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Projected Impact of Federal Policies on U.S. Wind Market Potential

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PROJECTED IMPACT OF FEDERAL POLICIES ON U.S. WIND MARKET POTENTIAL

WINDPOWER 2004 CONFERENCE
POSTER SESSION

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1. ABSTRACT

This paper presents results from the **W**ind **D**eployment **S**ystems Model (**W**in**DS**) for several potential energy policy cases. WinDS is a multiregional, multitime-period, Geographic Information System (GIS), and linear programming model of capacity expansion in the electric sector of the United States. WinDS is designed to address the principal market issues related to the penetration of wind energy technologies into the electric sector. These principal market issues include access to and cost of transmission, and the intermittency of wind power. WinDS has been used to model the impact of various policy initiatives, including a wind production tax credit (PTC) and a renewable portfolio standard (RPS).

2. BACKGROUND and MODEL OVERVIEW

WinDS is a computer model of expansion of generation and transmission capacity in the U.S. electric sector spanning 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. As reported last year at WindPower 2003[1], the WinDS model focuses on addressing the market issues of greatest significance to wind – specifically issues of transmission and intermittency.

The WinDS model examines these issues primarily by using a much higher level of geographic disaggregation than other models. As **Figure 1** represents, WinDS uses 358 different regions in the United States. Much of the data inputs to WinDS are tied to these regions and derived from a detailed GIS model/database of the wind resource, transmission grid, and existing plant data. The geographic disaggregation of wind resources allows WinDS to calculate transmission distances, as well as the benefits of dispersed wind farms supplying power to a demand region.

[1]Short, Walter; et al., May 2003, "Modeling the Long-Term Market Penetration of Wind in the United States," WindPower 2003 Proceedings, Austin, Texas

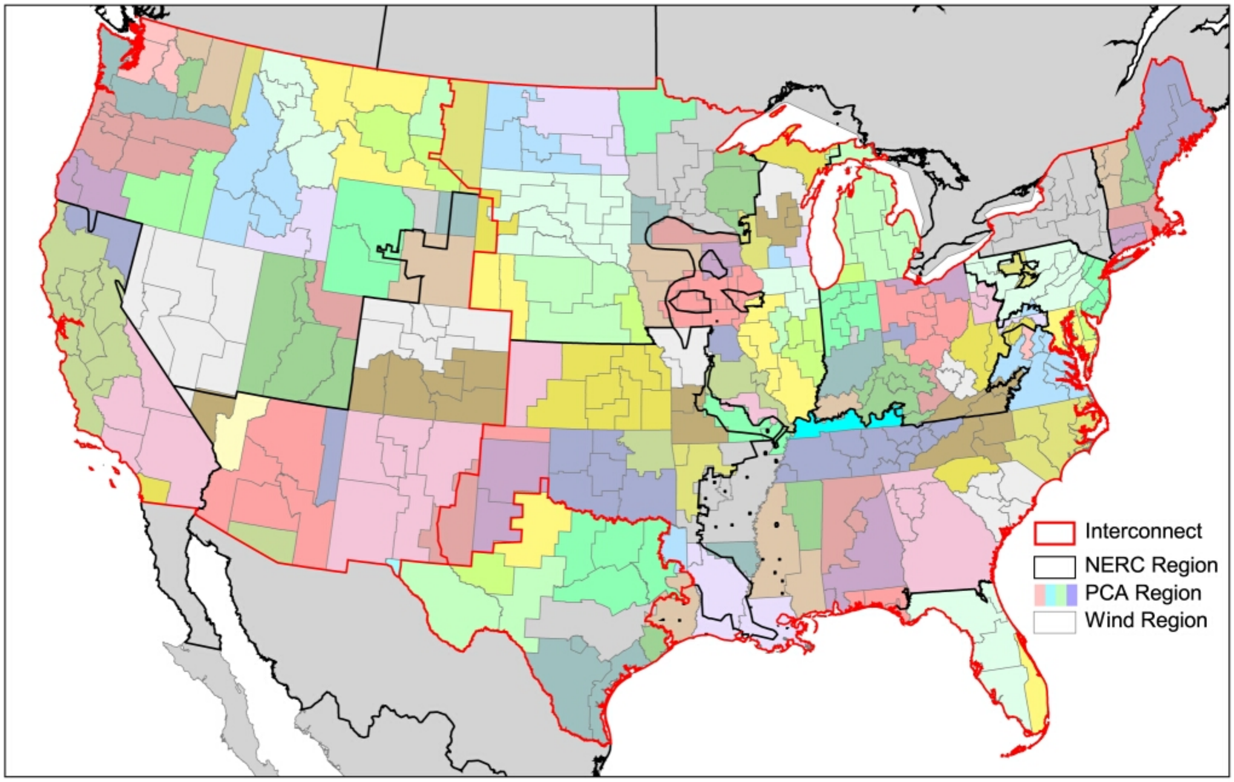

Figure 1: Regions Within WinDS

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, which also includes offshore wind resources, distinguishes between shallow offshore wind and deep offshore wind turbines. Shallow-water turbines are assumed to have lower initial costs because they employ a solid tower with an ocean bottom pier; while deep-water turbines are assumed to be mounted on floating platforms tethered to the ocean floor. Although there is a great deal of resource off the Northeast coast and West Coast, there is also a large resource in the Great Lakes in the Midwest.

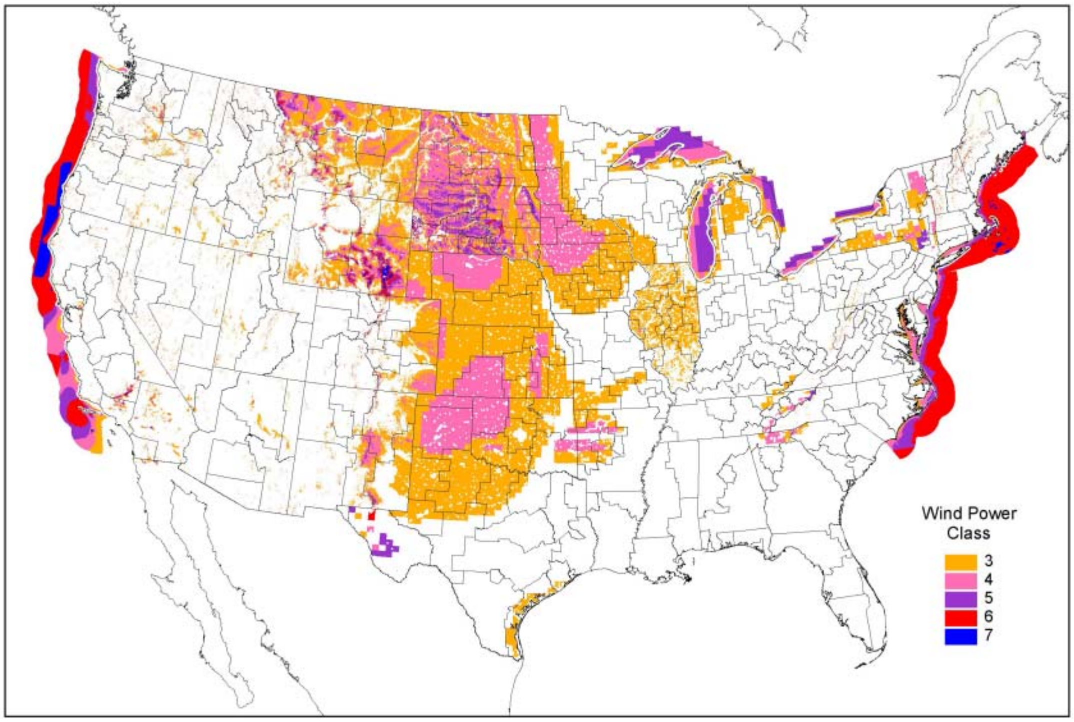

Figure 2: Wind Resources in WinDS

Linear programs, such as WinDS, work by minimizing an objective function. The WinDS objective function is a minimization of all the costs of the U.S. electric sector including:

- the present value of the cost for both generation and transmission capacity installed in each period (each period represents two years), plus
- the present value of the cost for operating that capacity during the next 20 years – fixed and variable operation and maintenance (O&M) and fuel costs – to meet load, plus
- the cost of several categories of ancillary services.

By minimizing these costs while meeting the system constraints (discussed below), the linear program determines which types of new capacity are the most economical to add in each period, for each region in the country. Simultaneously, the linear program determines what capacity should be used to provide the necessary energy in each period. Therefore, the capacity factor for each dispatchable technology in each region is an output of the model, and not exogenously defined.

The cost minimization that occurs within WinDS is subject to 73 types of constraints, which result in thousands of equations in the model (due primarily to the large number of regions). These constraints fall into several main categories, including:

- *Wind resources*: The total amount of wind installed in each region must be less than the wind resource potentially available, as estimated by the NREL Wind Resource and GIS team.
- *Wind access to existing transmission lines*: The amount of new wind-power capacity that can be transmitted on existing lines is limited by the transmission capacity available on nearby lines. The GIS portion of WinDS determines which wind resources would be most cost effective in using existing transmission capacity.
- *Load constraints*: The primary load constraint is that the electric load in each power control area (there are 136 power control areas in WinDS) must be met in each time-slice (of which there are 16) throughout a year. The load and its rate of growth in each North American Electric Reliability Council (NERC) region are derived from the Reference Case of U.S. Energy Information Agency's (EIA) Annual Energy Outlook.
- *Reserve margin constraint*: There are two types of reserves constraints – planning reserve margin and operating reserve. For the reserve margin constraint, WinDS updates its estimate (for each period) of the marginal capacity value of the next wind farm built in each region, using a detailed statistical approach. The capacity value is set equal to the amount of load that could be added – along with the wind – without changing the risk of a shortage in generation capacity at peak load times. The approach accounts for the dispersion of the wind sites contributing to the load and the correlation in the output of those sites.
- *Operating reserve constraint*: The operating reserve requirement induced by each new wind farm is also modified each period for each region. The additional operating reserve requirements due to wind are not proportional to the amount of wind, but rather to the variance in the sum of the normal operating reserve and the wind generation. This means that the operating reserves induced by wind are generally low per unit of wind capacity initially, but can grow quickly if the wind capacity becomes a significant part of system capacity – especially if the output of the new wind capacity is highly correlated with that of existing capacity.
- *Wind Surplus:* WinDS also accounts for surplus wind-generated electricity that is lost at the interconnection region level. When demand is low and the wind is blowing, there can be instances where the wind generation cannot all be used. WinDS uses the variance of the sum of all wind generation – together with a load duration curve and the forced outage rates of conventional technologies – to stochastically compute the expected amount of wind that cannot be used.
- *Emissions constraints*: At the national level, WinDS caps the air emissions from fossil-fueled generators for sulfur dioxide, nitrogen oxides, mercury, and carbon. The annual national emission caps and the emissions per MWH are input by the user.

3. BASE CASE ASSUMPTIONS AND 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 Annual Energy Outlook for 2004[2] to determine 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

Onshore wind-power cost and performance data in our Base Case are derived from projections made in 2002 by Princeton Energy Resources International[3] (PERI) for the DOE Wind Program. Offshore wind-power costs are derived from preliminary estimates made by NREL. In the Base Case, we assume that only 50% of the projected capacity-factor improvements will occur through R&D and only one-third of the cost improvements. **Table 1** shows the resulting R&D-driven cost and performance improvements used in WinDS for the Base Case. In addition to the improvements over time shown in **Table 1** for the Base Case, WinDS also allows for "learning" improvements in both the costs and capacity-factor values. For each doubling of installed worldwide wind capacity (a scenario of wind installations outside the United States reaching 130 GW by 2030 is input to WinDS), there is an 8% reduction in capital costs, and the capacity factor gets 8% closer to the projected PERI/NREL values.

Table 1: Base Case R&D-Driven Wind Costs and Performance

Wind Class	Year	Capacity Factor	Onshore Cap cost $/KW	Onshore Var O&M cents/kWh	Shallow Offshore Cap cost $/kW	Deep Offshore Cap cost $/kW	All Offshore O&M cents/kWh
4	2005	0.29	916	3.8	1313	1815	1.4
4	2010	0.35	914	3.7	1251	1728	1.3
4	2020	0.36	899	3.6	1187	1639	1.2
4	2030	0.36	899	3.6	1135	1567	1.2
4	2040	0.36	899	3.6	1117	1529	1.2
4	2050	0.36	899	3.6	1117	1529	1.2
6	2005	0.42	880	3.8	1313	1815	1.4
6	2010	0.45	880	3.7	1251	1728	1.3
6	2020	0.47	864	3.6	1187	1639	1.2
6	2030	0.47	864	3.6	1135	1567	1.2
6	2040	0.47	864	3.6	1117	1529	1.2
6	2050	0.47	864	3.6	1117	1529	1.2

With these Base Case inputs, WinDS projects that wind will provide about 227 GW of capacity in 2050, far larger than today's 6 GW (see bottom slice of graph in **Figure 3**). This growth is largely attributable to improvements in the cost and performance of wind turbines – however, there are other drivers. By about 2014, the increase in natural gas prices (as forecast by the

[2] United States Department of Energy (DOE), Energy Information Administration (EIA), "Annual Energy Outlook 2004," January 2004, DOE/EIA-0383(2004)

[3] Personal communication with Joe Cohen of Princeton Energy Resources International (PERI), April 29, 2003

AEO2004) stalls the recent growth in new installations of combined-cycle, natural gas-fired power plants (fourth slice from the bottom). At about the same time, installations of advanced pulverized coal plants with stringent emission controls begin to penetrate the new-build market (seventh slice from the bottom).

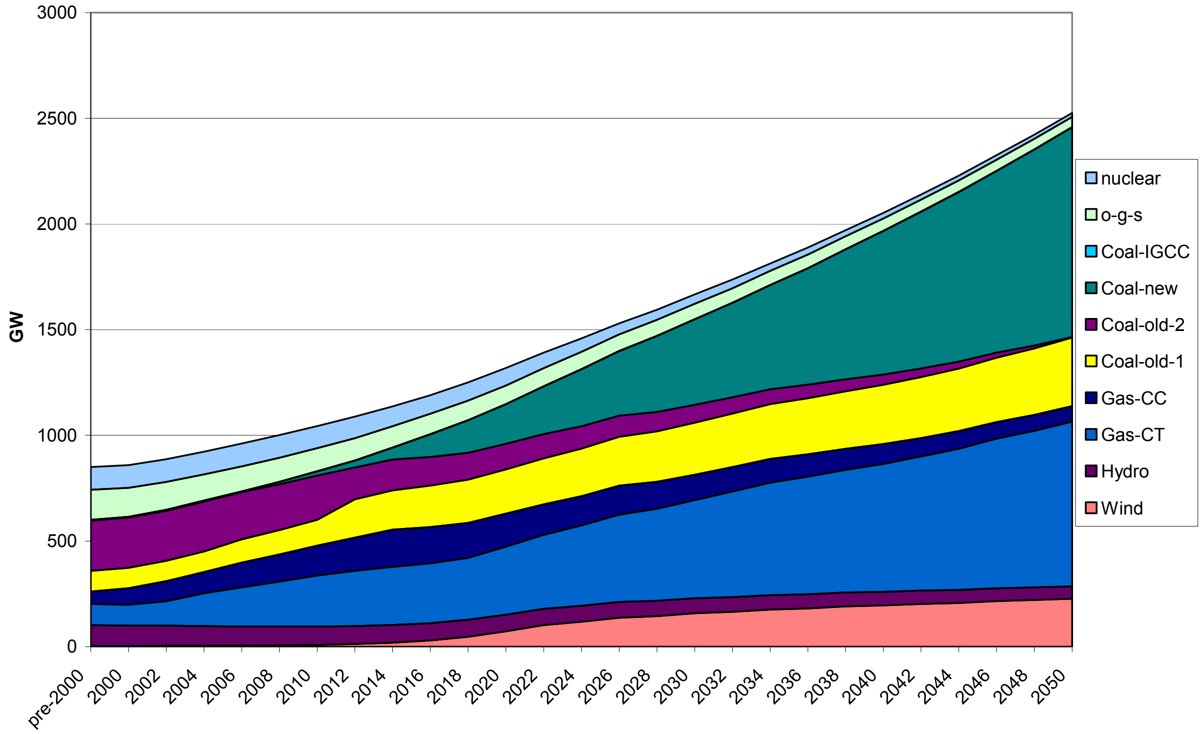

Figure 3: National Capacity Projections for the WinDS Base Case

The dominance of new coal plants in the new-capacity market of the second quarter (21st century) does not bode well for wind energy. Unlike the recently installed gas combined-cycle plants, the fuel for these coal plants is expected to remain relatively inexpensive, leaving little or no room for wind to penetrate the market as a fuel saver. Likewise, sulfur dioxide and NOx emissions from new advanced coal plants being installed today are significantly less than today's average existing coal plant, limiting wind's environmental advantages.

Realistically, the role of future coal plants in the Base Case may be somewhat mitigated by the fact that the consequent increase in demand for coal will put upward pressure on coal prices – WinDS currently does not capture such feedback. Because it is not a general equilibrium model, but only a model of capacity expansion in the electric sector, WinDS does not include price elasticity for coal or other fossil fuels.

4. SENSITIVITY CASES FOR FEDERAL POLICIES

The analysis examined three federal policies:

- Continued R&D on wind energy
- Extension of the production tax credit (PTC) to 2006
- Implementation of a national renewable portfolio standard (RPS)

Results for each are presented separately below.

Continued R&D on Wind Energy

As stated above, the primary reason for the surge in wind energy in the Base Case is the anticipated improvements in turbine costs and performance. **Figure 4** compares the projected deployment of wind in the Base Case with a case in which there is no R&D-driven improvements in turbine cost/performance. By 2050, the total wind deployed in this "No R&D" case is only 20 GW – or only 8% of the Base Case installations. Although both cases include improvements due to learning, the absence of the R&D improvements precludes the installations that could lead to significant learning-based cost/performance improvements.

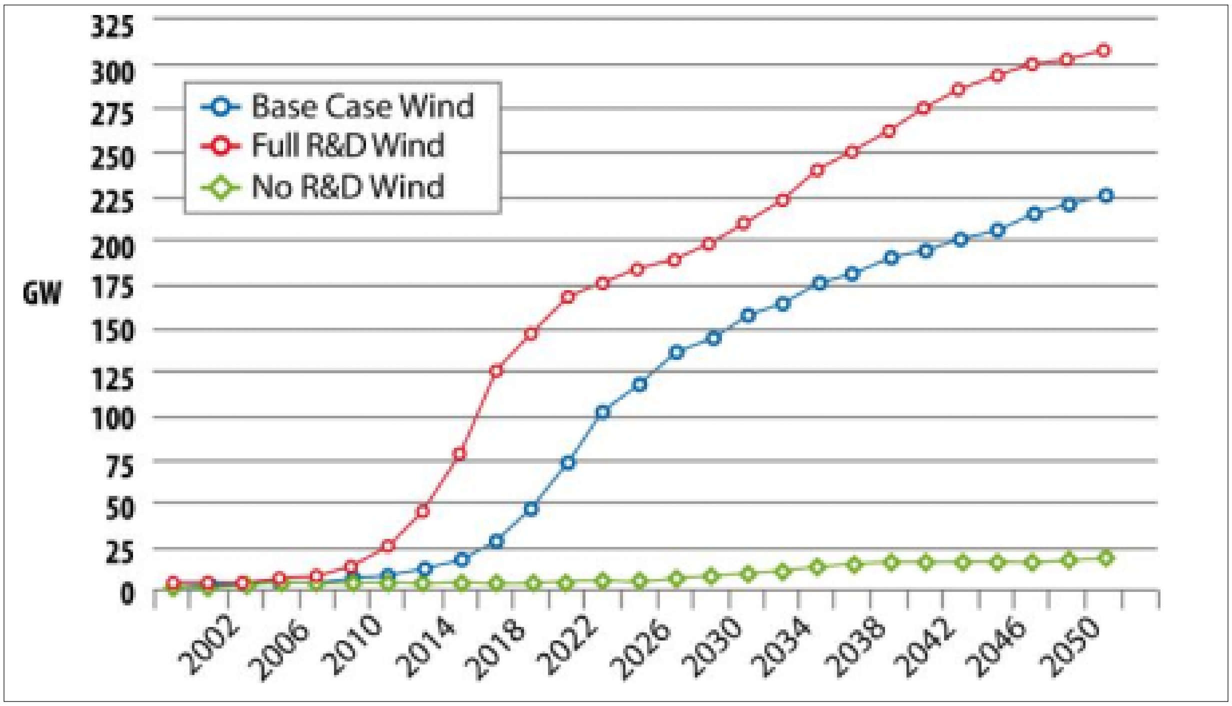

Figure 4: Wind Capacity Expansion with Varying Degrees of Technological Improvement

The Base Case assumes that, without learning, only 33% of the cost reductions projected by PERI/NREL for the DOE Wind Program will occur and only 50% of the capacity-factor improvements. **Table 2** shows this full set of wind cost and performance improvements as projected by PERI and NREL. The different rates of improvement in the costs and performance of onshore wind Classes 4 and 6 are driven by the DOE Wind Program focus on improving low-wind-speed turbines. Were these to be achieved, wind deployment would surge, to almost 310 GW by 2050 (also shown in **Figure 4**). Much of this increase is due to the installation of offshore wind turbines, which become economic if the NREL-projected offshore improvements are attained.

Table 2: PERI/NREL Wind Cost/Performance Projection

Wind Class	Year	Capacity Factor	Onshore Cap cost $/KW	Onshore Var O&M cents/kWh	Shallow Offshore Cap cost $/kW	Deep Offshore Cap cost $/kW	All Offshore O&M cents/kWh
4	2005	0.33	862	.19	1199	1664	1.4
4	2010	0.45	858	.17	1013	1405	1.2
4	2020	0.47	811	.15	820	1138	.78
4	2030	0.47	811	.15	664	921	.71
4	2040	0.47	811	.15	611	806	.71
4	2050	0.47	811	.15	611	806	.71
6	2005	0.44	754	.19	1199	1664	1.4
6	2010	0.50	754	.17	1013	1405	1.2
6	2020	0.54	707	.15	820	1138	.78
6	2030	0.54	707	.15	664	921	.71
6	2040	0.54	707	.15	611	806	.71
6	2050	0.54	707	.15	611	806	.71

Extension of the PTC to 2006

There are several reasons for continuing the PTC to 2006, which include:

- Increasing near-term deployment of wind energy
- Displacing generation and emissions by fossil-fired generators
- Encouraging growth of the U.S. wind industry
- Increasing local employment

WinDS has been used to assess only the first of these rationales. As shown in **Figure 5**, continuing the PTC to 2006 will significantly increase wind generation for the next 30 years. However, as might be expected, with continued R&D-driven improvements in wind turbines, the amount of wind capacity installed is the same after 30 years – with or without the PTC. Two counteracting forces lead to this result. The first – and more obvious – is that increased deployment leads to improved wind cost/performance through learning. The second is that the best wind sites are used quickly in the PTC extension case, leaving only lower-quality sites once the PTC has expired. However, in the Base Case, the better sites are not used until later, allowing the installations in the Base Case to eventually catch up with those of the PTC-extension case.

Although the results might lead to questions regarding the value of the PTC, there are several things to point out. First, in the Base Case, there is a dearth of wind installations until about 2016. By this time, the U.S. wind industry may have moved overseas. Furthermore, without the PTC, U.S. electric-grid operators will not have had the opportunity to learn how best to integrate wind into their systems, a market factor that WinDS does not capture. Finally, without the PTC extension, the installations and generation spurred by the PTC would not have increased employment, nor reduced fossil emissions, in the near term.

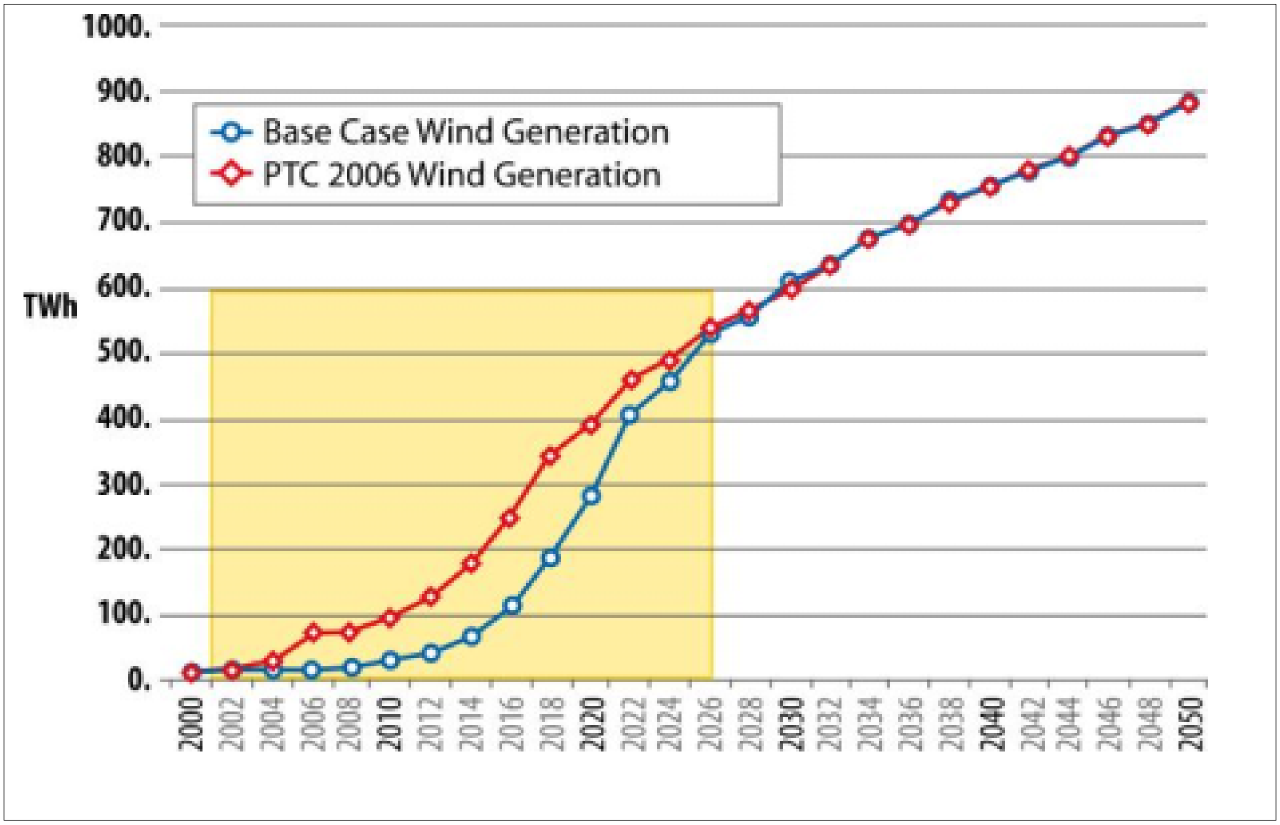

Figure 5: Wind Generation for a PTC Extension until 2006, Compared to Base Case

The analysis examined the cost to the government of the additional wind generation spurred by the PTC. While the PTC is assumed to be $18/MWh (2003$), the levelized cost per kWh spurred by the PTC is only $7/MWh, for two reasons. First, the PTC is available for only the first 10 years of generation by a turbine. If the turbine generates for 20 years or more, the wind generation will more than double the amount for which the PTC was paid. Second, the additional installations spurred by the PTC bring future wind costs down through learning, spurring more capacity builds and generation. In **Figure 6,** which presents the same data as **Figure 5** but with the scale changed (yellow area on Figure 5 represents area magnified in Figure 6)**,** the parallelogram roughly represents the generation on which the government must pay the 18$/Mwh tax credit. However, the total shaded area represents the total generation that occurs due to the PTC. For a majority of the area, the government does not need to pay the tax credit.

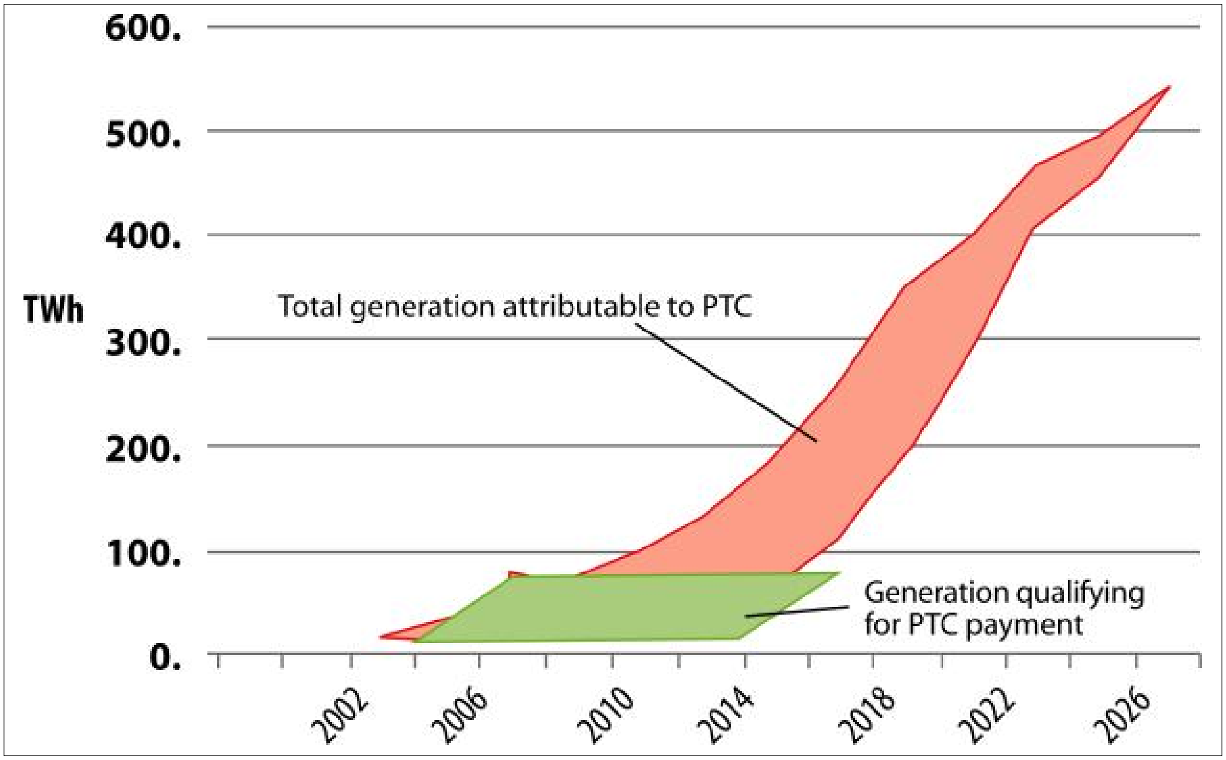

Figure 6: PTC Cost and Additional Generation

<u>National RPS</u>

We examined the efficacy of a national renewable portfolio standard that is incrementally imposed, accelerating between 2010 and 2020 and expiring by 2030. Because WinDS currently does not accurately address the capability of non-wind renewables to contribute to an RPS, the RPS was imposed only on wind energy. The RPS case considered here requires that by 2020, 15% of all generation will be met by wind. If a supplier does not purchase at least 15% of generation from wind power providers, then the supplier must pay a penalty for each MWh not bought. **Figure 7** compares the wind generation at two different penalty levels with that of the Base Case. At $18/MWh, the full goal of 15% from wind is met. At a much-reduced penalty of only $6/MWh, 13% of the generation in 2020 is still provided by wind, implying that the other 2% is met by paying the penalty.

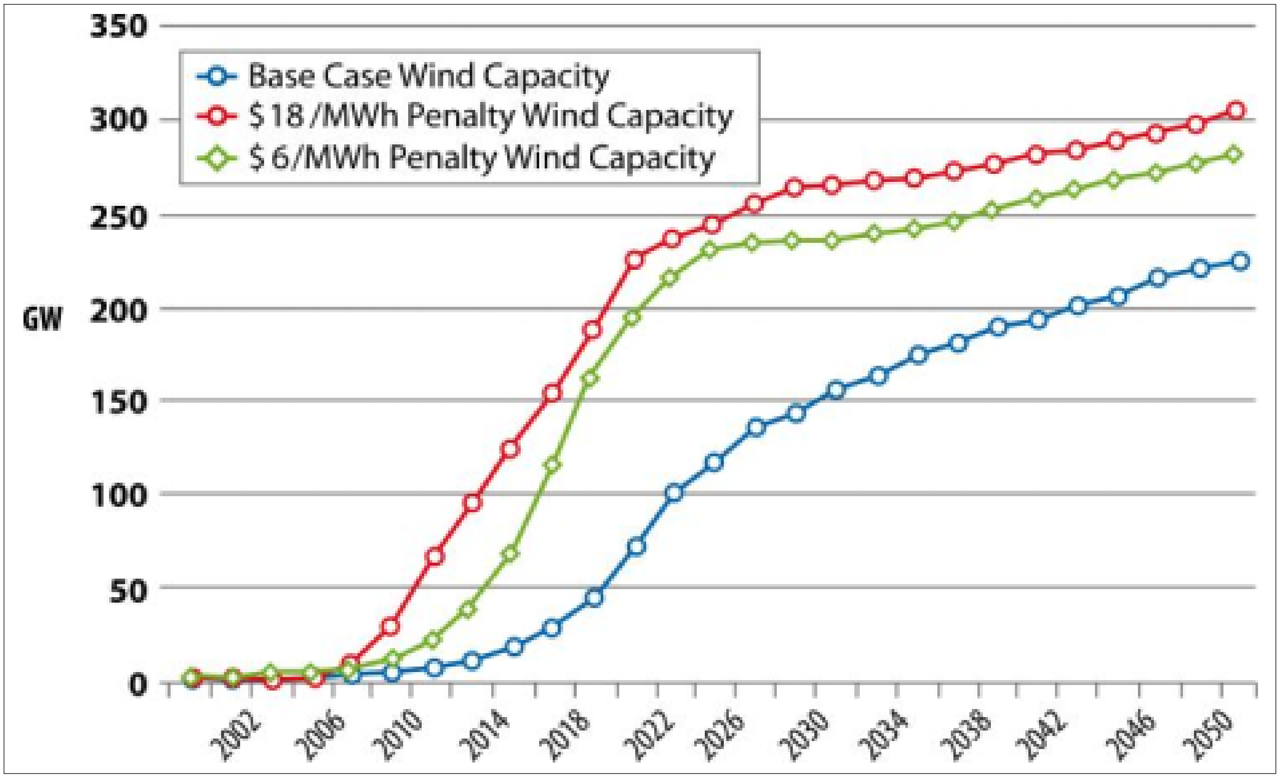

Figure 7: Wind Capacity for 15% RPS, Compared to Base Case

CONCLUSIONS

- If the cost and performance of wind turbines continue to improve, wind energy will contribute a substantial share of future U.S. electric generation.
- Extending the production tax credit to 2006 will increase the generation from wind during the next 25 years, which should help ensure a growing U.S. wind industry, as well as support local economies and job markets.
- A national RPS for wind will substantially increase the near-term penetration of wind energy.

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14. SUBJECT TERMS
Wind Deployment Systems Model; WinDS; GIS; wind; analysis models; wind power; production tax credit; PTC; renewable portfolio standard; RPS; wind resources; wind classes; wind markets; load constraints; offshore wind; PERI; Walter Short; Nate Blair; Donna Heimiller

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