WIND ENERGY DEVELOPMENT IN THE UNITED STATES: CAN STATE-LEVEL POLICIES PROMOTE EFFICIENT DEVELOPMENT OF WIND ENERGY CAPACITY?

A Thesis
submitted to the Faculty of the
Graduate School of Arts and Sciences
of Georgetown University
in partial fulfillment of the requirements for the
degree of
Master of Public Policy
in Public Policy

By

Blair S. Goldstein, B.A.

Washington, DC
April 14, 2011

Copyright 2011 by Blair S. Goldstein
All Rights Reserved

WIND ENERGY DEVELOPMENT IN THE UNITED STATES: CAN STATE-LEVEL POLICIES PROMOTE EFFICIENT DEVELOPMENT OF WIND ENERGY CAPACITY?

Blair S. Goldstein, B.A.

Thesis Advisor: J. Arnold Quinn, Ph.D.

ABSTRACT

In the absence of strong U.S. federal renewable energy policies, state governments have taken the lead in passing legislation to promote wind energy. Studies have shown that many of these policies, including Renewable Portfolio Standards (RPS), have aided in the development of wind energy capacity nationwide. This paper seeks to analyze whether these state-level policies have led to an efficient development of U.S. wind energy. For the purposes of this paper, wind energy development is considered efficient if competitive markets enable wind capacity to be built in the most cost effective manner, allowing states to trade wind energy between high wind potential states and low wind potential states. This concept is operationalized by analyzing how state policies that incentivize the in-state development of wind energy impact where wind capacity is developed. A multivariate regression model examining wind capacity in the 48 contiguous United States that had some wind capacity between 1999 and 2008 found these in-state policies are associated with increased wind capacity, controlling for states' wind potential. The results suggest that state-level policies are distorting where wind is developed. These findings support the enactment of a more comprehensive federal energy policy, such as a national RPS, a cap-and-trade program, or a targeted federal transmission policy. These federal policies could spur national markets that would result in the more efficient development of U.S. wind energy.

TABLE OF CONTENTS

INTRODUCTION

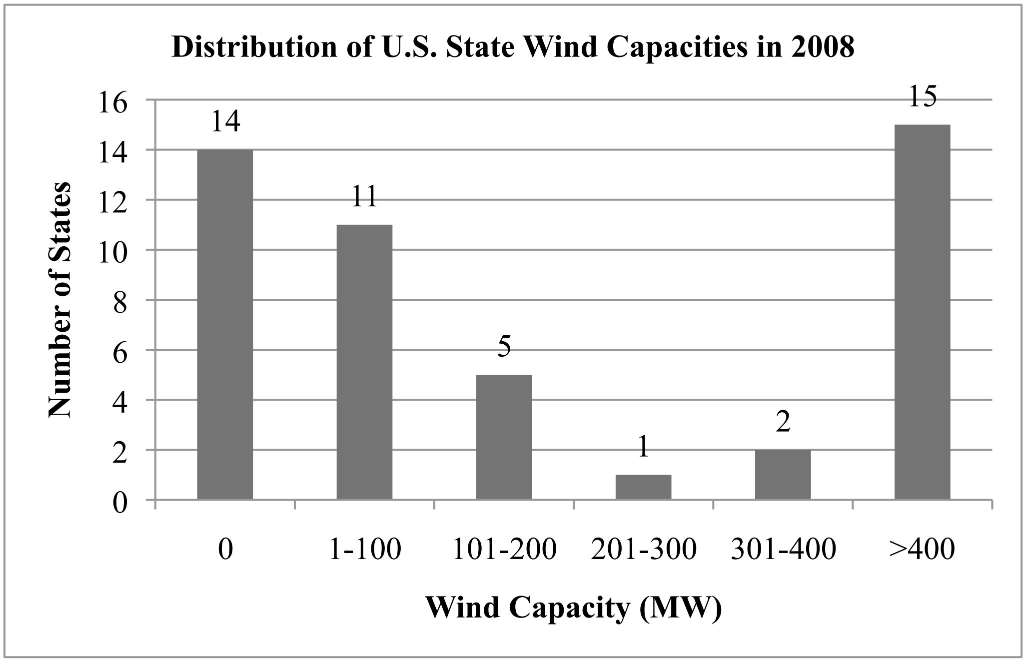
In the absence of an overarching United States federal renewable energy policy, state governments have adopted a range of policies to promote the development of wind energy. These policies have contributed to significant growth in wind energy capacity nationwide. Wind energy capacity in the U.S. is now more than 35,000 MW, the largest cumulative capacity in the world (U.S. Department of Energy 2010). Researchers have sought to explain which state-level policies are most effective at promoting wind energy development and which states are most likely to put these policies into place. Numerous studies have focused on state-level Renewable Portfolio Standards (RPS), which require a set portion of a state's retail electricity to come from renewable energy sources. Researchers expect wind energy development will benefit more from state-level RPS policies than any other renewable energy source (U.S. Department of Energy, 2007). Studies have shown that having a RPS is linked to increased wind energy capacity and that the impact of a state-level RPS is magnified when the RPS is mandatory and has a tight timeline for compliance (Adesoji 2010). Other studies have shown that states with relatively high levels of education, personal income, participation in environmental organizations, and Gross State Product are most likely to adopt this type of policy (Menz 2006; Ming-Yuan 2007).

This paper seeks to advance the discussion by analyzing whether these state-level policies have led to an efficient development of wind energy capacity in the U.S. For the purposes of this paper, wind energy development is considered efficient if competitive markets enable wind capacity to be built in the most cost effective manner, allowing states to trade wind energy between high wind potential states and low wind potential states. This concept is operationalized by analyzing how state policies that incentivize the in-state development of wind energy impact where wind capacity is developed. The results of this study will give insight into what role the federal government should play in creating national markets for wind energy. If state-by-state energy policies produce efficient outcomes, it would support the continued hands-off approach from the federal government. If, however, state-level policies do not produce efficient outcomes, it would suggest that a more comprehensive federal energy policy, such as a national RPS, a cap-and-trade program, or a targeted transmission policy could spur national markets that would result in the more efficient deployment of wind energy. This paper finds that in-state preference policies have a significant and substantial effect on where wind capacity is built in the U.S., suggesting the need for a unifying federal renewable energy policy.

BACKGROUND

During the time period 1999-2008, the average U.S. state wind capacity was 187.13 MW. However, wind development varied substantially from state to state, with a median capacity of 0.66 MW, a 25th percentile capacity of 0 MW, and 75th percentile capacity of 98.03 MW.[1] There were, for example, 14 states that had developed no wind capacity in this time period and 15 states with a wind capacity greater than 400 MW by 2008.

[1] In the sample used in this paper, the average wind capacity is 264.18 MW, the minimum capacity is 0 MW, and the maximum capacity is 7,112.67 MW.



States have the potential to develop substantially more wind energy capacity in coming years. According to the U.S. Department of Energy's National Renewable Energy Laboratory, the average state wind potential in the 48 contiguous United States is 217,894.7 MW.[2] Market forces alone have not taken advantage of this potential. The mix of electric generation fuels in the U.S. has not changed dramatically over time, with the exception of a trend toward natural gas. Coal remains the largest source of electric generation in the United States, comprising about 50% of total generation each year between 1999 and 2008.[3]

---

[2] The average wind potential in this sample is 306,934.4 MW

[3] The U.S. Energy Information Administration tracks total U.S. electricity generation by fuel

Table 1: Net Generation by Fuel in the U.S. (Thousand MWh / percent total generation)						
	2008	2006	2004	2002	2000	1998
Coal	1,985,801 (48.2%)	1,990,511 (49%)	1,978,301 (49.8%)	1,933,130 (50.1%)	1,966,265 (51.7%)	1,873,516084% (51.8%)
Natural Gas	882,981 (21.4%)	816,441 (20%)	710,100 (17.9%)	691,006 (17.9%)	601,038 (15.8%)	531,257 (14.7%)
Nuclear	806,208 (19.6%)	787,219 (19.4%)	788,528 (19.9%)	780,064 (20.2%)	753,893 (19.8%)	673,702 (18.6%)
Hydro	254,831 (6.2%)	289,246 (7.1%)	268,417 (6.8%)	264,329 (6.9%)	275,573 (7.2%)	323,336 (8.9%)
Wind	55,363 (1.3%)	26,589 (0.65%)	14,144 (0.36%)	10,354 (0.26%)	5,593 (0.15%)	3,026 (0.084%)
Total Energy	4,119,388	4,064,702	3,970,555	3,858,452	3,802,105	3,620,295
						Source: EIA

Renewable energy sources have struggled to compete with traditional fossil fuels, such as coal, because the comparative levelized costs are higher for renewable energy sources. Levelized costs capture the overall cost competiveness of a generating fuel, from building a generating plant to operating the plant. This includes the overnight capital cost; fuel cost; fixed and variable operating and maintenance costs; financing cost; and an assumed utilization rate for each plant type. As a result, federal and state governments have passed policies in an attempt to tilt this comparative advantage toward renewable fuels (Darmstatder 2003 and U.S. Energy Information Administration 2011). States cite several key reasons for incentivizing renewable energy development, including environmental and health benefits; green jobs; and diversification of the electricity sector.

The most significant federal renewable energy policy is the Federal Production Tax Credit. The tax credit provides a per-kWh incentive for renewable energy production, including wind energy, during the first decade of a project's operation. Congress has allowed the tax credit to lapse several times since it was first enacted in 1992. The latest changes to the tax credit were passed as part of the American Recovery and Reinvestment Act (ARRA) of 2009. ARRA extended the production tax credit for wind energy of 2.1 cents per-kWh through 2012. The act also gave wind facilities the option to turn down the production tax credit and elect the Federal Investment Tax Credit instead. The investment tax credit gives wind facilities installed between 2009 and 2012 a credit equal to 30% of the project's qualifying costs. Finally, ARRA allows wind projects that qualify for the investment tax credit to take advantage of a new Treasury Department program that gives a cash grant of equal value (U.S. Department of Energy 2009).

In the absence of a strong federal renewable energy policy, states have enacted state-by-state policies to promote renewable energy development. These policies have contributed to a surge in wind energy. U.S. wind capacity has increased from about 2,500 MW in 1999 to about 25,000 MW in 2008.[4] Popular state-level renewable energy policies include: mandatory green power options, public benefit funds, loans, tax incentives, and grants. One of the most common state-level policies is the RPS. As of 2008, 27 states and the District of Columbia had passed a mandatory RPS.[5] Another, five states had passed a voluntary RPS.[6] There is no standard RPS model. Instead, policies vary substantially. States require differing amounts of renewable energy

[4] The Department of Energy's Lawrence Berkeley Laboratory maintains information about national wind energy capacity. In 2009, U.S. wind capacity was about 35,000 MW.
[5] States with mandatory RPS in 2008 include: AZ, CA, CO, CT, DE, IA, IL, MA, MD, ME, MI, MN, MO, MT, NC, NH, NJ, NM, NV, NY, OH, OR, PA, RI, TX, WA, WI and DC
[6] States with voluntary RPS in 2008 include: ND, SD, UT, VA, and VT

generation, set different timelines for compliance, and allow different energy sources to contribute toward the renewable goal.

While some states allow renewable energy generated in any state or within the region to contribute toward the state RPS target, other states use the RPS policy to incentivize in-state energy development. For example, some states require a set portion of the renewable energy used to comply with the RPS to come from in-state sources. This includes Ohio, which requires 50% of the renewable resources to come from facilities located in the state. Other states incentivize in-state development though Renewable Energy Credit (REC) multipliers, which give additional weight to renewable energy generated within a state. A REC is a credit representing a unit of renewable energy generation that utilities can sell to help another facility meet its RPS target. For example, Colorado's RPS awards each MW of renewable energy generated outside the state 1 REC and each MW of renewable energy generated within Colorado 1.25 RECs. Other states, such as Texas, have strict guidelines regarding interstate transmission, which places a significant burden on out-of-state wind generators. Finally, some state-level RPS policies incentivize small, local energy production. Montana requires utilities to purchase 75 MW of nameplate capacity from community sources located within the state by 2015. States without an RPS have also adopted in-state preference policies. Vermont, for example, incentivizes the in-state development of wind through its Sustainability Priced Energy Enterprise Development Program. The program is not a renewable portfolio goal or standard.

In 1999, only Iowa and Texas had in-state preference policies. Iowa's Alterative Energy Production Law, for example, was passed in 1983 and required investor-based utilities to purchase 105 MW of in-state renewable generating capacity. The utilities used primarily wind energy to fulfill this obligation. However, by 2008 a total of 15 states had adopted policies to promote the development of renewable energy, including wind energy, within their borders. The last states in this time period to pass in-state preference policies were Michigan, Missouri, and Ohio.

Table 2: Year of State Enactment of In-State Preference Policies

State	**Year Instate Policy Adopted**
Arizona	2001
Colorado	2004
Delaware	2005
Iowa	1983
Illinois	2007
Michigan	2008
Missouri	2008
Montana	2005
North Carolina	2007
Nevada	2001
New York	2005
Ohio	2008
Oregon	2007
Texas	1999
Vermont	2005

Source: DSIRE
Includes information from 1983-2008

While the number of state-run programs is expanding, the Obama administration has also revived national interest in establishing a federal renewable energy policy. Since President Barack Obama took office, Congress and the administration have proposed a range of legislative and regulatory policies that could expand renewable energy development, while addressing policy goals about global warming, green jobs, and energy security. For example, Congress has considered policies such as cap-and-trade legislation and a national RPS while the U.S. Environmental Protection Agency (EPA) is moving forward with plans to regulate greenhouse gas emissions from stationary and mobile sources. These EPA policies incentivize the development of renewable energy sources, such as wind, which do not release greenhouse gas emissions. Obama also supports the adoption of a Clean Energy Standard, with the goal of obtaining 80% of U.S. electricity from renewable energy sources, nuclear power, clean coal, and natural gas by 2035 (Lehmann 2011).

However, the wind industry faces some unique hurdles to expansion. The Department of Energy laid out the key challenges in its 2008 report, “20% Wind Energy by 2030.” According to the report, the wind industry needs to improve wind turbine technology, expand markets to purchase wind energy, and increase access to transmission lines to deliver the energy. Access to transmission lines is particularly important since high wind areas are often located far from areas with high electricity demand (U.S. Department of Energy 2008). The wind industry is also facing price pressures. U.S. wind power prices rose in 2009. A Department of Energy review of wind projects built in 2009 found the capacity-weighted average 2009 sales price for bundled power and RECs was about $61 per-MWh. This is up from a 2008 average of about $51 per-MWh and 2002 average of $32 per-MWh.[7] Prices varied by region in 2009. The lowest prices, on average, were in Texas and the Heartland region while the highest prices were in New England, California, and the East. The impact of these higher prices was compounded by reductions in the wholesale electricity price of natural gas, a key competitor for wind energy. Wind was on the low end of wholesale electricity prices from 2003 through 2008. However, wind prices rose in 2009 as natural gas prices dropped. Natural gas prices are not expected to increase to pre-recession levels when the U.S. economy recovers (U.S. Department of Energy 2010). These challenges could slow wind energy development in coming years.

[7] Prices listed in 2009 dollars

LITERATURE REVIEW

The increasing number of state-level renewable energy policies has fueled a growing body of research into which states choose to enact these policies and how effective state-level policies are at promoting renewable energy development. Econometric studies have identified characteristics shared by states that have adopted a RPS, such as high levels of education. It is hypothesized that higher levels of education are positively correlated with knowledge of the negative impacts of burning fossil fuels, such as global warming. Studies have also found a link between RPS adoption and high Gross State Product and personal income. Studies hypothesize, for example, that as personal income rises, people's perceived costs of environmental regulations decreases. On a state level, higher Gross State Product is expected to give states more financial resources to implement environmental policies. Finally, studies have found that states with high participation in environmental organizations and states with Congressional representatives that tend to support environmental causes are also more likely to adopt environmental regulations, such as a RPS (Menz 2006; Ming-Yuan 2007). These trends suggest that the passage of state policies that incentivize renewable energy development, including wind energy, is tied to local political, social, and economic realities. These measures are not connected to whether renewable energy development in a given state is efficient from a national perspective, including whether the state has substantial wind potential or is located near electricity load centers.

I have also identified five papers that use econometric models to measure the effect of state-level policies on renewable energy development (Adelaja n.d; Adesoji 2010; Kneifel 2008; Menz 2006; Yin 2010). The papers analyzed the effectiveness of various policies, such as mandatory green power options, public benefit funds, loans, and grants. There was general consensus that mandatory green power options had a positive, significant effect on renewable energy development. These policies give utility customers the option of buying electricity that is generated by renewable energy sources. However, the papers came to differing conclusions about whether public benefit funds were statistically significantly associated with increased renewable energy development. Public benefit funds are set up by states to support energy efficiency and renewable energy projects. They are often paid for through charges on customers' monthly electricity bill or through contributions by the utilities.

In addition, the literature explores the impact of state-level RPS on the development of renewable energy. The five econometric papers all found that state-level RPS are positively associated with the development of renewable energy, including wind energy. A model by Adesoji et al., for example, found that the impact of a RPS was largest when the RPS was mandatory, had been in place for numerous years, and had a tight timeline for compliance (Adesoji 2010). However, these studies include RPS variables that have varying degrees of nuance, and therefore, reflect reality to varying degrees. A 2010 paper by Yin and Powers uses the most sophisticated model. The authors' construct a panel data model with a RPS variable that accounts for the amount of new renewable generation required by the RPS and whether the RPS targets can be met with the help of in-state or out-of-state RECs. The authors found that a RPS has a positive effect on the development of renewable energy capacity in a state. However, allowing the free trade of RECs with out-of-state utilities weakened the in-state impact (Yin 2010). These findings highlight the power of interstate trade to direct where renewable energy is developed. This is a similar concept to the one explored in this paper. The key difference is Yin and Powers analyze how trade can reduce the in-state development of renewable energy while this paper analyzes how in-state preference policies can increase the in-state development of renewable energy. These are different, but complementary, ideas. In addition, the Yin and Powers' paper considers policy impacts on all renewable energy development, not specifically wind power, and only considers the impact of a RPS model that allows the out-of-state sale of RECs. This paper takes a broader look at the impact of state-level policies and considers preference policies whether or not they are tied to a mandatory RPS or REC program.

In addition to the Yin and Powers paper, there is some qualitative research on the impact on out-of-state renewable energy production on a state's renewable energy development. Studies have cited anecdotal evidence about interstate interactions. For example, an article by Menz and Vachon noted that a 66 MW wind development was built in West Virginia to meet the demand for renewable energy in Pennsylvania, New Jersey, and Maryland (Menz 2006). A more comprehensive qualitative paper in the 2010 Connecticut Law Review explores market distortions that arise from geographic-based trade barriers in many state-level RPS policies. The author found that three-quarters of states with RPS policies erect regional or in-state restrictions of some kind. These include policies that directly address wind power development and policies that impact other renewable energy sources, such as solar power. The paper concludes that, "RPSs that favor in-state or in-region generation splinter the market and stunt trade. They limit renewables overall value by making them worth less in one jurisdiction than another…" (Davies 2010). This paper tests this hypothesis using multivariate regression analysis.

HYPOTHESIS AND CONCEPTUAL FRAMEWORK

The primary purpose of this paper is to test whether state-level policies promoting wind energy development are leading to an efficient development of U.S. wind capacity. My hypothesis is that state-level policies are not leading to efficient outcomes because each state is considering renewable energy development in its own political vacuum. This distortion could substantially impact how U.S. wind capacity is developed coming years. U.S. states still harbor large reserves of undeveloped wind energy capacity. U.S. wind capacity in 2009 in the 48 contiguous states was about 35,000 MW, while total wind potential was about 10,460,000 MW.

The development of wind energy in the U.S. is driven by a variety of factors, including: state and federal policies; economic conditions; and technological improvements in wind turbines. States cite several key reasons for adopting renewable energy policies. First, states point to environmental and health benefits. Unlike traditional, carbon-based fuels, renewable energy sources do not release greenhouse gas emissions that contribute to global warming. Nor do they release traditional air pollutants, such as particulate matter, that can lead to negative environmental and health outcomes. For example, California's RPS cites the need to "protect public health (and) improve environmental quality."[8] States have also pointed to the opportunity to create green jobs in their state, both through the building of new renewable energy projects and the service of these facilities. For example, a Colorado law cites the need to "attract new businesses and jobs (and) promote development of rural economies."[9] Finally, many states cite the need to contribute to the diversification of the electricity sector. States that can generate electricity from a variety of sources are less susceptible to changes in the price or supply of any one fuel source. It also adds to states' energy independence goals. For example, Maryland's RPS legislation says that the law recognizes the "fuel diversity and security benefits of renewable energy resources."[10]

[8] California Senate Bill 1078
[9] Colorado Section 40-2-124
[10] Maryland House Bill 1308

Academic supporters of renewable energy policies, such as RPS policies, cite similar benefits to the development of renewable energy sources. A 1999 article in *The Electricity Journal*, for example, lists six key benefits to developing renewable energy capacity. The benefits include "(1.) Environmental benefits, including greenhouse gas mitigation, from the displacement of additional fossil or nuclear generation; (2.) Price stability and reliability benefits from the existence of multiple and distributed fuel sources; (3.) Readiness benefits in case of a sudden fuel price spike or fuel supply disruption; (4.) Technology development benefits, including export potential; (5.) Long-run national energy-independence benefits; (and) (6.) Sustainable-energy-path benefits, including, conserving fossil resources for future generations (Haddad 1999).

On a national level, the Federal Production Tax Credit has played an important role in the development of renewable energy nationwide. The tax credit provides an inflation-adjusted per-kWh incentive for qualifying facilities during the first decade of operation. The credit has been set to expire and then renewed by Congress several times. Development has historically risen leading up to the years when the credit is set to expire, such as 1999, 2001, and 2003, and tapered off in years when the credit's future was uncertain. Other federal tax and financial incentives have also played an important, but less significant, role in wind development, such as the Renewable Energy Production Incentive. Created under the Energy Policy Act of 1992, the Renewable Energy Production Incentive awards a cash incentive to public utilities and cooperatives that do not qualify for the Federal Production Tax Credit. However its effectiveness has been compromised because it is subject to annual Congressional appropriations. This has led developers to question the reliability of the production incentive as a stable source of funding (Lori 2005).

Economic and technological changes have also impacted wind energy development. Wind energy capacity has increased as technological advancements in wind turbines allow more megawatts to be produced by each turbine. The average capacity of installed wind turbines has increased by 145% since 1998-1999, with the average capacity of turbines installed in the U.S. in 2009 at about 1.74 MW[11]. Older studies also cite the declining cost of wind projects as a catalyst for development (Lori 2005). But, in recent years, costs have risen. The average cost of wind power projects vacillated between $1,200 and $1,602 per kW from 1999 and 2006. But in 2009, the average cost rose to $2,122 per kW. Some studies note that there is an expectation that the cost of wind projects will decline again in the near future (U.S. Department of Energy 2010). Lastly, wind development can be hindered by lack of access to transmission lines. The expansion of these lines is important because high-wind areas are often located in remote areas, far from load centers (U.S. Department of Energy 2010).

DATA AND METHODS

The multivariate regression model used to analyze the efficiency of U.S. wind energy development is:

$$WINDCAPACITY_{IT} = \beta_0 + \beta_1*INSTATE_{IT} + \beta_2*INSTATElag_{IT} + \beta_3*INSTATElag2_{IT} + \beta_4*POTENTIAL_{I} + \beta_5*MANRPS_{IT} + \beta_6*VOLRPS_{IT} + \beta_7*MANPERCENT_{IT} + \beta_8*VOLPERCENT_{IT} + \beta_9*TAXCREDIT_{T} + \beta_{10}*REC_{IT} + \beta_{11}*GSP_{IT} + \beta_{12}*GREEN_{IT} + \beta_{13}*CONSUMPTION_{IT} + \beta_{14}*TURBINESIZE_{T} + \mu_{IT}$$

[11] Average turbine capacity in 2008 was 1.66 MW

Where:

Dependent Variable:

- **$WINDCAPACITY_{IT}$** is a measure of the cumulative state wind capacity in MW generated in a given year in a given state. This variable captures the growth in wind energy capacity over time. The data for this variable come from the Department of Energy.

Policy Variables:

- **$INSTATE_{IT}$** is a binary variable indicating whether a given state offered any incentive for in-state wind generation in a given year. The coefficient on this variable measures how much additional wind energy results from this in-state preference. The data for this variable come from DSIRE and the Union of Concerned Scientists.
- **$INSTATElag_{IT}$** is a binary variable indicating whether a given state offered any incentives for in-state wind generation in the previous year. The coefficient on this variable measures how much additional wind energy results from having this in-state preference in the previous year. The data for this variable come from DSIRE and the Union of Concerned Scientists.
- **$INSTATElag2_{IT}$** is a binary variable indicating whether a given state offered any incentives for in-state wind generation in the two years previous. The coefficient on this variable measures how much additional wind energy results from having this in-state

preference two years ago. The data for this variable come from DSIRE and the Union of Concerned Scientists.

Control Variables:

- **$POTENTIAL_I$** is a measure of a state's potential installed wind capacity in MW. These estimates take into account available windy land area, excluding lands that cannot be developed, such as land managed by the National Park Service. The data for this variable come from the Department of Energy.
- **$MANRPS_{IT}$** is a binary variable indicating whether a given state has a mandatory RPS in any given year. The coefficient on this variable measure how much additional wind energy results form having a mandatory RPS. The data for this variable come from DSIRE and the Union of Concerned Scientists.
- **$MANPERCENT_{IT}$** is a measure of the overall target percent for a mandatory RPS for a given state in any given year. The figure is a percent of retail sales that must be derived from eligible renewable energy sources. The coefficient on this variable shows much wind energy capacity is associated with each additional percentage point of renewable energy required by the mandatory RPS. The data for this variable come from DSIRE.[12]
- **$VOLRPS_{IT}$** is a binary variable indicating whether a given state has a voluntary RPS in any given year. The coefficient on this variable measures how much additional wind

[12] This is captures the absolute target percent for a given state. For example, Colorado's mandatory RPS target was set at 15% from 2004-2006. State law changed in 2007, increasing the target percent to 20%. Therefore, MANRPS for CO equals 15 from 2004-2006 and 20 from 2007-2008.

energy results from having a voluntary RPS. The data for this variable come from DSIRE and the Union of Concerned Scientists.

- **$VOLPERCENT_{IT}$** is a measure of the overall target percent for a voluntary RPS for a given state in any given year. The figure is a percent of retail sales that the state wants to generate from eligible renewable energy sources. The coefficient on this variable shows much wind energy capacity is associated with each additional percentage point of renewable energy set by the voluntary RPS. The data for this variable comes from DSIRE.
- **REC_{IT}** is a binary variable indicating whether a given state has a REC trading program in a given year. The coefficient on this variable shows how much additional wind energy capacity is associated with having a REC trading program. The data for this variable come from DSIRE.
- **$GREEN_{IT}$** is a binary variable indicating whether a utility in a given state offers green energy pricing for wind in any given year. The coefficient on this variable shows how much additional wind energy capacity is associated with having a green energy pricing program in a given state in a given year. The data for this variable come from the Department of Energy.
- **GSP_{IT}** is a measure of a state's Gross State Product for a given year. This variable controls for the varying incomes of each state. The data for this variable come from the U.S. Bureau of Economic Analysis.
- **$TAXCREDIT_{T}$** is a binary variable indicating whether the Federal Production Tax Credit was available for the entire given year. This coefficient on this variable shows how much

additional wind capacity is associated with the availability of the tax credit. The data for this variable come from DSIRE.

- **$\mathbf{CONSUMPTION_{IT}}$** is a measure of a state's combined commercial, industrial, and residential electricity consumption in MW for a given year. This controls for the size of state electricity demand. The data for this variable come from the U.S. Energy Information Administration.
- **$\mathbf{TURBINESIZE_{T}}$** is a measure of the average turbine size in MW in the U.S. in a given year. This captures the technological advances that have aided wind energy development. Turbine size is a cleaner measure tracking the development of the wind energy industry than wind power project costs. The costs of installed wind power projects have vacillated overtime, reflecting many external factors such as national economic conditions and availability of turbine components in the marketplace. The data for this variable come from the Department of Energy.

The paper analyzes state-level data from 1999-2008 for the 48 contiguous states. It only includes states that have some wind capacity during this time period.[13] Many of the states dropped from the sample have little or no wind potential. For example, Mississippi has no wind capacity and no wind potential, Delaware has no wind capacity and 9.5 MW of wind potential, and Florida has no wind capacity and 0.4 MW of wind potential. The remaining sample includes 11 states with in-state preference policies.[14] As descriptive statistics show, about 13% of the sample had an in-state preference policy during this time period and about 30% of the sample had a mandatory RPS policy.

[13] This includes all 48 contiguous states except AL, AZ, CT, DE, FL, GA, KY, LA, MD, MS, NC, NV, SC, and VA

[14] This includes CO, IA, IL, MI, MO, MT, NY, OH, OR, TX and VT

Table 3. Descriptive Statistics (1999-2008)					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
$WINDCAPACITY_I$	340	264.18	649.02	0	7,112.67
$INSTATE_{IT}$	340	0.13	0.34	0	1
$INSTATElag_{IT}$	340	0.1	0.30	0	1
$INSTATElag2_{IT}$	340	0.11	0.32	0	1
$POTENTIAL_I$	340	306,934.4	425,413.8	46.6	1,901,530
$MANRPS_{IT}$	340	0.30	0.46	0	1
$VOLRPS_{IT}$	340	0.082	0.28	0	1
$MANPERCENT_{IT}$	340	3.52	7.02	0	30
$VOLPERCENT_{IT}$	340	0.96	3.43	0	25
$TAXCREDIT_T$	340	0.7	0.46	0	1
REC_{IT}	340	0.23	0.42	0	1
GSP_{IT}	340	250,091.1	297,526	17,232	1,921,493
$GREEN_{IT}$	340	0.66	0.48	0	1
$CONSUMPTION_{IT}$	340	49,706.06	57,868.13	3,426.8	317,839.8
$TURBINESIZE_T$	340	1.3	0.33	0.71	1.66

* Table includes information on the 48 contiguous United States where wind capacity is greater than 0

There are several limitations to this dataset. First, there is no perfect variable to capture the key policy question, whether state policies are leading to an efficient development of U.S. wind energy capacity. Instead, the proxies $INSTATE_{IT}$, $INSTATElag_{IT}$, and $INSTATElag2_{IT}$ capture whether a state has policies in a given year that incentivize in-state wind generation. The coefficients on these variables measure how much additional wind energy results from this in-state preference. As a result, these variables can provide insight into whether state-level policies are creating inefficient outcomes by incentivizing states to develop in-state wind capacity regardless of wind potential. In this model, $INSTATE_{IT}$=1 if the state had any policy in a given year that incentivized the development of wind energy within state borders. Often these policies promote many different renewable energy sources, including wind energy. The majority of these policies were part of a state RPS, but several in-state preference policies were part of other renewable energy policies. The lagged versions of the $INSTATE_{IT}$ variable were also included to capture the impact of having the in-state incentive in the previous two years. This captures the multi-year impact of these policies.

This dataset also has some problems with incomplete data. Most of the variables have information for the time period 1999-2009. However, the variable $CONSUMPTION_{IT}$, which measures a state's electricity consumption in a given year, only has information for the time period 1999-2008. The Department of Energy is set to release 2009 consumption data in June 2011. As a result, the entire sample was reduced to 1999-2008 to accommodate this information.

Finally, there are omitted variables that have the potential to bias the coefficients in the model. For example, the model does not control for the distance between a wind development and a load center. This concept is difficult to control for because wind facilities may be located near many different load centers in several states. While I expect more wind to be developed in high-wind regions located near large load areas, it is unclear whether leaving out this variable positively or negatively biases the key variable of interest, $INSTATE_{IT}$. The model also does not control for whether neighboring states have a RPS that can be met with out-of-state wind energy. I expect states with neighbors that allow out-of-state generation to contribute to renewable energy goals to development more wind than states do not have these opportunities to sell wind energy. However, the model does control for whether a state offers a REC trading program, which should pick up some of this effect. Finally, the model does not have a variable that captures wind facilities' access to transmission in a given state in a given year. This concept is difficult to control for before wind facilities may rely on in-state and out-of-state transmission lines serving multiple load centers. However, transmission is key to wind development.

EMPIRICAL RESULTS AND POLICY ANALYSIS

Simple statistics suggest that in-state preference policies are impacting how wind energy is developing nationwide. As Table 4 shows, states with a policy promoting the in-state development of wind between 1999-2008 had more than 5 times as much wind energy capacity as states without these policies. However, this difference cannot be solely attributed to relative wind potentials among states. As Table 5 shows, states with in-state preference policies have less than 3 times as much wind potential, on average, compared to states without these policies.

Table 4: Relationship between In-State Preference Policies and State Wind Capacity

In-State Policy	**Wind Capacity**		
	Mean	Std. Deviation	Frequency
0	172.32	419.80	296
1	882.15	1,289.53	44
Total			340

Table includes information on the 48 contiguous United States where wind capacity is greater than 0 in 2008
Sources: DSIRE and Department of Energy

Table 5: Relationship between In-State Preference Policies and State Wind Potential

In-State Policy	**Wind Potential**		
	Mean	Std. Deviation	Frequency
0	246,168.70	326,794.52	296
1	715,721.73	705,477.83	44
Total			43

Table includes information on the 48 contiguous United States where wind capacity is greater than 0 in 2008
Sources: DSIRE and Department of Energy

Multivariate regression analysis isolates the impact of in-state preference policies on wind energy development, taking into consideration other key characteristics of the states.

Table 6: Regression Analysis

The Impact of In-State Wind Preference Policies on State Wind Capacity (1999-2008)

Variable	**Coefficient**	**Standard Error**	**p Value**
$INSTATE_{IT}$	-188.52	153.16	0.239
$INSTATElag_{IT}$	281.89	96.39	0.003**
$INSTATElag2_{IT}$	243.37	120.71	0.044*
$POTENTIAL_{I}$	0.000267	0.0000751	0***
$MANRPS_{IT}$	-245.46	213.92	0.251
$VOLRPS_{IT}$	1,204.21	818.14	0.141
$MANPERCENT_{IT}$	21.28	9.49	0.025*
$VOLPERCENT_{IT}$	-68.28	47.33	0.149
REC_{IT}	122.79	152.56	0.421
GSP_{IT}	0.000713	0.000238	0.003**
$TAXCREDIT_{T}$	49.63	20.90	0.018*
$CONSUMPTION_{IT}$	0.00405	0.000648	0.010**
$TURBINESIZE_{T}$	213.47	82.59	0***
n	340		
R Squared Within	0.2888		
R Squared Between	0.8320		
R Squared Overall	0.6058		
rho	0.176		

Notes: * p<0.05, **p<0.01, ***p<0.001
Includes data from the 48 contiguous states where wind capacity is greater than 0 during the 1999-2008 time period, this excludes: AL, AZ, CT, DE, FL, GA, KY, LA, MD, MS, NC, NV, SC, and VA
Includes robust standard errors
Sources: DSIRE, Union of Concerned Scientists, EIA, DOE, & BEA

In this model, INSTATE is negative and not statistically significant. However, the lagged versions of this variable, INSTATElag and INSTATElag2, are both positive and statistically significant. INSTATElag is statistically significant at the 99% confidence level and INSTATElag2 is statistically significant at the 95% confidence level. The positive significant coefficients on the lagged variables suggest that in-state preference policies are associated with an increase in a state's wind energy capacity. Specifically, the model shows that, all else equal, a state that passed an in-state preference policy in 2006 has an additional 344.74 MW of wind capacity in 2008, on average, compared to a state with no in-state preference policy. This is a substantial amount, since 344.74 MW is larger than the average MW capacity for states in this sample. It is also substantially larger than the capacity increase associated with the key federal policy, the Federal Production Tax Credit. All else equal, having the tax credit in a given year is associated, on average, with a 49.63 MW increase in state wind capacity. However, the negative coefficient on the variable INSTATE suggests that the impact of these in-state preference policies may fade over time. While there may be an initial increase in wind capacity when an in-state preference policy is proposed or passed, the impact does not last in perpetuity.

In addition, the coefficient on MANRPS is negative but not statistically significant. Unlike the wind energy literature, this suggests that having a mandatory RPS alone is not statistically significantly associated with more or less wind energy capacity in a given state. Although this is unexpected, the variable capturing the percent of renewable energy mandated by the RPS is positive and significant. It appears that the MANPERCENT variable is capturing the positive impact of having a mandatory RPS. According to the model, all else equal, an additional percentage point of mandatory renewable energy capacity required by a state RPS increases wind capacity by an average of 21.28 MW. The average mandatory RPS target in this sample is 3.52%, meaning a mandatory RPS is predicted to increase wind capacity, on average, by 74.90 MW. This is substantially smaller than the impact of in-state preference policies. Other statistically significant variables in the model include, wind potential, Gross State Product, electricity consumption, and turbine size. These finding are consistent with the wind energy literature.

The model uses robust standard errors to control for heteroskedasticity. A graph of the error terms shows the error variance increases as wind capacity increases. Normalizing the dependent variable by dividing by state electricity consumption or wind potential did not solve the problem. Normalizing wind capacity with total electricity consumption was likely unsuccessful because the variable picks up variations in electricity consumption from seasonal changes and economic activity, which are not controlled for in this model. Normalizing by wind potential was likely unsuccessful because all states have substantially more potential than capacity. Future researchers may try to normalize the dependent variable using a state's total electricity generation capacity in a given year. This variable would remove some of the complications associated with consumption variation over time.

These results suggest that state-level policies promoting the in-state development of wind energy have not led to the most efficient build out of wind energy capacity nationwide. Instead, wind energy is being driven by a patchwork of state-by-state policies. For example, South Dakota and Wyoming are both high wind potential states that, in the absence of state-level promotional policies, have not developed large wind energy capacities. By 2009, South Dakota had developed 0.035% of its 882,412.4 MW wind potential. Similarly, Wyoming has developed 0.20% of its 552,072.6 MW wind potential. Meanwhile, other states with in-state preference policies have developed a substantial portion of their relatively low wind potential. Oregon, for example, has developed 6.5% of its 27,100.3 MW wind potential, while West Virginia has developed 17.5% of its 1,883.2 MW potential. Some of these differences may be attributable to the state's distance to load centers. While South Dakota and Wyoming are relatively isolated, Oregon wind facilities can serve load centers within the state as well as California and Washington. Similarly, West Virginia is located near large cities on the East Coast.

There are several policies that the federal government could enact to improve efficiency, including the passage of a national RPS, a cap-and-trade program, or a targeted transmission policy. A national RPS would set a minimum national renewable energy capacity that would likely include wind energy. Since 1996, more than two-dozen federal RPS policies have been introduced in Congress. None of these proposals, including an amendment to the Energy Policy Act of 2005 or the RPS proposal in the 2009 Waxman-Markey bill, were successful (Davies 2010). If passed, a national RPS would create incentives for utility companies to increase their renewable energy capacity in the cheapest and most efficient way. This would lead to more wind energy development in states with high wind potential, particularly when wind is located near large electricity loads.

According to a qualitative study promoting a national RPS in the July 2010 edition of the Connecticut Law Review, the current state-by-state RPS structure does not create these incentives. Instead, utilities operating in states that incentivize in-state wind development face disincentives for establishing out-of-state trading partners. This is especially true when neighboring states do not have a mandatory RPS to generate a market for renewable energy (Davies 2010). As Table 6 shows, states with in-state preference policies boarder many states with either no RPS or a voluntary RPS. For example, Colorado borders four of these states: Nebraska, Wyoming, Utah, and Oklahoma. Colorado has developed more wind energy capacity than any of these four neighboring states, despite having substantially less wind potential than Nebraska, Wyoming, and Oklahoma.[15]

Table 7: Number of States with Either No RPS or a Voluntary RPS Bordering States with an In-State Wind Preference Policy	
State	Number of Neighboring States with Either No RPS or a Voluntary RPS
NY, VT	0
OR, MI	1
IA, IL	2
MT, OH, TX	3
CO	4
MO	5

Notes: Data are for 2008
Source: DSIRE
Includes states where wind capacity is greater than 0 in 2008

The federal government could also implement a cap-and-trade program to allow market forces to create efficient renewable energy development. A cap-and-trade program would set a limit for how much carbon dioxide each utility company could release. Companies that can reduce their emissions most efficiently will do so and then sell their excess emission credits to companies whose reductions are less cost effective. Companies located in high wind potential states would have an incentive to build wind energy capacity to replace high carbon energy sources, allowing them to meet their cap and possibly sell excess credits. This policy would allow states to continue to take a regional approach to renewable energy development, but based on what is efficient instead of what is incentivized at the state level. According a 2010 article in

15 Colorado had 1,067.65 MW of wind capacity in 2008 and 387,219.5 MW of wind potential, Nebraska had 116.88 MW of wind capacity in 2008 and 917,998.7 MW of wind potential, Oklahoma had 708.05 MW of wind capacity in 2008 and 516,822.1 MW of wind potential, Wyoming had 676.26 MW of wind capacity in 2008 and 552,072.6 MW of wind capacity, and Utah had 19.79 MW of wind capacity in 2008 and 13,103.7 MW of wind potential.

the Connecticut Law Review, "By adopting market unification for renewable credits, Congress can promote the stability of state regulation and encourage each state to take an ambitious approach to promoting renewables that is tailored to its regional situation" (Rossi 2010). Recent attempts to pass a cap-and-trade program were unsuccessful. The 2009 Waxman-Markey bill passed the House, but did not pass the Senate. The Senate's cap-and-trade bill, known as the Kerry-Boxer bill, was also unsuccessful.

Finally, the federal government could pass policies to support the expansion of transmission lines in high wind potential states to allow more of these states to develop their wind energy. Wind is often located in isolated areas, far from the cities and the industry that use the energy. Without new transmission lines, the energy produced by wind turbines has no way to be transported to these load centers. A study by the National Renewable Energy Laboratory found that it would cost about $93 billion[16] to expand transmission in the eastern two-thirds of the United States so that wind could supply 20%-30% of the country's electricity (U.S. Department of Energy 2011). Some utility companies have argued that these transmission costs are exasperated by state-level policies that require the in-state development of renewable energy. For example, the Illinois Commerce Commission has said that location-based requirements can increase the costs of siting new generation and building new transmission, since it may be cheaper to do so in states other than the one incentivized by state law (Federal Energy Regulatory Commission 2010a).

The federal government has begun to take proactive steps to address the transmission needs of new renewable energy sources. In December 2010, for example, the Federal Energy Regulatory Commission (FERC) passed two orders supporting transmission planning and

[16] Cost estimated in 2009 dollars

financing for renewable energy. FERC approved a transmission planning process plan by the California Independent System Operator Corporation. The plan is designed to support new transmission to allow the state to meet its 33% RPS and other public policy goals. Among other things, the plan created the category of policy-driven transmission facilities, which is transmission built to meet state and federal policy goals. It also set up a transmission planning process that encourages statewide participation and encourages competitive bidding for these policy-driven projects (Federal Energy Regulatory Commission 2010b). FERC also approved a plan by the Midwest Independent Transmission System Operatory, Inc., which serves states such as Illinois and Wisconsin in the Midwest. The plan created a new category of transmission projects known as Multi Value Projects and allowed for costs of these projects to be spread out to utilities across the region. The goal is to spur investment of new transmission, including transmission supporting new renewable energy generation (Federal Energy Regulatory Commission 2010a). However, no nationwide transmission policy supportive of renewable energy development has been passed.

Anecdotal evidence highlights how these political and financial hurdles can guide where utilities choose to development wind capacity. For example, Horizon Wind Energy LLC, which develops wind energy in the U.S. and operates about 3,300 MW of wind capacity, said state policies and access to transmission lines often guide where the company develops its wind projects. The company has invested in Minnesota, which has a mandatory RPS, and Iowa, which has a mandatory RPS and in-state preference policies, but not South Dakota, which has neither. According to Horizon's Vice President of Communications and Government Affairs, "South Dakota has significant wind potential, but there is limited demand and there is the challenge of transmission. So we have decided we're going to focus elsewhere" (Riveran 2011). The federal government can help change this calculus by investing in transmission lines and passing national policies to bring wind to market.

CONCLUSION

State-level renewable energy policies, such as RPS and in-state preference policies, have aided in the development of American wind energy capacity state-by-state. While this development has dramatically increased wind energy capacity in recent years, it lacks the efficiency of a unified, nationwide policy. Descriptive statistics and a multivariate regression model indicate that wind potential alone is not driving the development, but that in-state preference policies and RPS policies are impacting where new capacity is built. As a result, states with in-state preference policies and relatively low wind capacity, such as Colorado, have developed more wind capacity than their high-wind potential neighbors. These inefficiencies create a policy window for federal action. By creating a national market for renewable energy through a federal RPS or cap-and-trade program, utilities will have incentives to build new wind capacity in the most cost effective and efficient way. This development could be further aided if the federal government supports the creation of new transmission lines in high-wind potential states to bring this energy to market.

REFERENCES

Adelaja, Soji and Yahannes G. Hailu. n.d. Projected Impacts of Renewable Portfolio Standards on Wind Industry Development in Michigan. White Paper Prepared for the Office of the Governor State of Michigan, Land Policy Institute Michigan State University.

Adesoji Adelaja, Yohannes G. Hailu, Charles H. McKeown, and Ahadu T. Tekle. 2010. Effects of Renewable Energy Policies on Wind Industry Development in the US. *Journal of Natural Resources Policy Research* 2, no. 3 (July): 245-262.

Darmstatder, Joel. 2003. The Economic and Policy Setting of Renewable Energy: Where do Things Stand? Discussion Paper, Resources for the Future.

Davies, Lincoln L. 2010. Power Forward: The Argument for a National RPS. *Connecticut Law Review* 42, no.5 (July): 1339-1403.

Haddad, Brent M. and Paul Jefferiss. 1999. Forging Consensus on National Renewables Policy: The Renewable Portfolio Standard and the National Public Benefits Trust Fund. *The Electricity Journal* (March): 68-80.

Kneifel, Joshua. 2008. Effects of State Government Policies on Electricity Capacity from Non-Hydropower Renewable Sources. Masters Thesis, University of Florida.

Lehmann, Evan. 2011. Obama, Announcing Clean Energy Standard, Looks for a compromise. *E&E Publishing, LLC*, January 26.

Federal Energy Regulatory Commission. 2010. *Order Conditionally Accepting Tariff Revisions,* Docket No. ER10-1791-000, December 16.

Federal Energy Regulatory Commission. 2010. *Order Conditionally Accepting Tariff Revisions and Addressing Petition for Declaratory Order,* Docket Nos. ER10-1401-000, ER10-2191-000, EL10-76-000, December 16.

Lori Bird, Mark Bolinger, Troy Gagliano, Ryan Wiser, Matthew Brown, and Brian Parsons. 2005. Policies and market factors driving wind power development in the United States. *Energy Policy* 33: 1397-1407.

Menz, Fredric C. and Stephan Vachon. 2006. The effectiveness of different policy regimes for promoting wind power: Experiences from the states. *Energy Policy* 34: 1786-1796.

Ming-Yuan Huang, Janaki R.R. Alavalapati, Douglas R. Carter, Matthew H. Langholtz. 2007. Is the choice of renewable portfolio standards random? *Energy Policy* 35: 5571-5575.

Rivera, Corina. 2011. South Dakota pursues wind energy incentives, but transmission challenges persist. *SNL Financial*. March.

Rossi, Jim. 2010. The Limits of a National Renewable Portfolio Standard. *Connecticut Law Review* 42, no. 5 (July): 1425-1450.

U.S. Department of Energy. 2008. *20% Wind Energy by 2030:Increasing Wind Energy's Contribution to U.S. Electricity Supply*.

U.S. Department of Energy. National Renewable Energy Laboratory. 2010. *2009 Wind Technologies Market Report*, by Ryan Wiser and Mark Bolinger.

U.S. Department of Energy. National Renewable Energy Laboratory. 2011. *Eastern Wind Integration and Transmission Study: Executive Summary and Project Overview*, prepared by EnerNex Corporation.

U.S. Department of Energy. National Renewable Energy Laboratory. 2009. *PTC, ITC, or Cash Grant: An Analysis of Choices Facing Renewable Power Projects in the United States*, by Mark Bolinger, Ryan Wiser, Karlynn Cory, and Ted James.

U.S. Energy Information Administration. 2011. *Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011*.

Yin, Haitao and Nicholas Powers. 2010. Do state renewable portfolio standards promote in-state renewable generation? *Energy Policy* 38: 1140-1149.