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Long-Term National Impacts of State-Level Policies

Preprint

N. Blair, W. Short, P. Denholm, and D. Heimiller

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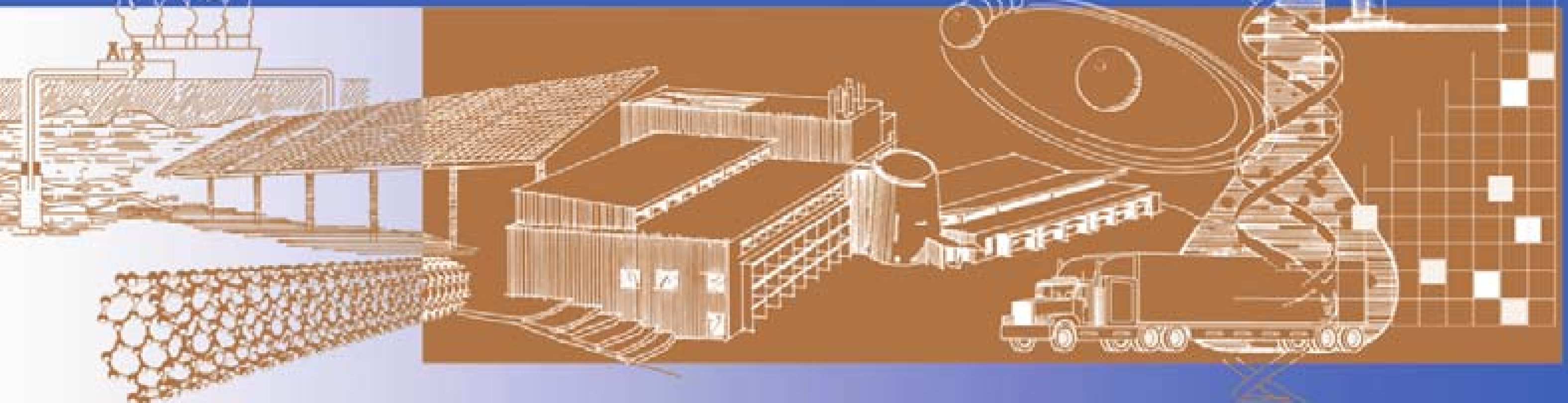

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Long-Term National Impacts of State-Level Policies*

WINDPOWER 2006

Nate Blair, Walter Short, Paul Denholm, Donna Heimiller
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401-3393
nate_blair@nrel.gov
walter_short@nrel.gov
paul_denholm@nrel.gov
donna_heimiller@nrel.gov

ABSTRACT

This paper presents analysis conducted with the Wind Deployment System Model (WinDS) – a model of capacity expansion in the U.S. electric sector. With 358 regions covering the United States, detailed transmission system representation, and an explicit treatment of wind intermittency and ancillary services, WinDS is uniquely positioned to evaluate the market impacts of specific state-level policies.

This paper provides analysis results regarding the impact of existing state-level policies designed to promote wind-capacity expansion, including state portfolio standards, mandates, and tax credits. Our results show the amount of wind deployment due to current state-level incentives as well as examine their lasting impact on the national wind industry. For example, state-level mandates increase industry size and lower costs, which result in wind capacity increases in states without mandates and greater market growth even after the policies expire. Although these policies are enacted by individual states, the cumulative effect must be examined at a national level. Finally, this paper examines the impact on wind-capacity growth by increasing the penalty associated with the state-level renewable portfolio standards (RPS). Our results show national and regional wind energy deployment and generation through 2050.

Section 1: WinDS Overview

WinDS is a computer model that optimizes the regional expansion of electric generation and transmission capacity in the continental United States over the next 50 years. It employs a Geographic Information System (GIS) to develop region-specific data for input to a linear program (LP). Most of the methodology description that follows addresses the linear-program portion of the model and is simply referred to as WinDS. Where it is important to distinguish the analysis that is done in the GIS from the LP, the GIS capability is specifically identified.

WinDS minimizes system-wide costs of meeting electric loads, reserve requirements, and emission constraints by building and operating new generators and transmission in 26 two-year periods from 2000 to 2050. The primary outputs of WinDS are the amount of capacity and generation of each type of prime mover—coal, gas combined cycle, gas combustion turbine, nuclear, wind, etc.—in each two-year period. **Figure 1** shows an example of WinDS capacity estimates for the United States for different generation technologies over the next 50 years.

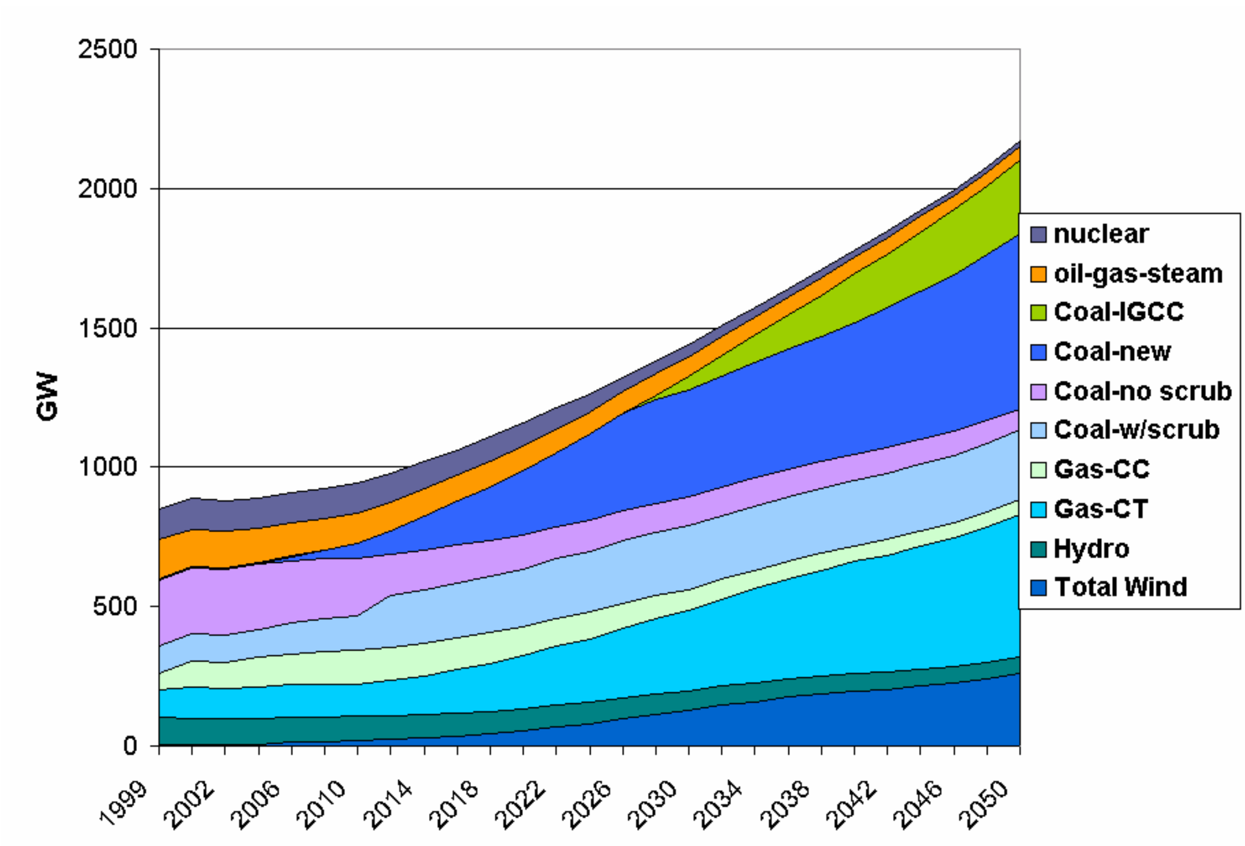

Figure 1. Base Case WinDS Capacity Estimates

While WinDS includes all major generator types, it was designed primarily to address the market issues of greatest significance to wind—transmission and intermittency. The WinDS model examines these issues primarily by using a much higher level of geographic disaggregation than other models. As **Figure 2** represents, WinDS uses 358 different regions in the continental 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.

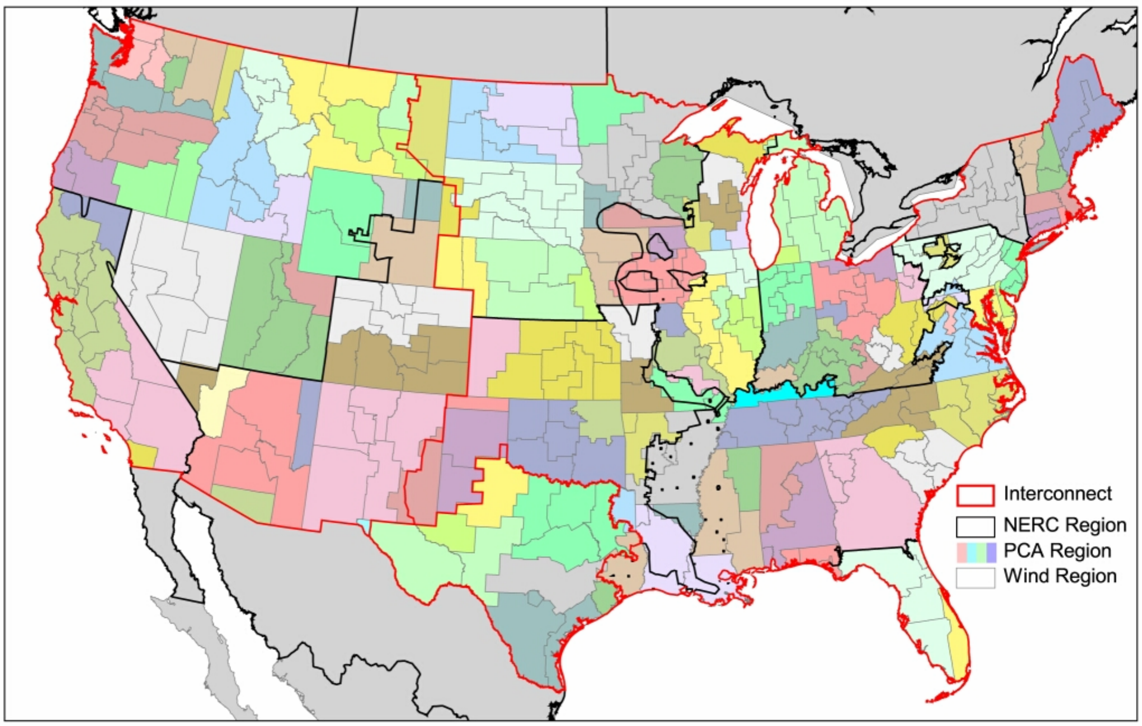

Figure 2. Regions within WinDS

As shown in **Figure 3**, 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 and distinguishes between shallow 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.

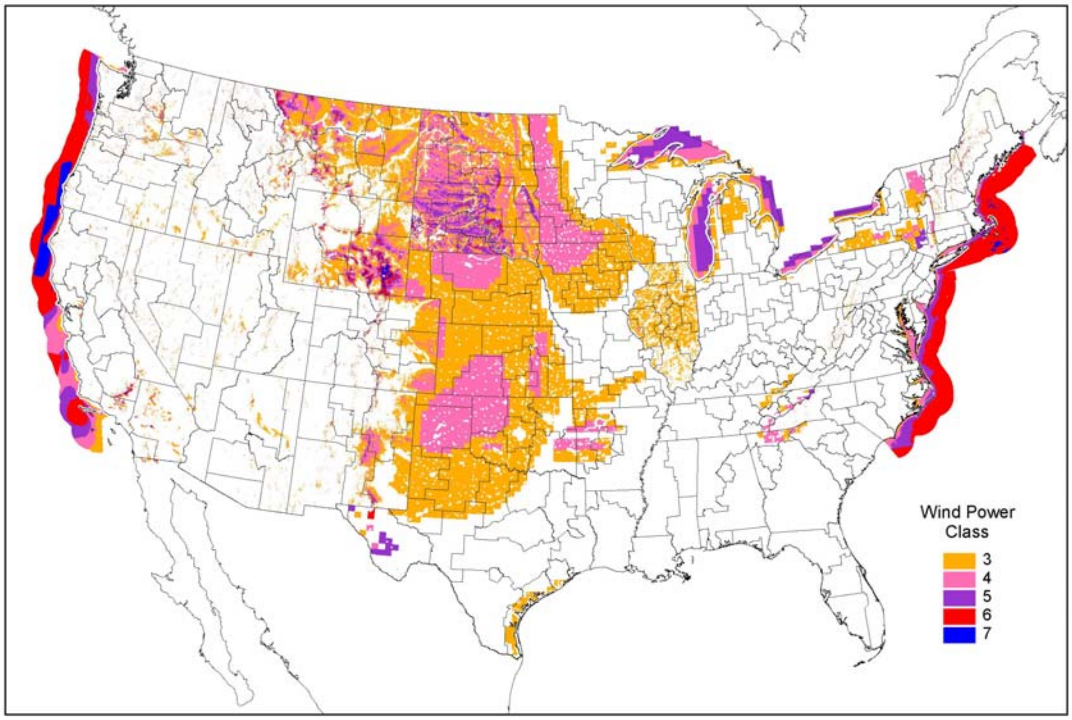

Figure 3. Wind Resources in WinDS

These different classes and types of wind have different costs and performance characteristics. Generally the higher wind-class sites (i.e. Class 7), are the preferred sites. However, **Figure 4** shows that, at any given point in time, the wind turbines installed will be at a mix of sites with different wind-resource classifications. This occurs because, in selecting the installation sites, WinDS considers not only the resource quality, but also examines factors such as transmission availability, transmission costs and losses, correlation of the wind output with neighboring sites, environmental exclusions, site slope, and population density.

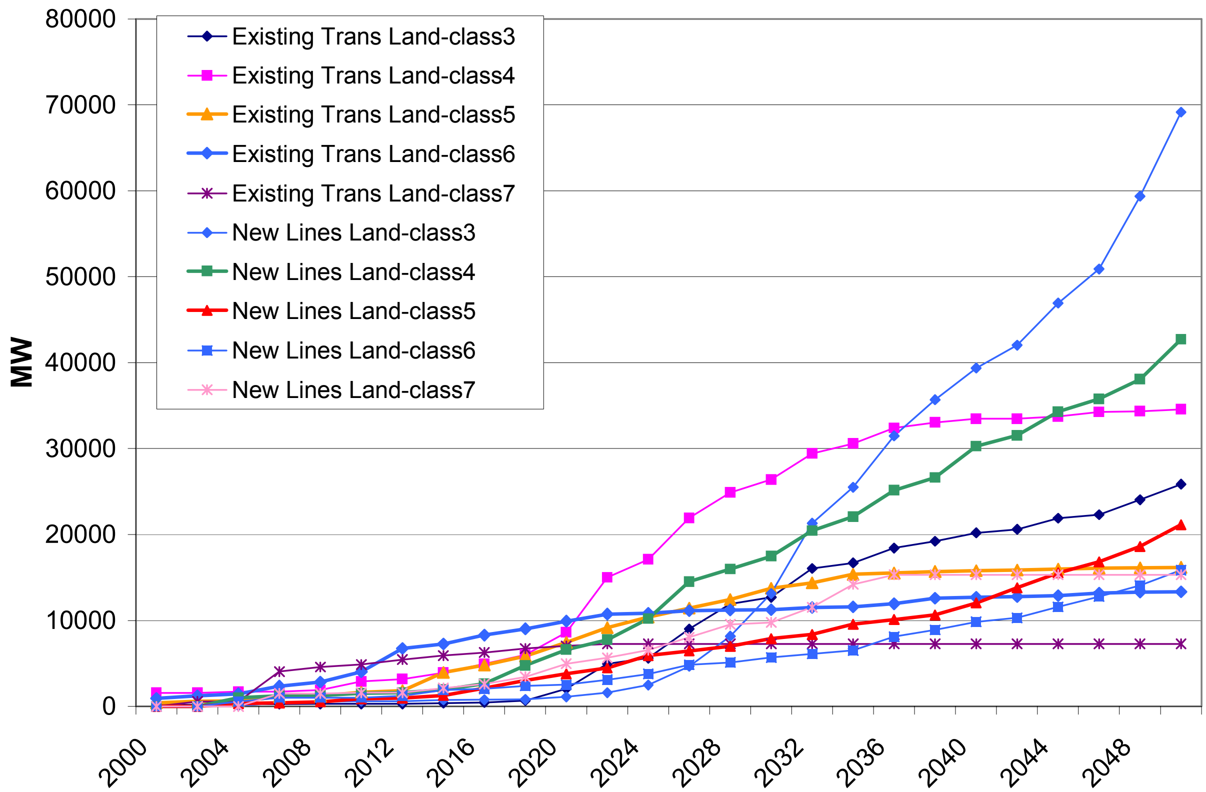

Figure 4. Wind Capacity Results by Type and Class

WinDS is also disaggregated over time—not only with the 26 two-year periods between 2000 and 2050, but also within each year. Each year is divided into four seasons with each day of each season divided into four diurnal time slices. These 16 time slices during each year allow WinDS to capture the intricacies of meeting peak electric loads, with both conventional sources and intermittent wind generators.

WinDS models the major conventional electricity generators, including:

- pulverized coal
- integrated gasification combined-cycle coal
- existing unscrubbed coal boilers
- existing scrubbed coal boilers
- natural gas combined cycle

- natural gas combustion turbines
- nuclear
- hydroelectricity

Fuel costs are exogenously specified over time by NERC region, as are electric loads. WinDS is a national electric capacity expansion model, not a general equilibrium model. Assessing the potential of wind energy under any given scenario requires that the scenario be exogenously specified in terms of fuel costs and electric loads, and by NERC region over the 50-year time horizon of WinDS.

While the focus of WinDS is on wind-energy technologies, the model does include some detail on other generation technologies. For example, there are four types of coal-fired power plants within WinDS—existing boilers without SO_2 scrubbers, existing with scrubbers, new advanced pulverized coal plants, and new integrated-gasification combined-cycle plants. These plants can burn either high-sulfur or, for a cost premium, low-sulfur coal. Generation by coal plants is restricted to base and intermediate load, with cost penalties (representing ramping/spinning costs) if power production during peak load periods exceeds production in shoulder-peak hours. Nuclear is considered to be base load. Combined-cycle, natural-gas plants are considered capable of providing some spinning reserve and quick-start capability, but the primary source of peak power and operating reserves are combustion turbines and hydroelectricity. Hydroelectricity capacity is not allowed to increase, due to resource and environmental limitations. Hydro is also energy-constrained, due to water resource limitations.

WinDS tracks emissions from both generators and storage technologies of carbon, sulfur dioxide, nitrogen oxides, and mercury. Caps can be imposed at the national level on any of these emissions. Alternatively, a carbon tax can be imposed that linearly escalates to the maximum tax level over time.

Section 2: Base Case Results

The WinDS Base Case results are highly dependent on the primary inputs to the model. The conventional power costs and performance along with the fuel prices for gas, coal and nuclear are taken from the U.S. Energy Information Agency's Annual Energy Outlook[1]. In this analysis, the 2005 version of the AEO was used. The wind cost and performance data comes from the annual benefits projection titled "Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs – FY 2007 Budget Request".[2] Table 1 shows a brief summary of the wind cost and performance data with improvements due to research and development. The learning-by-doing improvements are calculated endogenously within WinDS, using an 8% learning rate based on both U.S. and world production estimates.

[1] http://www.eia.doe.gov/oiaf/archive/aeo05/index.html
[2] http://www1.eere.energy.gov/ba/pdfs/39684.pdf

Table 1: Onshore Turbines Cost and Perf. Due to R&D

Resource Class	Install Year	Capacity Factor	Capital cost ($/kW)*	Fixed O&M ($/kW-yr)	Variable O&M ($/MWh)
3	2000	32.9%	1136	7.76	5.15
3	2010	34.9%	1112	7.76	4.53
3	2020	37.6%	1082	7.76	4.04
3	2050	37.7%	1049	7.76	3.84
4	2000	34.8%	1136	7.76	5.15
4	2010	37.4%	1112	7.76	4.53
4	2020	40.9%	1082	7.76	4.04
4	2050	41.4%	1049	7.76	3.84
5	2000	40.2%	1081	7.76	5.15
5	2010	42.4%	1058	7.76	4.53
5	2020	44.2%	1020	7.76	4.04
5	2050	45.1%	995	7.76	3.84
6	2000	44.0%	1081	7.76	5.15
6	2010	45.8%	1058	7.76	4.53
6	2020	47.6%	1020	7.76	4.04
6	2050	48.3%	995	7.76	3.84
7	2000	54.4%	1044	7.76	5.15
7	2010	55.4%	980	7.76	4.53
7	2020	56.2%	963	7.76	4.04
7	2050	56.3%	963	7.76	3.84

* Overnight capital cost

Figure 5 indicates the average coal and natural gas costs currently used within the model, based on AEO 2005. Higher gas prices will be a minor driver but higher coal prices would dramatically increase the amount of wind capacity deployed in the future due to the prevalence of new coal capacity being built.

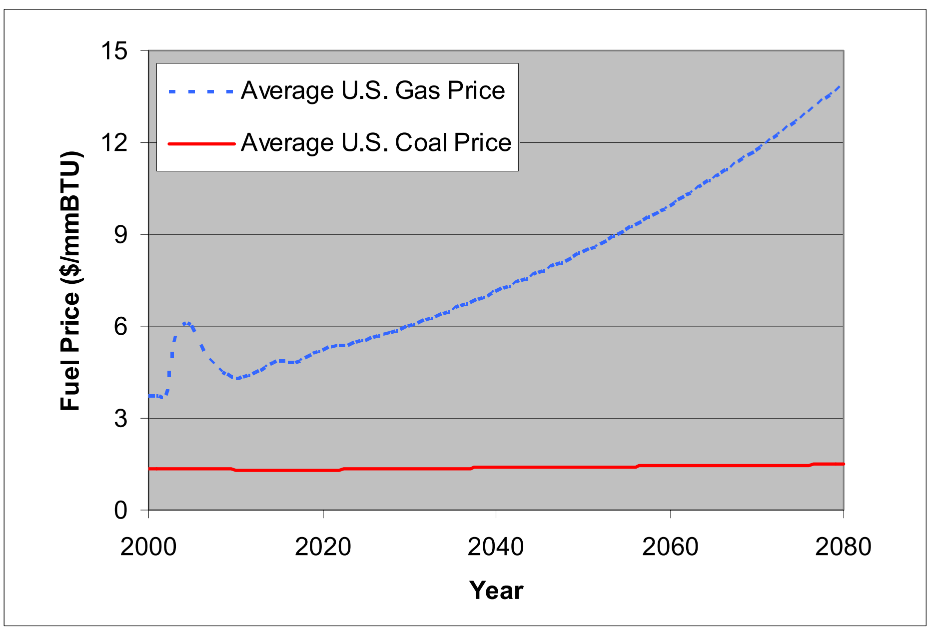

Figure 5. AEO 2005 Natural Gas and Coal Prices used in WinDS

As **Figure 6** indicates, the fraction of total national generation from wind power increases to roughly 10% by 2050. It also shows that various types of coal generation—including integrated gasification combined cycle (IGCC), new pulverized coal plants (coal-new), and existing coal plants (coal-old-1 and coal-old-2)—combine to make up more than 80% of the national generation by 2050. This wind fraction includes the impact of the state-level incentives discussed below. It indicates that additional state incentives, federal incentives, or improved R&D would help wind reach a higher fraction of national generation. **Figures 1 and 4** (above) also are from this same base case model run. They indicate the overall capacity from each generation source (including wind), as well as the amount of wind by class and transmission type (existing grid lines or new lines, which include new lines to serve load within the same region). However, the state incentives examined in this paper are generally concerned with generation by wind.

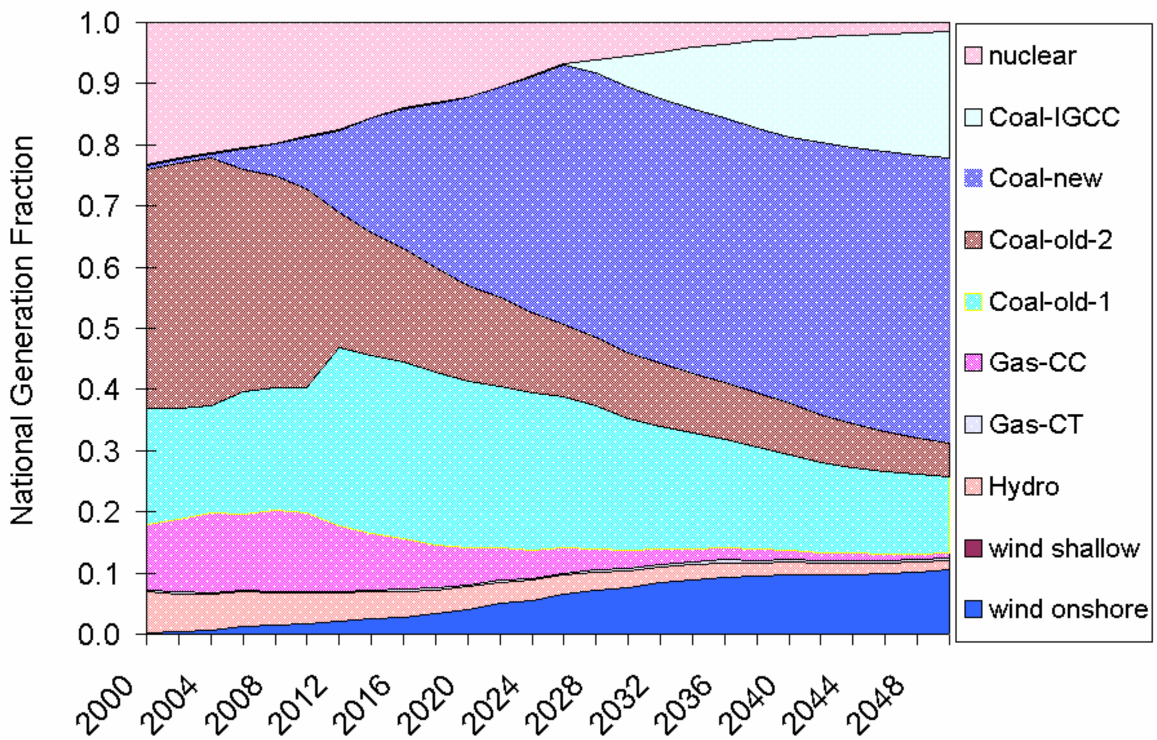

Figure 6. Base Case Generation Fractions (including state-level incentives)

Also of interest to states is the location of the wind capacity. Wind capacity can secure state benefits such as economic development, out-of-state investment, energy payments to local land owners and tax revenue to the states. **Figure 7** indicates where the wind capacity is built in the base case by 2050. As expected, the states with strong wind resource and load are the site for much of the future wind deployment. In **Figure 9**, the amount of wind generation that is due to state-level incentives is also mapped. Note that, in the base case, roughly 260 GWs of wind are deployed by 2050, compared to roughly 9 GWs currently.

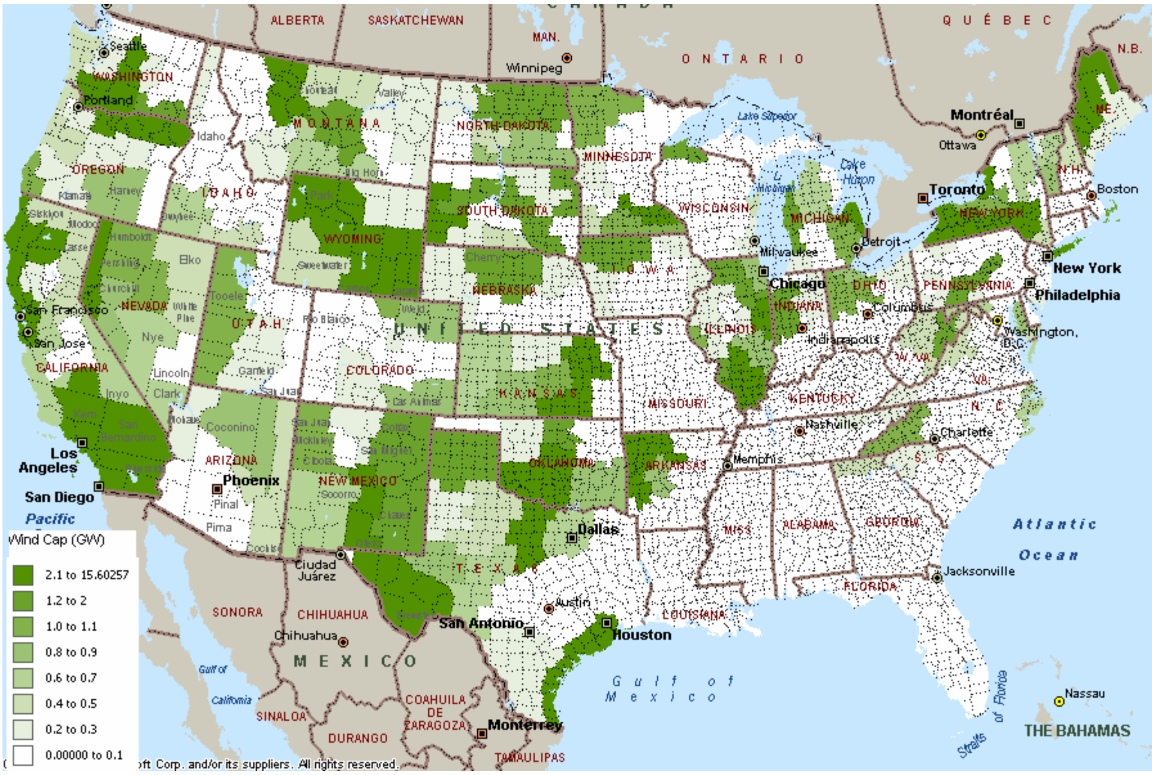

Figure 7. Base Case Wind Capacity in 2050

Section 3: Treatment of State-Level Incentives

WinDS currently models three state-level incentives—state-level renewable portfolio standards (RPS), state-level production tax credits (PTC), and state-level investment tax credits (ITC). There are a multitude of other local and state incentives, including benefits such as property and sales tax reductions. These incentives, which have not been modeled yet, are in addition to the federal PTC (scheduled to expire in 2007).

The information about the state-level incentives was gleaned from the Database of State Incentives for Renewable Energy (DSIRE) database[3] and other sources such as the Union of Concerned Scientists.[4] For WinDS, several different pieces of information were needed including:

- When the incentive takes effect. Typically, this is when the legislation is initiated.
- For an RPS, when the incentive reaches its full level.
- The level of incentive—either the dollar amount of the PTC or ITC, or the generation fraction associated with the RPS.
- For an RPS, what generation fraction is can be, or must be, met by wind.
- The duration of the incentive—how long it lasts once it reaches full enforcement.
- In the case of the RPS, the penalty for noncompliance.

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[3] DSIRE – Database of State Incentives for Renewable Energy http://www.dsireusa.org/

[4] http://www.ucsusa.org/clean_energy/clean_energy_policies/clean-energy-policies-and-proposals.html

- What fraction of the state electricity load is actually subject to the incentive. In the case of the RPS, small utilities (such as municipalities and cooperatives) often are exempt or allowed to opt-out of the RPS.

As shown in Table 2 and Table 3, 20 states with an RPS and eight states with either a PTC or ITC have been modeled. It should be noted that these incentives are in addition to the standard federal incentives (including the federal PTC that ends in 2007, accelerated depreciation, and others). In Table 2, the "Year Fraction Reached" indicates the year at which the state will reach the "Legislated RPS Fraction (%)." The "Yrs to Maintain" indicates how long the RPS fraction must be maintained after the "Year Fraction Reached." For states in which a duration was not indicated, or the legislation indicated that the RPS would not end, a value of 100 years was used to maintain the fraction throughout the simulation. The penalty (in $/MWh) is the cost for each MWh that the load-serving entities in the state fall short of the wind RPS fraction of generation. The "State Load Fraction Included" indicates the amount of electricity consumed within the state that is subject to the RPS.

The "Final Fraction due to Wind" is the fraction of total state electricity consumption that must be met by wind by the "Year Fraction Reached." This value accounts for the legislated RPS fraction, the state load fraction included in the RPS, and a decision on the amount of RPS that will be met by wind. Currently, the WinDS model does not accurately model biomass, geothermal, photovoltaics, or landfill gas generation capacity expansion. Several of these sources are expected to be significant contributors to these state RPSs. Therefore, the amount that must be met by wind was decided on exogenously based on the relative attractiveness of the biomass, geothermal, and wind resources for each state. For example, if the biomass resource was excellent and the wind resource was average, then a smaller fraction of the RPS was assumed to be required from wind power in the future. This exogenous assessment produced estimates from 85% down to 50% of the RPS requirement that must be met by wind. WinDS assumes complete compliance with this net RPS either through building wind or by paying the penalty.

Although many states allow wind generation to be shipped into the state in contribution to the RPS, a minority of states require that renewable energy, used to meet their RPS, must be generated from within the state. It is expected that such requirements will eventually be ruled in violation of interstate commerce laws[5]. Thus, WinDS assumes that the wind contributions to state RPSs can be transmitted in from other states.

[5] Renewable Orphans: Adopting Legal Renewable Standards at the State Level, Steven Ferrey, The Electricity Journal, Volum 19, Issue 2, Pages 52-61

Table 2. State-level Renewable Portfolio Standards as Implemented in this Study

	Year Fraction Reached	Yrs to Maintain	Penalty ($/Mwh)	Legislated RPS Fraction (%)	State Load Fraction Included	Final Fraction due to Wind
AZ	2025	1	50	1.1	1.00	0.0079
CA	2017	1	5	20	0.63	0.0340
CO	2015	100	50	10	0.69	0.0440
CT	2010	100	55	10	0.94	0.0130
DE	2019	100	25	10	0.75	0.0560
IL	2013	100	10	15	0.92	0.0620
MA	2009	100	50	4	0.85	0.0260
MD	2019	100	20	7.5	0.80	0.0450
MN	2015	1	10	1125MW	1.00	0.0718
MT	2015	100	10	15	0.90	0.0750
NJ	2008	100	50	6.5	1.00	0.0290
NM	2011	100	10	10	0.53	0.0260
NV	2015	100	10	20	0.89	0.1330
NY	2013	1	5	25	0.84	0.0350
OR	2020	100	5	Bnft Fund	1.00	0.0780
PA	2020	100	45	8	0.98	0.0140
RI	2019	1	55	15	0.99	0.0690
TX	2009	10	50	5880 MW	1.00	0.0100
VT	2012	1	10	Bnft Fund	1.00	0.0500
WI	2011	1	10	2.2	0.75	0.0060

Table 3. State-level Production Tax Credit (PTC) and Investment Tax Credits (ITC) as Used in this Study

State	PTC $/MWh	ITC	Assumed State Corporate Tax Rate
IA		5.00%	10.0%
ID		5.00%	7.60
MN		6.50%	9.8%
NJ		6.00%	9.0%
NM	10		7.0%
OK	2.5		6.0%
UT		4.75%	5.0%
WY		4.00%	9.0%

There are several issues that make modeling these state-level incentives quite difficult. First, many laws do not explicitly outline how long the final RPS fraction must be maintained. In reality, once the RPS fraction is met, if it is not continually enforced and wind is not yet economical on its own, the generation fraction from wind will start to fall. This is because the load continues to grow, and that growth is met by another generation source—typically new coal plants. Also, if developers know that they will only need to pay the RPS penalty for one year, then they would rather do that than build more wind capacity. Therefore, specification of the RPS duration is critical.

Another issue is determining each state's exact penalty for RPS noncompliance. Several states impose "standard utility enforcement" mechanisms to enforce compliance, which makes it difficult to determine the future costs for noncompliance. As shown below, the penalty level directly impacts the level of compliance with the RPS.

A third issue is determining what fraction of the RPS will be met by wind. As discussed, WinDS does this exogenously, because the model does not currently handle biomass, geothermal, or other sources that could meet the RPS. Ideally, the state RPS guidelines would specify the breakdown between wind and other renewables in meeting the RPS.

The duration of the state-level PTC and ITC also is an issue. As with the federal PTC, the current status is often determined for a short period of time (in terms of the modeling horizon) and is often expected to be renewed. Nonetheless, WinDS assumes that the state-level credits expire at the time cited by current legislation.

Finally, the legislation is frequently changing. Between the time that this study was done and the AWEA conference, several states added one of these state incentives and several others (notably Arizona, Minnesota, New Jersey, and Wisconsin) made significant increases to their incentives. This frequent legislative changes and extensions can be good for wind, but are always difficult to predict and model.

Section 4: State-Level Incentives Results

Two scenarios were examined to determine the additional wind capacity due to state-level incentives. The first scenario is the base case, which includes the state-level incentive requirements. WinDS was also run with the base case assumptions but without the state-level incentive requirements of Tables 2 and 3. These two runs are shown in **Figure 8** by two blue lines (referencing the left y-axis), which resulted in just more than 250 GWs of wind capacity in 2050. A third blue line indicates the difference between these two runs (and references the right y-axis). This third line shows that the difference due to state incentives remains roughly 8 GWs after 2012. Thus much of the impact of state-level incentives occurs early on.

The second scenario determines the impact of state-level incentives if wind costs and performance did not improve with future research and development. These runs result in roughly 50 GWs of wind in 2050 and are shown by two red lines in **Figure 8**. This is a significantly lower value than the base case, as expected. However, this scenario still results in more wind capacity being present than in the AEO 2005 reference case, which is shown for comparison. By looking at the red delta line for "no technology improvements," one can see that the additional wind capacity due to state incentives continues to move upward, in excess of the base case delta, to a typical value of 12 GWs—and eventually up to almost 18 GWs. The lesser impact of state-incentives in the base case is because the incentives are not needed as much in the base case with its lower wind energy costs.

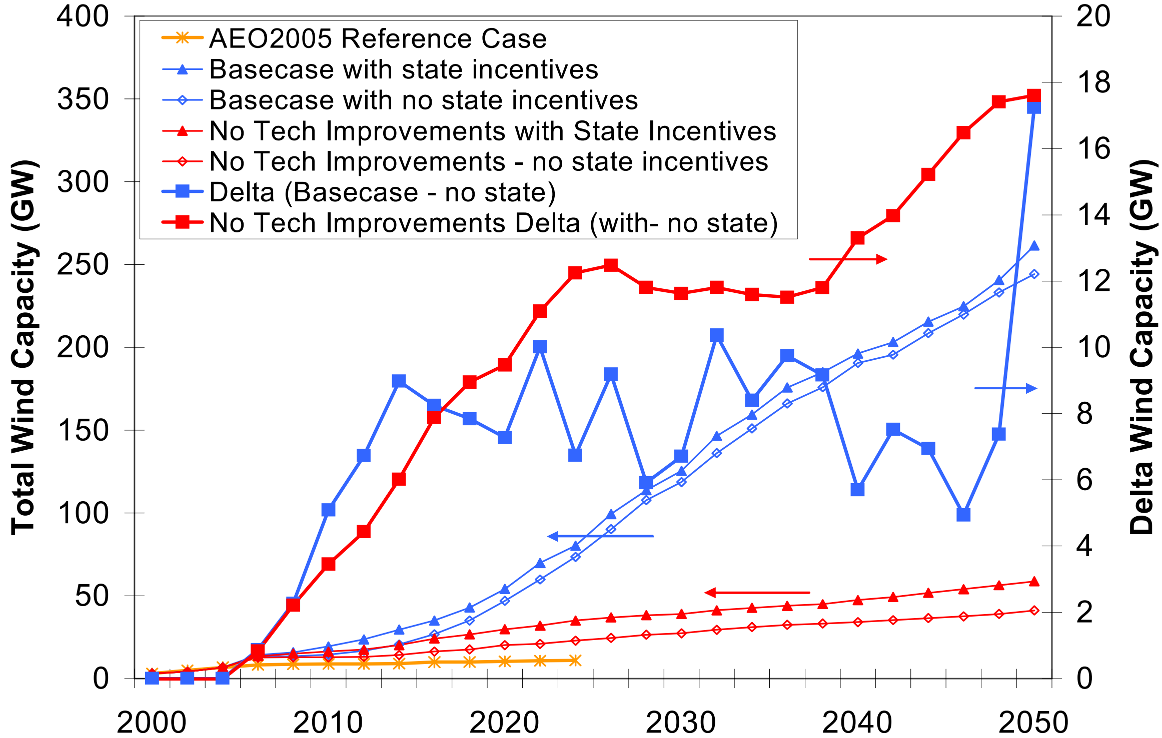

Figure 8. Wind Capacity With and Without State Incentives (with and without R&D improvements)

The next question to examine is whether the state incentives actually change the deployment pattern of the wind and its use. **Figures 9 and 10** examine the geographic location of wind-generation use. Both graphs compare the wind generation consumed in each region with state incentives and without state incentives, for the case without research and development improvements. If the region is red, that indicates that it consumes more wind energy generation with state incentives enacted. If the region is blue, then the region consumes more wind energy generation without the state incentives enacted. **Figure 9** does this for 2030, while **Figure 10** does this for 2050—both graphs are reflective of the state incentives. As expected, the regions that are red (more wind with incentives) are generally located in the states that have attractive incentives, e.g. Nevada (RPS 13%), New Mexico (PTC), Texas (mandate for wind). Continuing, other red states have RPS's including Illinois, Oregon, New Jersey, and New York.

Those regions that are blue are in states with no or less attractive incentives. These state with no/less attractive incentives can showmore use in the no-incentives case because it is no longer economic to ship the power to a nearby state that has good incentives in the base case. Instead, the power is used in the producing state. For example, without the state incentives in Nevada, more wind generation is used in California which is more economical. One might note that both California and Arizona have an RPS but neither is very large (3.4% in CA and .7% in AZ) and aren't driving the situation as much as the neighboring state provisions do.

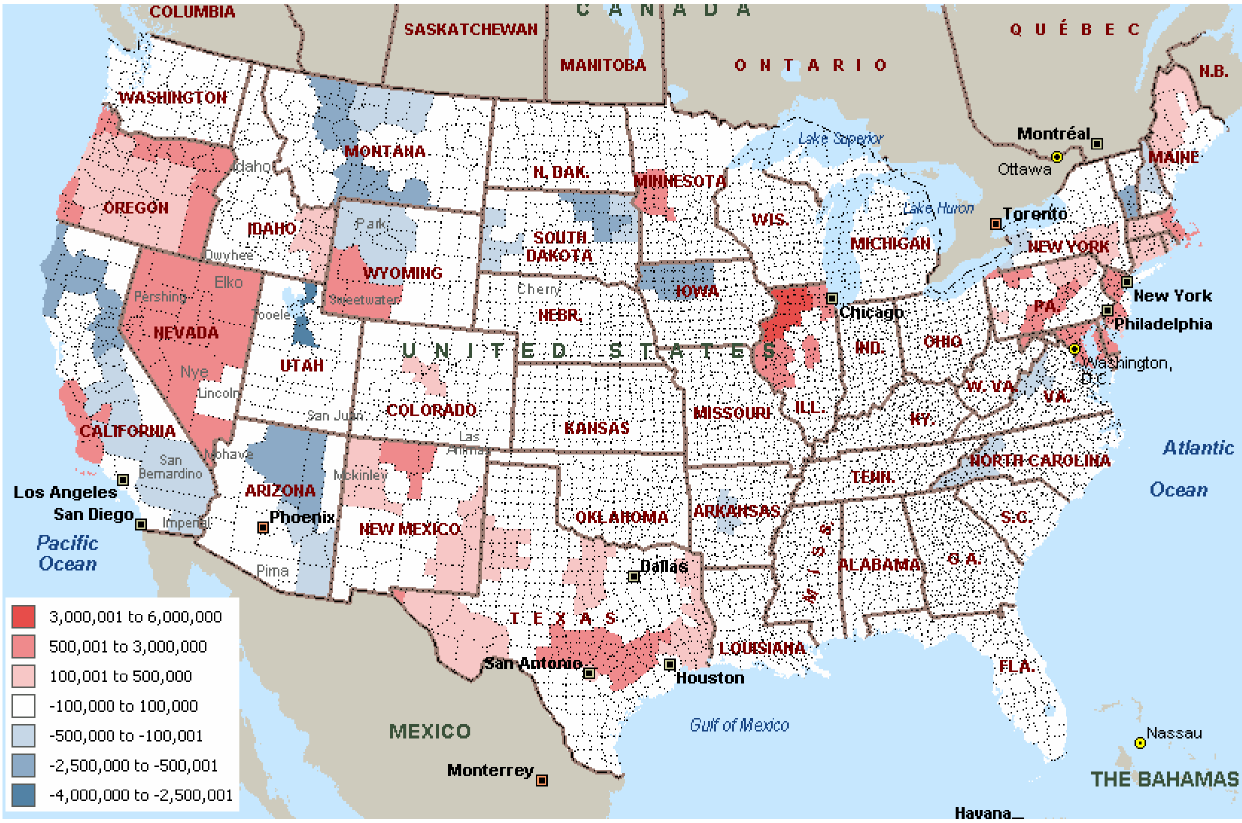

Figure 9. Delta Wind Consumed in 2030 (MWh) (normal state incentives - no state incentives)

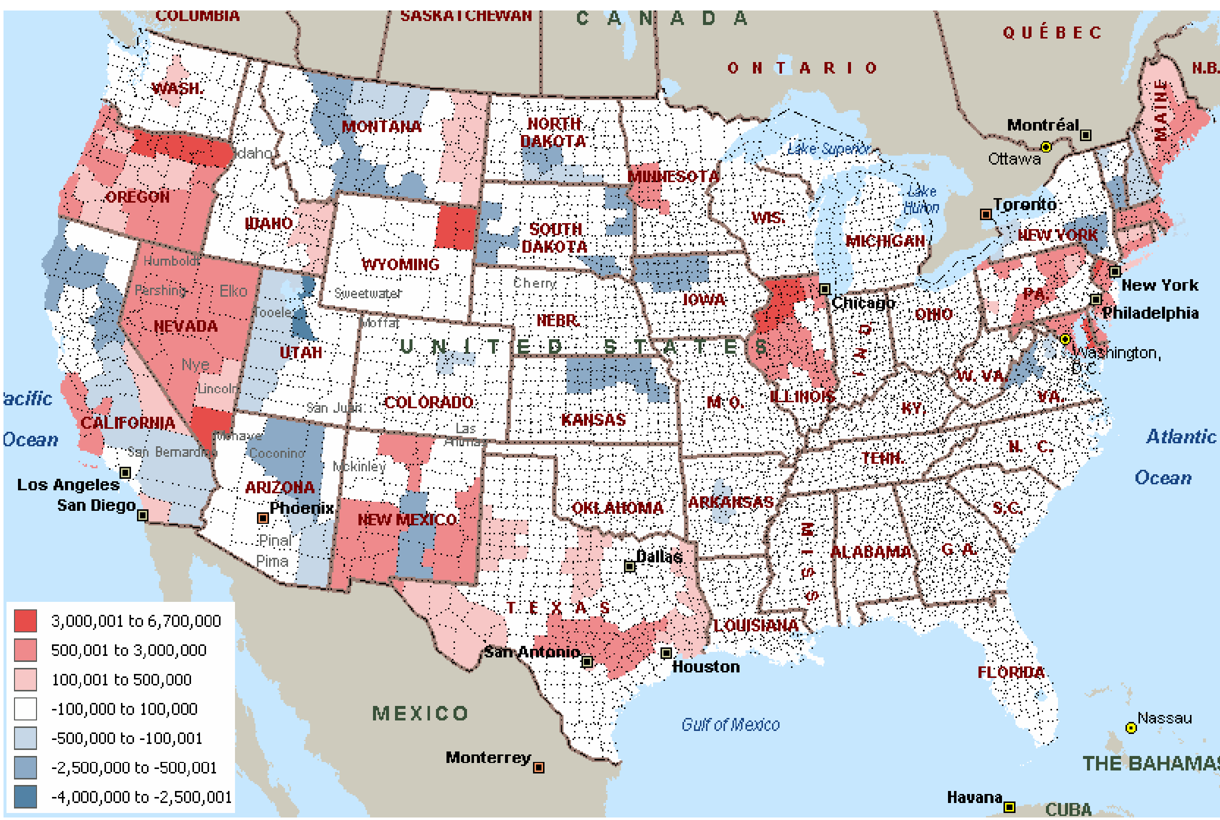

Figure 10. Delta Wind Consumed in 2050 (MWh) (normal state incentives - no state incentives)

The final question examined is the impact of the RPS penalty on the amount of additional wind added. The base case state incentives have two states with an RPS penalty of only $5/MWh, and seven states with a penalty of $10/MWh, which might be too low to enforce compliance. Therefore, a series of runs were done with varying levels of RPS penalty (applied to all states with an RPS as described above). As **Figure 11** shows, the increasing penalty levels significantly increase the amount of wind capacity added by the RPS. Note that this graph only extends to 2030 to examine the near-term impacts more easily. The base case level (the combination of all values in Table 2) has a trajectory between $5/MWh and $10/MWh. Once the parametrically imposed RPS penalty gets above $20/MWh, no additional wind capacity is added. Therefore, if the penalties for each state were increased to at least $20/MWH, on average, more wind capacity will be installed.

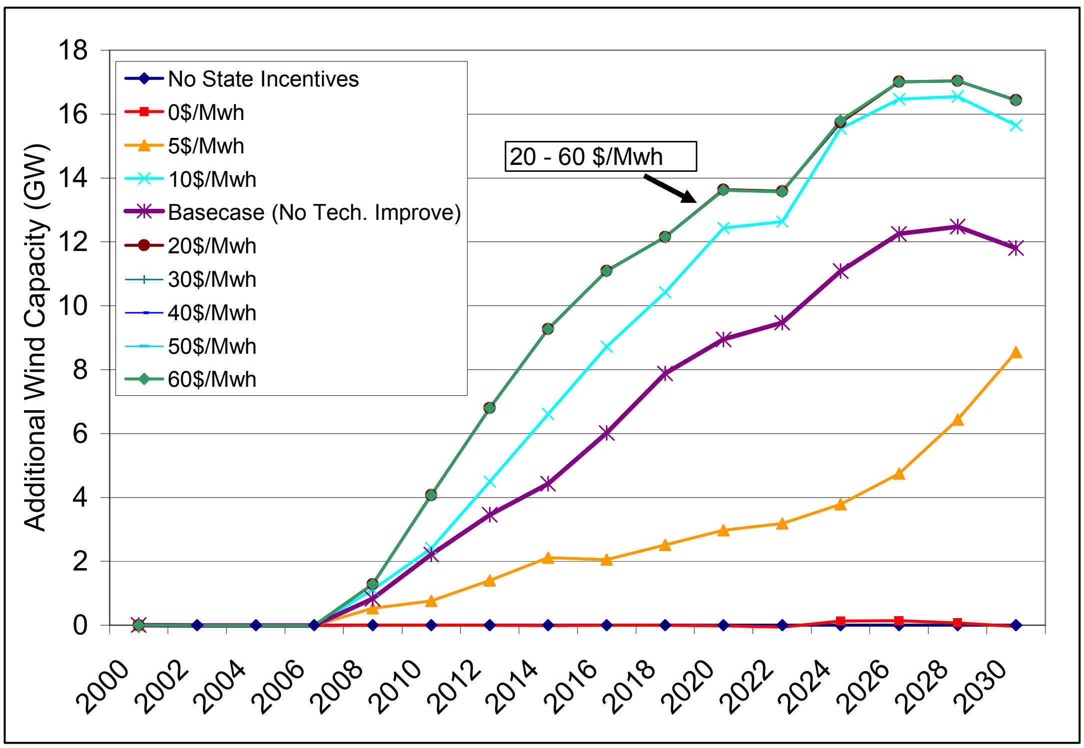

Figure 11. Increased Penalty Values vs. Additional Wind Capacity Due to state RPS Compliance

Section 5: Conclusions

- State-level incentives drive a significant fraction of the early growth in wind installations.
- In the second decade of the 21st century, current incentives most likely will not continue to be a primary factor in new wind growth. This is especially true if R&D leads to a better general economic position for wind through improved cost and performance. If wind technology fails to improve, then state incentives could continue to provide support to the wind industry.
- Enhanced incentives and the increase of incentives to new states could continue to spur wind energy growth. Additional RPS, PTC, and ITC legislation is being considered and

added to at this time. This new legislation and increased targets could significantly alter the results of this study.

- Higher penalty amounts and enforcement are critical to reaching expected RPS penetration levels. A penalty of at least $20/MWH in all states is required to achieve compliance with the amount desired by the RPS legislation.
- Continued work on including additional state-level incentives and updating existing incentives is necessary for more precise near-term analysis. The WinDS team will continue to update the state-level incentives within the model on a regular basis.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
This paper presents analysis conducted with the Wind Deployment System Model (WinDS) – a model of capacity expansion in the U.S. electric sector. With 358 regions covering the United States, detailed transmission system representation, and an explicit treatment of wind intermittency and ancillary services, WinDS is uniquely positioned to evaluate the market impacts of specific state-level policies. This paper provides analysis results regarding the impact of existing state-level policies designed to promote wind-capacity expansion, including state portfolio standards, mandates, and tax credits. The results show the amount of wind deployment due to current state-level incentives as well as examine their lasting impact on the national wind industry. For example, state-level mandates increase industry size and lower costs, which result in wind capacity increases in states without mandates and greater market growth even after the policies expire. Although these policies are enacted by individual states, the cumulative effect must be examined at a national level. Finally, this paper examines the impact on wind-capacity growth by increasing the penalty associated with the state-level renewable portfolio standards (RPS). The results show national and regional wind energy deployment and generation through 2050.

15. SUBJECT TERMS
Wind Deployment System Model; WinDS; wind; deployment; wind capacity; state policies; national energy policy; renewable portfolio standards; RPS; state portfolio standard; wind generation; Nate Blair, Walter Short; Paul Denholm; Donna Heimiller

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