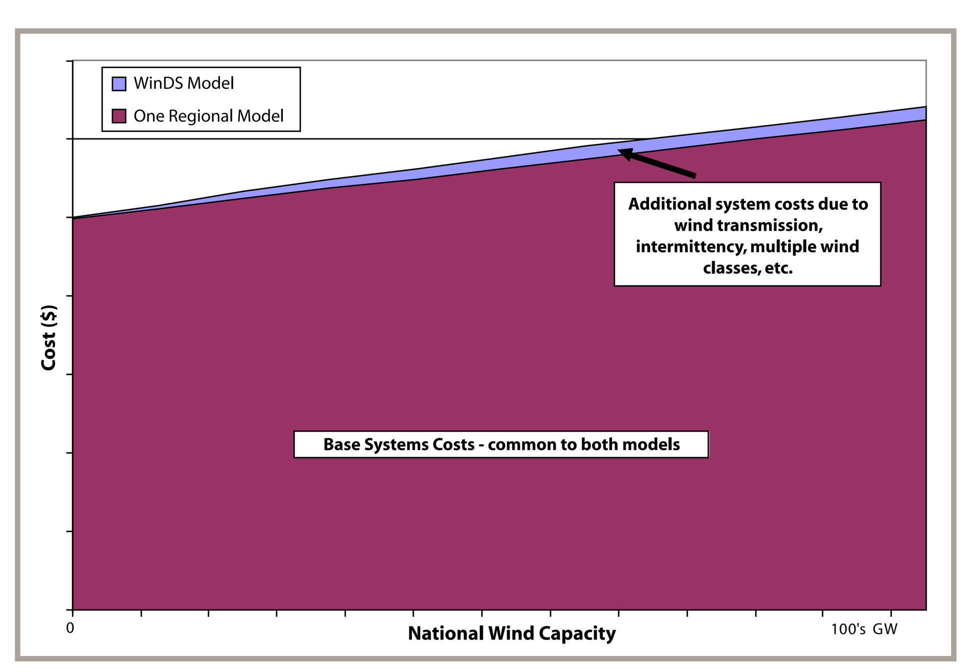

Figure 5. Conceptual Cost Graph

- the cost for conventional generation and capacity differences due to wind-power changes
- the difference in cost between having only a single class of wind versus having five wind classes
- the cost of surplus wind

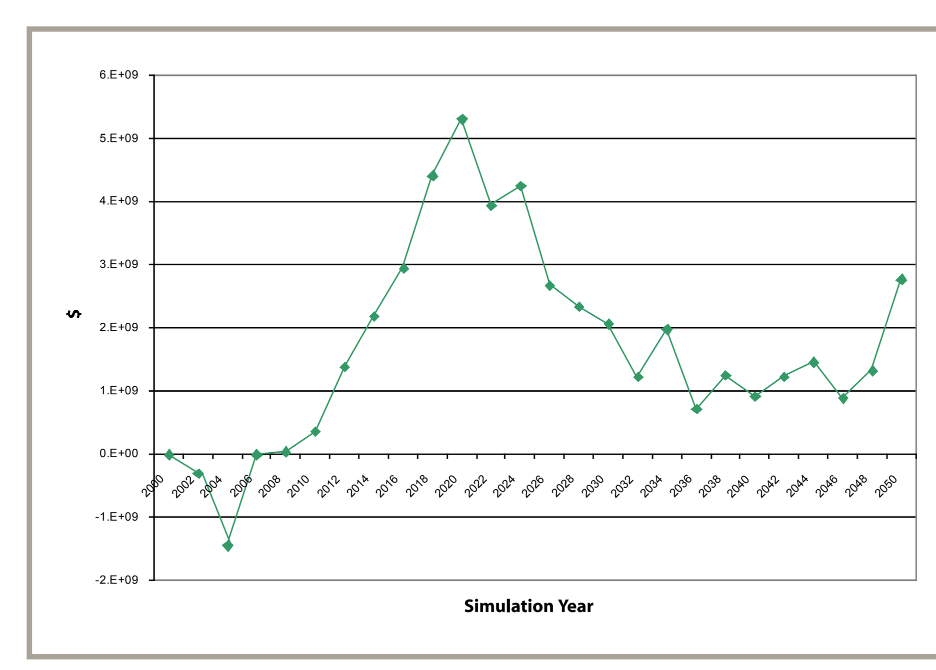

Figure 6. Cost Difference ($) per Period

Figure 6 demonstrates the change in total system costs for each period between the standard WinDS model run and the one-region model run. To develop the supply curve, these total system costs are divided by the wind capacity added in each period.

SUPPLY CURVE FOR ONE-REGION MODEL

Figure 7 is the final supply curve to be used in a one-region model, plotted as the sum of the major drivers (described below).

- **Wind Capital** represents the difference in cost of the wind capacity installed in the one-region model and the WinDS model. The level increases because WinDS requires a greater wind capacity for the same wind generation than the one-region model. This is because:
  - The WinDS model gets less generation per capacity installed, due to increasing use of Class 3 and 4 (unlike only Class 5 in the one-region model) for greater penetration
  - WinDS gets less generation, due to transmission losses that are not in the one region model.
  - The penalty imposed on densely populated or mountainous regions in WinDS is not in the one-region model.
  - Wind surplus is not present in the one-region model
- **Wind Transmission** increases throughout, because the WinDS model has to use resources further from the load, increasing the transmission costs (not included in the one-region run).
- **Conventional Transmission** is small but significant, due to changes in conventional generation differences between models.

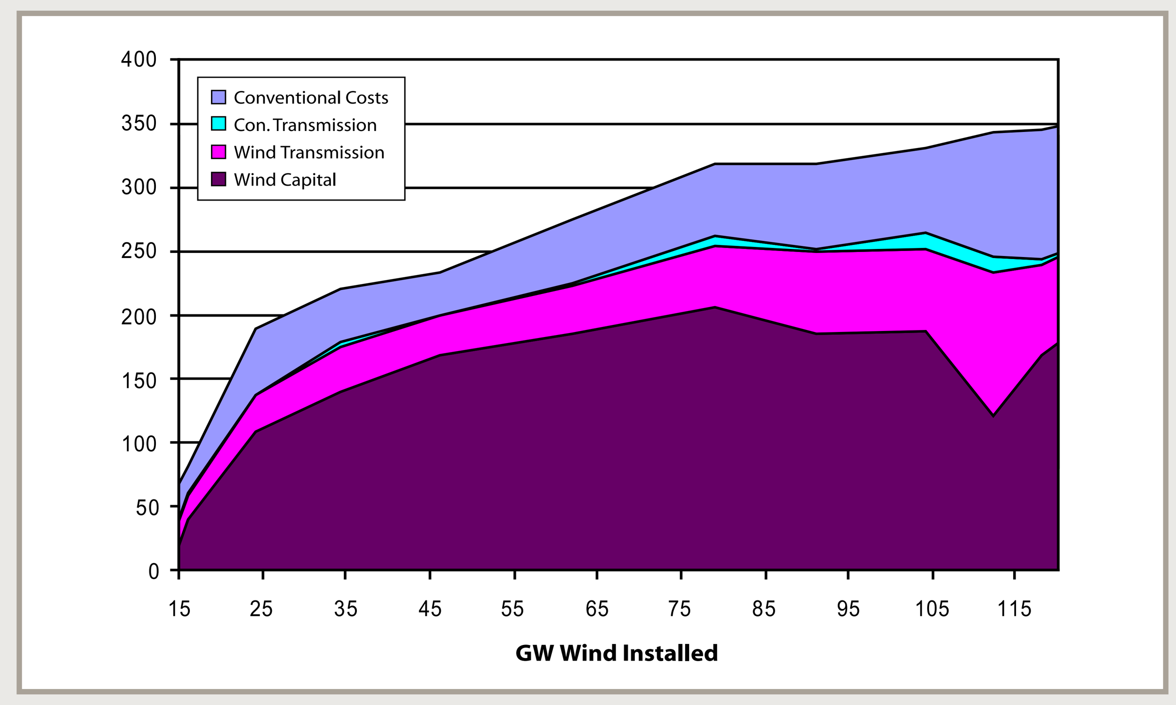

Figure 7. Supply Curve for One-Region Models

- **Conventional Costs** are the cost differences from conventional capacity capital and operating differences. The WinDS model builds more conventional capacity to meet wind operating reserve requirements that are not in the one-region model, and to compensate for the decrease in wind capacity value with penetration (no decrease in the one-region model).

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