EVALUATION OF RENEWABLE ENERGY POLICIES: THE DETERMINANTS OF WIND POWER ADOPTION UNDER A QUOTA OBLIGATION

by

Deanna Ratnikova

B.S. in Chemistry, Austin Peay State University, 2007

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This thesis was presented

by

Deanna Ratnikova

It was defended on

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and approved by

Martin Staniland, PhD, Professor

John Mendeloff, PhD, Professor

Nuno Themudo, PhD, Assistant Professor

Thesis Advisor: Martin Staniland, PhD, Professor

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Global energy use has expanded at unprecedented rates to keep up with the demands of growing economies and populations. Issues such as climate change mitigation, sustainable development, and energy security have complicated energy expansion, and countries worldwide are reevaluating their current sources of energy, where it comes from, and how much of it they utilize. Renewable energy (RE) technologies have emerged as the answer for many countries' energy problems satisfying the need for cleaner technology while still expanding energy supplies as a tool for further economic development. These new technologies, however, face significant market barriers that impede the uptake of new RE technologies and necessitate government intervention.

The research in the paper analyzes the impact of the quota obligation policy, more commonly called the renewable portfolio standard (RPS) in the United States (US), on the adoption of wind power. The first analysis in the paper observes past regulatory policies and applies what is learned from their implementation to the RPS. The manner in which electric utilities responded is also examined to determine how the utilities may respond to further regulatory mandates such as a federal RPS. The second analysis utilizes data from the 35 states with an RPS in estimating a structural model of wind power development which accounts for particular characteristics of the RPS target and other drivers of wind power development such as state economic and population factors. This research shows that several other factors play a key role in increasing wind capacity within US states in addition to the RPS. These factors include a state's wind energy potential, state GDP, and state population change. Additionally, it was found that there is a momentum effect associated with time since RPS adoption and that increases in wind energy prices do not negatively affect development in states with an RPS.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Energy use is expanding globally at unprecedented rates to keep up with the demands of a growing world population and continued economic growth. The International Energy Agency (IEA), for instance, estimates that primary energy demand will increase globally by 55 percent between 2005 and 2030, and during that same period in developing countries, where economies and population are expected to grow fastest, the demand is projected to grow by 74 percent (Avato and Coony 2008, xiii). This situation forces countries worldwide to reevaluate their current sources of energy and how much of it they utilize. Both technical and behavioral change is imminent as the world faces the fact that no known energy source is free of significant limitations, liabilities, or uncertainties in relation to international economic, environmental, and security objectives (Holdren 2006, 4).

This paper focuses on the role of renewable energy policies, in particular the renewable portfolio standard (RPS), on wind power adoption in the United States (US). Under a two-stage research design, past regulatory policies are first observed, as well as how electric utilities responded to these policies. Second, utilizing newly generated and other publicly available data, a quantitative analysis of wind power adoption in US states is conducted using regression analysis.

1.1 RENEWABLE ENERGY AS AN ANSWER

Several issues are currently at the forefront of politics—economic growth, sustainable international development, climate change, and national and international security. These top issues illustrate the complex, evolving, and interconnected nature of the economic, environmental, and security aims that the 21st century energy strategy must serve (Holdren 2006, 3). Many answers to the current energy situation and its diverse goals point to new and improved clean energy technologies. Renewable energy (RE) technologies are among the most popular of this broad set of clean energy technologies.

Although definitions of RE electricity vary, it is widely accepted that RE technologies include any electricity produced from a renewable fuel source such as sunlight, wind, geothermal heat, wave or tidal energy, running water and organic matter (Berry and Jaccard 2001, 263). These fuels are more commonly associated with a certain technology such as photovoltaic cells or wind turbines. RE technologies enable shifts in the trajectory of the energy sector in many different ways, allowing it to deliver improved services, to become more efficient, and to respond to environmental concerns such as air pollution and climate change (Sagar and van der Zwaan 2006, 2601). They usually have significantly lower social and environmental impacts and risks when compared to electricity derived from non-renewable fossil fuels such as fewer smog-contributing emissions and reduced emissions of greenhouse gases (Berry and Jaccard 2001, 264). Furthermore, many of these technologies will improve energy access and energy systems reliability and reduce the impact of high and volatile energy prices and disruptions in individual fuel supplies (Avato and Coony 2008, xiii-xiv). Renewable electricity also has the potential to enhance energy security by increasing supply diversity and increasing the use of indigenous fuels or technologies. RE supports economic development through higher labor intensity, reduced payments on imported fuels, and new opportunities for local technologies or expertise (Berry and Jaccard 2001, 264).

Despite these benefits, RE sources are, on average, more expensive than conventional electricity sources when compared on a financial cost basis, and because of this, electricity producers have concentrated their investment on conventional technologies. New RE technologies, therefore, even after their technical feasibility has been demonstrated, face a number of barriers such as cost, infrastructure needs, slow capital stock turnover, market organization, and information and financing constraints (Sagar and van der Zwaan 2006, 2603-2604). All of these barriers can impede or constrain the uptake of new technologies and imply a need for government intervention, insofar as policies and regulations can create incentives for and eliminate barriers to the effective acquisition, absorption, and deployment of technology (Gallagher, Holdren, Sagar 2006, 206). Given the tendency of market investment to focus on the financial dimension, governments have developed an array of policies to improve the financial situation of RE technologies. This paper will evaluate one particular policy, the quota obligation, designed to benefit RE technologies.

1.2 THESIS OVERVIEW

The thesis begins with a discussion of the quota obligation policy, more commonly called the RPS in the US, and its different design features. A review of the various RPS policies adopted in US states will follow. Wind power development in the US is then observed. The third section of the paper outlines the two-stage research design including a literature review of previous research on determinants of wind power adoption and methodology. In the first stage of the research, past regulatory policies are observed, as well as how electric public utilities responded to these policies. The regression analysis follows with data description, descriptive statistics, and results. The paper is rounded out with a conclusion and discussion of the policy implications based on the research results.

2.0 BACKGROUND

2.1 RENEWABLE PORTFOLIO STANDARDS

The quota obligation, commonly called the RPS in the US, is a policy that sets a percentage or designated amount of electricity capacity that must come from eligible RE sources, usually by a specified date. Electric utilities or other retail electric providers must provide this set amount of green electricity for which, in most cases, they receive renewable energy credits (RECs) that can, in some designs, be traded or sold for extra income. Electric generators or suppliers can acquire RECs by constructing and operating RE facilities or, alternatively, they can purchase RECs from others. At the end of the target period(s), electricity generators or suppliers must demonstrate that they are in compliance in order to avoid paying a penalty. The regulatory agent behind the RPS determines compliance based on actual renewable electricity contracts, or if RECs are used, compliance is demonstrated through the ownership of credits.

The RPS is quickly emerging as a popular mechanism among US state policymakers to increase the penetration of RE in the electricity supply mix. Historically, regulatory agencies and state legislatures have been the driving force behind RPS policy formulation, but some policies have been adopted through citizen ballot initiatives (Cory and Swezey 2007, 1). This approach, also known as a cap-and-trade if RECs are used, creates a competitive market for RECs because RE generators will compete for market share by searching for innovative technologies and cost reduction strategies (Huang et al 2007, 5572). The RPS applies to all competitors equally and it relies on the free market to ensure that RE is developed in the most economical way. Furthermore, the RECs built within the RPS scheme encourage the most cost-effective compliance (Swisher and Porter 2006, 190). In summary, there are three main reasons for its growing popularity: (1) an RPS maintains continuous incentives for RE producers to seek cost reductions and can be designed to ensure these reductions are passed on to consumers, (2) because an RPS ensures the attainment of a specific market share, it can be directly linked to policy targets such as CO_2 reduction, and (3) an RPS minimizes government involvement relative to other measures as the government's budget need not be involved and the selection of winning bids is made by market forces rather than government evaluation (Berry and Jaccard 2001, 265).

2.1.1 RPS Design

No RPS policy is designed exactly the same. It is thus important to understand the major components of this policy and the ways in which each RPS can differ. Three main design features are discussed in detail in this section: the target, eligible resources, and administration.

First, the RPS target can be mandatory or voluntary. In the case of US states with an RPS, 30 states have a mandatory target, while five states have voluntary goals. Second, the target may apply to energy production or installed capacity. Installed capacity is considered easier to verify instead of production, but energy production is more correlated with the desired environmental benefits and provides an incentive to maximize the production from individual projects (Berry and Jaccard 2001, 267). Third, and one of the most obvious design factors, is the size of the target in terms of a percentage or designated amount. Choosing the target size depends in part upon the local cost and availability of different RE sources and the price of other energy supplies, and ideally, it should be large enough to move the industry towards the environmental objective but not so large that it causes significant increases in electricity prices (Berry and Jaccard 2001, 266). In addition to the size, the RPS target must also identify timing specifics as lead time may be necessary to permit cost-effective responses.

Two of the more complicated elements of the RPS target design are whether there should be multiple targets and how, if at all, the target should be adjusted. As will be discussed in a later section, many US states are revising their RPS policies to include multiple/separate targets for different types of RE sources. The first approach to the RPS is to set a target for all RE sources, but the second and increasingly popular approach is to set separate targets for different classes of RE sources. For example, New York has a two-tiered approach with a Main Tier and a Customer-Sited Tier. Resources eligible for New York's Main Tier include forms of biomass, liquid biofuels, fuel cells, solar PV, and hydroelectric, ocean, tidal, and wind power, while resources eligible for the Customer-Sited Tier include fuel cells, solar PV, wind turbines, and methane digesters (DSIRE 2009). The idea behind this new approach is to increase support for currently higher-cost technologies and achieve greater energy supply diversity. As will be shown later, grouping RE together without identifying the still expensive RE technologies leads to the advancement of the least-cost options and works to the disadvantage of the other RE technologies. It is important to note that both approaches enhance environmental objectives, but they differ in the overall up-front costs required.

The last issue with RPS target design is target adjustment. When enacting a mandatory RPS, there is always the possibility of increasing the electricity price, especially if the target is set too high. To counteract this risk, RPS policies can include a cost cap on RE sources which would effectively adjust the target. It should be noted, however, that changes to the target after enactment could jeopardize the credibility and predictability of the policy.

The second main design feature is the resources deemed eligible for meeting the target. The RPS must specify the eligible resources. This depends in part upon the objectives of the policy and the local viability of different types of resources as different RE sources will have variable costs and benefits (Berry and Jaccard 2001, 267). While some RPSs limit the eligible resources to RE sources of electricity in the strictest sense, others allow for energy efficiency components which may include fossil fuel-based cogeneration or fuel cells. A second issue with resource eligibility is whether to allow existing and/or new investments to count towards the target. Third, eligible resources must address whether all sources are accepted or only grid-connected sources. The simplest approach is to focus on the grid-transmitted market share of RE, but it is argued that the environmental objectives of an RPS are equally served by the development of RE anywhere, including off-grid (Berry and Jaccard 2001, 267).

The third main design feature is administration of the policy. First, there must be some sort of certification of the RE sources. This could be accomplished through the grid operator or the government agency responsible for administering the RPS. Second, administrators must conduct compliance monitoring and, if the policy calls for it, administer non-compliance penalties. Once again, this duty could be accomplished through the grid operator or the government agency responsible. This process is complicated if non-grid production is considered an eligible resource. If this is the case, an additional entity may be required in order to verify compliance. Non-compliance penalties are usually handled by the government agency responsible for the RPS but could be administered by the grid operator or another entity (Berry and Jaccard 2001, 268).

2.1.2 RPS Policies in the United States[i]

As of January 2010, mandatory RPS schemes exist in 30 states (including the District of Columbia) and five states have non-binding goals. Figure 1 presents a timeline of RPS policy enactment in the US. It is important to note that many states have revised their policies since the date of their first RPS enactment. Tables 1 and 2 reflect the most recent provisions of each state's policy.

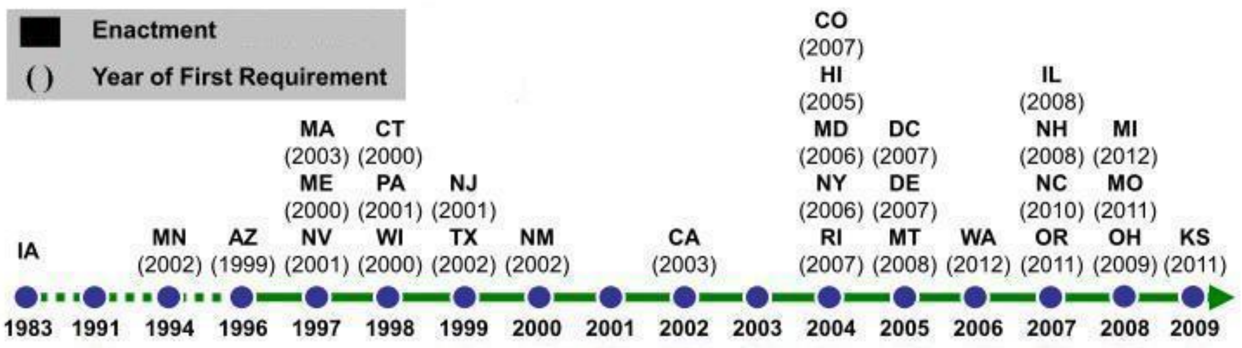


Figure 1. Timeline of US State RPS Policy Enactment

The variable compliance targets are shown in Tables 1 and 2. Note that IOU stands for investor-owned utility. If IOU is listed next to a target, this indicates that the mandatory goal listed applies only to these utilities.

Table 1. Select Elements of State Mandatory RPS Policies

State	Current Final Target	State	Current Final Target
Arizona	15% by 2025	Missouri	15% by 2021
California	33% by 2020	Montana	15% by 2015
Colorado	20% by 2020 (IOU)	Nevada	25% by 2025
Connecticut	23% by 2020	New Hampshire	23.8% by 2025
Delaware	20% by 2019	New Jersey	22.5% by 2021
District of Columbia	20% by 2022	New Mexico	20% by 2020 (IOU)
Hawaii	40% by 2030	New York	24% by 2013
Illinois	25% by 2525	North Carolina	12.5% by 2021 (IOU)
Iowa	105 MW by 1999	Ohio	12.5% by 2024
Kansas	20% by 2020	Oregon	25% by 2025 (Large utilities)
Maine	40% by 2017	Pennsylvania	8.5% by 2020
Maryland	20% by 2022	Rhode Island	16% by 2019
Massachusetts	11.1% by 2009	Texas	5880 MW by 2015
Michigan	10% by 2015	Washington	15% by 2020
Minnesota	25% by 2025	Wisconsin	10% by 2015

Table 2. Select Elements of State Non-Binding Goals

State	Current Final Target
North Dakota	10% by 2015
South Dakota	10% by 2015
Utah	20% by 2025
Vermont	20% by 2017
Virginia	15% by 2025

Of the more than 9,000 megawatts (MW) of new non-hydro RE capacity that has come on line in states with an RPS from 1998 through 2008, nearly all added capacity has come from wind power, with biomass, solar, and geothermal playing lesser roles (Wiser and Barbose 2009). Figure 2 illustrates the actual breakdown of RE capacity additions brought on line by RPS policies.

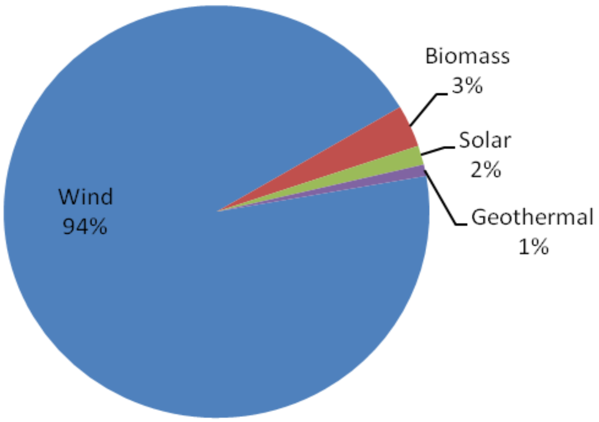


Figure 2. Total RPS-Motivated Capacity Additions from 1998-2008

As anticipated by the design of the policy, experience shows that the RPS promotes mainly the lowest-cost technology—which, in the US case, is wind power. In response to technology diversity issues, states have begun to design their policies so as to provide differential support to the currently higher-cost RE technologies. The three most popular solutions are technology tiers, set-asides, and credit multipliers. Table 3 shows the state application of these three main solutions to address technology diversity.

Table 3. Current Technology Diversity Policies in US States with an RPS or Non-Binding Goal

State	Technology Tier	Set-Aside	Credit Multiplier
Arizona	●	●	
Colorado	●	●	●
Connecticut	●		
Delaware	●	●	●
District of Columbia	●	●	●
Illinois	●	●	
Kansas			●
Maine	●		●
Maryland	●	●	●
Massachusetts	●	●	
Minnesota	●		
Missouri	●	●	●
Montana	●		
Nevada	●	●	●
New Hampshire	●	●	
New Jersey	●	●	
New Mexico	●	●	
New York	●		
North Carolina	●	●	
Ohio	●	●	
Oregon	●	●	●
Pennsylvania	●	●	
Texas	●		●
Utah			●
Virginia			●
Washington			●
TOTAL	22	16	13

Several states have established technology tiers as a method of increasing RE technology diversity. Technology tiers consist of different targets for different resources, usually with varied schedules and compliance rules. A technology tier carves out a portion of the RPS obligation for a subset of eligible technologies (EPA 2006, 5-9). The most common technology tier approaches include: (1) general resource tiers which classify technologies as class I or II, (2) specific resource tiers which focus on a particular RE source, and (3) specific application tiers which work towards customer-sited distributed generation (DG) or community and small-scale goals. Tiers may also exist for technologies that are either new or existing.

Some support for technology diversity is provided through set-asides in which a fraction of the RPS must be met with certain technologies. In most cases, target periods are the same as those of the overall RPS goal. Specific resource and specific application technology tiers are sometimes considered the same or very similar policies as set-asides.

Finally, technology diversity is also supported through credit multipliers in which certain technologies provide more than 1 MWh of RECs for each MWh of generation towards meeting the RPS targets. The multipliers may also be used to encourage in-state development. Because they grant additional credit, credit multipliers increase the economic incentive for developers to install the specified technology (EPA 2006, 5-9).

2.2 WIND POWER IN THE UNITED STATES

Worldwide, wind energy has been one of the fastest growing forms of renewable energy in the past decade. In just the US, wind-powered electricity has emerged as the fastest growing source of electricity. The commercial development of grid-connected wind generators started after the oil price crises in the 1970s with assistance later in that decade from the Public Utility Regulatory Policies Act of 1978 (PURPA)—a policy that will be discussed in depth later in this paper. In the early 1980s, most commercial wind turbines were assembled using a variety of standard components; only blades and control systems were specially tailored for the wind turbine industry (IEA 2004, 80). With increasing market volume, however, a larger number of specialized suppliers, including larger companies, are providing tailored components (IEA 2004, 80).

From 1990 to 2009, installed wind capacity in the US increased from 1,525 MW to 34,863 MW (American Wind Energy Association 2004 and US DOE 2009). From 1990 to 2003, electricity generated from US wind sources increased by 282 percent, while electricity generated from other RE sources decreased by 3.2 percent and generation from conventional sources (fossil fuels and nuclear power) increased by 30.2 percent (US DOE 2004). As of 2009, wind capacity existed in 36 states, ranging from negligible amounts in several states (Alaska, Massachusetts, New Jersey, Ohio, Rhode Island, and Vermont) to 2,798 MW in California, 3,604 MW in Iowa, and 9,403 in Texas (US DOE 2009). A map illustrating current total installed wind capacity levels for all US states is included in the appendix.

In high wind areas, wind power is competitive with other forms of electricity generation (IEA 2002, 57). The cost of wind-produced electricity has declined sharply as wind power technology has developed over the decades (IEA 1997, 36). These trends have been driven by environmental concerns, the rising price of natural gas, and the rapidly falling production costs for electricity generated from wind turbines that have made it cost competitive with thermoelectric generation (Bohn and Lant 2009, 88). Prices for wind-produced electricity decreased from over $61/MWh in 1999 to under $35 in 2005 as the mean capacity of installed turbines doubled from 0.7 to 1.4 MW and operation and maintenance costs declined (Wiser and Bolinger 2007). Recently, prices have risen slightly, however, due to increasing demand and an increased prices for turbines, most of which are produced in Denmark (Heiman and Solomon 2004), and possibly because most production efficiency improvements with the current technology have been captured. A 2007 Department of Energy study by Wiser and Bolinger also found that wind turbine prices have been rising recently due largely to demand outpacing supply.

Potential wind energy production in the US is large as the Great Plains region alone has the potential to produce twice the current national electricity demands (Swisher, Real de Azua, and Clendenin 2001). Wind potential is also significant offshore in the Pacific Northwest, and the Mid-Atlantic coastline has a generation potential of 330,000 MW compared to the region's current electricity use, which is estimated at 73,000 MW (Bryant 2007).

It should also be noted that success with wind power in the US has been frequently tied to the federal production tax credit (PTC). An incentive within the Energy Policy Act (EPAct) of 1992, the PTC allows a business with taxable income to claim a tax credit for every kilowatt hour (kWh) of generation for the first 10 years of a project's operation (Swisher and Porter 2006, 188). Referring to Figure 3, the US experienced drastic decreases in annual wind installations three times within the past ten years—each decrease correlating to the expiration of the PTC. In recent years, however, many are attributing increases in wind installations to the rise in the number of RPS policies adopted by US states. The literature suggesting this correlation between RPSs and wind power adoption will be reviewed in the next section and will be a research focus in this paper.

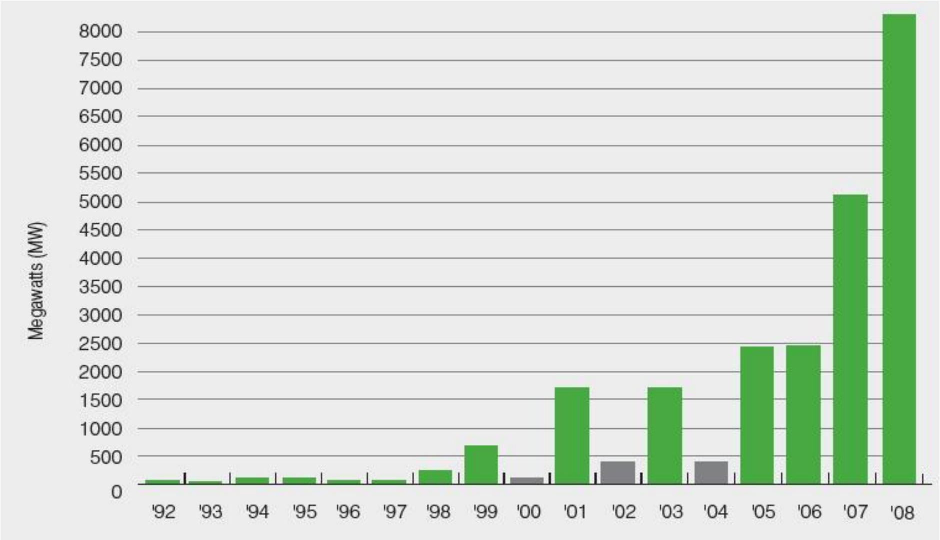


Figure 3. Annual Installed US Wind Power Capacity (American Wind Energy Association 2009)

3.0 RESEARCH DESIGN

Although RPS policies began in earnest in the late 1990s, it took several years for literature to start recognizing the impact of an RPS on wind power growth. In a 2003 National Renewable Energy Laboratory publication, Bird et al. found RPSs to be the most important driving force behind US wind power development, and in a 2005 presentation to the National Wind Coordinating Committee, Ryan Wiser calculated that state RPS policies were responsible for 47 percent of US wind development from 2001 to 2004. Most recently in 2007, Wiser and Bolinger estimated that between the years 2001-2006 approximately 50 percent of the wind power capacity built in the US was motivated to some extent by state RPSs. Now, nearly all studies on wind power development recognize RPS policies as a major driving force behind this development.

Most of the research that has addressed this topic consists of studies that identify factors that drive development of wind and/or other RE sources. In 2002, Gouchoe et al. examined 10 state financial incentive programs in six states using a case-study approach to determine the main factors that influence their effectiveness at stimulating deployment of RE technologies. A 2003 study by Langniss and Wiser reviews the implementation of Texas's RPS concluding that a properly designed and carefully implemented RPS can be an effective support mechanism for RE development. Also in 2003, Deyette et al. evaluated the commitment of states to support RE sources by comparing projected RPS commitments, renewable electricity funding, and state RE purchases with each state's renewable electricity generation and RE potential. In 2005 Bird et al. explored the main factors and market drivers in the 12 states where a significant amount of wind energy had been developed or planned. These factors included RPS, federal and state financial incentives, consumer demand for green energy, and natural gas prices. Also, published in 2005, Menz and Vachon analyzed the contribution to wind power development of several state-level policies, including RPSs, fuel generation disclosure rules, mandatory green power options, public benefits funds, and electricity retail choice facilitated by electricity market restructuring. More recently, in 2007, Adelaja and Hailu estimated the impacts of RPS adoption on Michigan by projecting installed wind capacity and predicting the impact on investment, employment, earnings, and lease payments to land owners. This paper uses Adelaja and Hailu's wind capacity installation determination model to design the regression analysis in part two of the research.

4.0 METHODOLOGY

The research in this paper takes on a two-stage design with past regulatory policies being observed first, as well as how electric utilities responded to these policies. The second stage of the research utilizes newly generated and other publicly available data to conduct a quantitative analysis of wind power adoption in US states using regression analysis.

4.1 PART ONE

Because the RPS is essentially a regulatory mandate, it is helpful to observe previous regulatory policies affecting the electric industry in the US. Stage one of the research examines four past regulatory policies affecting electric utilities: PURPA, the Clean Air Act and its amendments, the Clean Water Act (CWA), and EPAct of 1992. The background and nature of the policy is discussed, as well as the manner in which electric utilities reacted and responded to the policy.

4.2 PART TWO

For this analysis, data are aggregated by state; fifteen states that lack a mandatory or voluntary RPS policy are excluded (see Tables 1 and 2 for a list of states included). The prediction is based on an econometric model from Adelaja and Hailu that estimates the relationships between installed wind power capacity and its hypothesized determinants using cross section data from US states with an RPS. In Adelaja and Hailu's study, a wind capacity installation determination model is used to econometrically estimate the impacts of RPS adoption on wind power adoption. The details of the data and the wind determination model are provided in the section on part two of the analysis. The analysis in this paper will be based on a 35-state model of wind installations by RPS adopters over a ten year period (1999-2009). Data on installed wind power capacity in

MW as of 2009 were derived from the Department of Energy's Wind Powering America site. The approach in this study is to model Installed Wind Power Capacity (IWPC) measured in MW as a dependent variable regressed against hypothesized determinants.

5.0 ANALYSIS

5.1 PART ONE: PREDECESSOR REGULATORY MANDATES AND ELECTRIC UTILITIES' RESPONSE

As opposed to Denmark and Germany, where local cooperatives have been a major factor in the growth of wind power, 90 percent of US wind power capacity is owned by independent power producers (Wiser and Bolinger 2007). Twenty-five percent of new capacity built in 2006 was initiated by IOUs with only four percent coming from community-owned wind power (Bohn and Lant 2009, 89). Wind power has been facilitated by the increase in environmental standards facing electric utilities. Electric utilities in the US are among the most environmentally sensitive industries in the country. They are heavily exposed to the impacts of environmental regulations and have undergone a number of changes within the past 30 years to comply with state and federal regulatory policies. Several of these policies will discussed in this section, but it is important to first discuss the background of the industry and all of the changes that have been overshadowed by its regulation and restructuring.

Since the mid-1930s, electric utilities have been subject to comprehensive federal and state economic regulation. Until the late 1970s, this regulatory framework remained virtually unchanged. Electricity service is considered a natural monopoly, meaning that the industry has (1) a tendency toward declining long-term costs, (2) high threshold investment, and (3) technological conditions that limit the amount of potential entrants (Abel 1998). In 1935, the federal regulation scheme was codified with the Federal Utility Act, and the most notable features of this act were the Federal Power Act (FPA) and the Public Utilities Holding Company

Act (PUHCA) which defined the nature of federal electric utility regulation. As the industry evolved, however, flaws with the natural monopoly theory developed. Because exclusive franchises in the utility's service area are granted by the government and several utilities do not own all of their generating facilities, there is actually nothing natural about a utility's monopoly.

Restructuring of the electricity industry began in 1996 with California and Rhode Island leading the way at the state-level passing legislation allowing retail customers to choose their electricity source (Menz and Vachon 2006, 1788). Since then, over twenty states have adopted electricity restructuring legislation, but the process has been delayed or indefinitely suspended in eight states following difficulties in 2001 in California. In the states that have gone through with the restructuring process, retail customers have access to various sources of electricity and service providers. As part of the process, electricity distribution companies have been pressured to inform the public about RE choices, thus facilitating market entry by wind power and other "green" electricity producers.

5.1.1 Public Utility Regulatory Policies Act

The oil crises of the 1970s raised concerns about the security of US energy and electricity supply, and these concerns led to PURPA being signed into law in 1978 as part of the National Energy Act. PURPA required utilities to purchase electricity produced by non-utility entities, sources directly competitive with the utilities' own generation, and encouraged the development of small-scale electric generation facilities, particularly those using renewable resources (Menz and Vachon 2006, 1788). The policy's overarching goals were to encourage energy conservation and energy efficiency and stimulate the development of generation of electricity from RE sources. The changes the policy made to traditional electricity regulation started a movement towards a market-oriented approach to electricity supply (Abel 1998, 1).

In addition to giving the federal government regulatory power in the domain of economic regulation of electric power (formerly the responsibility of the states), PURPA also augmented utilities' electricity generation with more efficiently produced electricity, provided equitable rates to consumers, and created a new type of wholesale generators called Qualifying Facilities (QFs) (Abel 1998, 2). QFs are exempt from regulation under PUHCA and FPA, and only two types of generators—small power producers and co-generators—can qualify as a QF to receive the benefits of PURPA. All of the power produced by QFs had to be purchased by the local utilities in their service area at avoided cost which is defined as “the likely costs for both energy and facilities that would have been incurred by the purchasing utility if that utility had to provide its own generating capacity” (Abel 1998, 3).

PURPA created several issues for electric utilities as a whole. First, because the policy opened up the electricity generating sector to other entrants, electric utilities questioned the justification of the natural monopoly of generation ownership and regulation. Secondly, the cost-based rates that originally guided wholesale transactions also came into question since QFs usually do not have enough market power to influence the rates they charge and the Federal Energy Regulatory Commission (FERC) began to approve certain rates that came from competitive bidding. These particular rates, commonly called market-based rates, were instrumental in moving electricity towards a market approach. It is argued, however, that this push towards a competitive market was not the workings of the free market. While PURPA did introduce competitive generators into the electricity market, it did so using regulatory intervention.

In one particular state, California, electric utilities had a more specific problem with PURPA. In the mid-1990s, the FERC disapproved of California's allocation of PURPA contracts. The California Commission structured a proposal based on a Biennial Resource Plan Updated (BRPU), the establishment of "benchmark prices" and bidding by the QFs (Cudahy 1995, 430). Interestingly enough, California reserved around half of the capacity solely for RE bidders. As expected, electric utilities under the California Commission's rule complained that California's system would result in unnecessary power being purchased at inflated prices. More specifically, electric utilities in California alleged that the solicitations to QFs brought in bids from cogeneration facilities at prices below what had been awarded for some RE capacity; that portions of the solicitations were set aside for RE bidding; that the bids were segmented into separate capacity blocks; that the bids were distorted to reflect environmental externalities; that the final orders ignored updated need projections; that the solicitations were not open to non-QF bidders; and that the orders threatened to create stranded costs in a restructured electric utility industry (Cudahy 1995, 430).

The FERC found fault in California's method of calculating avoided cost. The agency noted that it, and not the states, had the authority to make the rules governing QF rates and that any state process to determine avoided costs had to also follow the FERC's statutes and regulations. Overall, the problem made the FERC draw a line between internalized environmental costs, which had become pecuniary costs of the electric utility, and costs to society which had not yet been internalized (Cudahy 1995, 431).

5.1.2 The Clean Water Act

CWA has its origins as far back as 1948 with the Federal Water Pollution Control Act. This was the first in depth statement of federal interest in clean water programs, and because water pollution was mainly viewed as a state and local problem, it provided local and state governments with funds to address water pollution problems. During the late 1950s and into the 1960s, several laws amended this 1948 statute. These new laws dealt largely with federal assistance to municipal dischargers and with federal enforcement programs for all dischargers (Copeland 2008, 2). Mounting negative perceptions and frustrations with the water pollution programs led to more amendments in 1972. The 1972 amendments established two major goals that still remain today: zero discharge of pollutants and that water quality is both "fishable" and swimmable" (Copeland 2008, 2).

Today, CWA consists of two main components: regulatory requirements and Title II and VI which relate to municipal sewage treatment plant construction. The component of interest in this research is that of the regulatory requirements which apply to industrial and municipal dischargers. CWA is termed a technology-forcing statute because it places rigorous demands on those who are regulated by it (including electric utilities) to achieve higher and higher levels of pollution abatement (Copeland 2008, 3). Industries had to install best available technology that is economically achievable to clean up waste discharges.

CWA directly affects electric utilities as water is critical to the functioning of most electric generation facilities. Utilities often rely on cooling water impoundments to reduce the temperature of the water used to cool steam electric plants. These plants also frequently depend on water to operate and cool turbines and isolate and manage generation process emissions and wastes (Edison Electric Institute 2007, 1). Under section 402 of the CWA, generating facilities that discharge into navigable waters are required to obtain permits.

The Environmental Protection Agency's (EPA) definition of waters in the US specifies that waste treatment systems designed to meet the requirements of the CWA are not waters of the US (Edison Electric Institute 2007, 5). This exception for cooling ponds and other treatment facilities has been critical for electric utilities. Many have built ash ponds, cooling ponds, and settling basins to treat pollutants, and these solutions have been considered industrial facilities for pollution control and as exceptions by the EPA. The waters from these facilities therefore do not have to meet water quality standards until the point of discharge from the systems into jurisdictional waters.

The RPS can also be considered a technology-forcing statute because it requires states to utilize certain technologies to meet the target. As observed in this example, electric utilities have opted to search for exceptions to the regulation. In the case of the currently proposed federal RPS policies where energy efficiency can be called upon as an exception in extraordinary circumstances to meet the target amount, this example indicates that states and electric utilities will push for these exceptions in order to minimize the impact upon their budgets.

5.1.3 The Clean Air Act and its Amendments

The Clean Air Act aims to limit airborne emissions through investment in cleaner technologies and daily operations and protect the environment and humans from harmful air pollutants. Minimum national standards for air quality were established under the act, and it established a comprehensive permit system for all major sources of air pollution including electric utilities and power plants. While regulation has curbed emissions, the policy has had other unintended and potentially costly effects on the electric industry and its decisions. This section will chronologically discuss the act and its amendments and how electric utilities responded.

In 1970, the Clean Air Act Amendments were passed required the EPA to establish air standards for six major pollutants including sulfur dioxide (SO_2). These amendments required all new or modified electric power plants (both coal-fired and oil-fired plants) to limit their SO_2 emissions. It was expected that power plants would meet these standards by installing pollution abatement capital such as flue gas desulfurization systems, known more commonly as scrubbers (Lee 2002, 492). Most plants, however, chose instead to purchase low-sulfur coal for their new plants because it was the most economical choice. According to Lee, these amendments and the choices of power plants increased the demand for low-sulfur coal by 29.6 percent and reduced the demand for high-sulfur coal by 0.7 percent (2002). In order to protect the employment of high-sulfur miners and counter the relocation of US coal production, policymakers enacted further regulation in 1977 requiring plants to install scrubbers (Lee 2002, 492). As noted in Lee's 2002 research study, the sulfur regulations reduced the average annual rate of productivity growth by 1.52 percent for power plants illustrating the costly effect of regulation on the industry.

In 1990, the Clean Air Act was amended to establish a regulatory framework and criteria for minimizing pollutants from various sources including power plants. The Clean Air Act Amendments of 1990 added an acid deposition control program setting goals for the year 2000 of reducing annual SO_2 emissions by 10 million tons from 1980 levels and reducing annual NO_x emissions by 2 million tons, also from 1980 levels (McCarthy et al. 2007, 14). The SO_2 reductions were imposed in two phases. Under Phase 1, owners/operators of 111 electric generating facilities larger than 100 MW had to meet tonnage emission limitations by January 1, 1995, and Phase 2 included facilities larger than 75 MW, with a deadline of January 1, 2000 (McCarthy et al. 2007, 14). As a result of the 1990 amendments, many utilities switched their plants to run on natural gas (Calvert and Hock 2001, 4). Rising prices for natural gas, however, have caused utilities to look to other low-emission options for electricity generation, such as wind power.

A key finding from the observation of the Clean Air Act and its amendments and electric utilities' responses is that, unless a compliance option is specified, electric utilities will opt for the least-cost plan towards meeting regulatory standards. As shown in the section on US state RPS policies, this has held true thus far in terms of wind power and RE sources. Just as subsequent amendments to this policy enforced the use of scrubbers, an increasing number of states are amending their RPS policy to include set-asides and technology tiers.

5.1.4 The Energy Policy Act of 1992

EPAct of 1992, in regards to competition within the sector, followed in the footsteps of PURPA. The policy increased competition in the electricity generating sector by creating new entities that can generate and sell electricity at wholesale prices without being regulated as utilities under PUHCA (Abel 1998, 4). As already noted in the section on wind power, EPAct is also important for establishing the PTC whose expirations and subsequent re-enactments have been directly correlated to the booms and busts of the wind industry. In this section, only the manner in which EPAct affected competition is observed as the PTC does not heavily impact electric utilities.

As PURPA began a shift towards more regulatory responsibilities for the federal government, EPAct continued that shift away from the states by creating new options for utilities and regulators to meet electricity demand (Abel 1998, 1). EPAct came about because, following PURPA, there were still issues calling for further reform. Voiced by independent power producers (IPPs) and some utilities, the main concern was that IPPs should be exempt from PUHCA regulation which was making their companies overly complex in structure. EPAct therefore created new entities that can generate and sell electricity at wholesale without being regulated as a utility under PUHCA.

EPAct established exempt wholesale generators (EWGs) and foreign utility companies (FUCOs) as entities that are not considered electric utilities and are thus exempt from the FPA and PUHCA (Abel 1998, 5). Because of the creation of EWGs and the policy's wheeling provisions, EPAct is considered an example of US commitment to competition in the electricity sector. The commitment to competition, however, is bundled with a renewed interest in diversifying the supply mix and energy conservation. EPAct requires states to consider cogeneration and RE resources, and the policy also provides that rates should be set at levels that will encourage utilities to make investments in demand-side management (Cudahy 1995, 427).

Overall, EPAct further opened the electricity market to competitive wholesale generation and required electric utilities to open their transmission lines to all electricity producers thus allowing alternative energy—such as wind power—access to the electricity market (Menz and Vachon 2006, 1788). With the increase in competition (and electricity market restructuring), however, the expiration of transitional rate caps resulted in higher prices as utilities were able to adjust rates to recover higher distribution and transmission costs, in addition to higher wholesale power costs (US EIA 2007). Most of the price increases were attributed to market restructuring which resulted in the suspension or modification of the process, but EPAct also played a role in competition increasing retail rates. This example serves to prove that, when it is possible, electric utilities will distribute the costs of regulation to consumers. As policymakers consider additional regulatory mandates such as RPSs, it is vital to consider the impact the regulation will have on energy prices for consumers.

5.2 PART TWO

5.2.1 Data Description

For each, the source of data and hypothesized effect on installed wind power adoption are indicated.

1. Target time frame (positive) – This is the number of years between the date of adoption and the target year. Target time frame is labeled TMFR in the model.
2. Time since RPS adoption (positive) – This is the current number of years since RPS adoption. Time since RPS adoption is labeled TSINC in the model.

3. Target amount/percentage (positive) – This is the portion of the state's energy supply that is mandated to be renewable. The target amount/percentage is labeled TAMOU in the model.
4. Whether RPS is mandatory (positive) or voluntary (negative) – This is labeled MVSV in the model.

The first four data factors were collected from Wiser and Barbose's 2009 update to their Department of Energy study on RPS policies and the Database for State Incentives for Renewables and Efficiency (DSIRE). These four factors characterize the RPS target and will help estimate the effect of each target element of RPS legislation on wind power capacity installation. This should indicate the trade-offs involved when designing the RPS target.

5. Wind energy potential (positive) – Although it appears obvious that a state's wind potential would positively impact its deployed capacity, with or without an RPS, it is important to measure the strength of the correlation. The relationship is hypothesized as positive since the more available wind resources a state has, the more likely developers will target the state for wind power installations. Data is the total windy land area in km^2 that has 30 percent gross capacity factor at 80 meters. The data was collected from the US Department of Energy's Wind Powering America wind resource estimates (2010). Wind energy potential is labeled WPOT in the model.
6. Wind energy price (negative) - National average prices for wind power are competitive, but in 2006 they varied by region from $27 per megawatt hour (MWh) in Texas to $48 per MWh in the Northeast (Wiser and Bolinger 2007). The demand for wind energy was thus affected in comparison to electricity prices from other sources and to the extent that it is elastic. The relationship is therefore hypothesized to be negative. Data was collected from the studies on wind power in US states from Bohn and Lant (2009) and Wiser and Bolinger (2007). Wind energy price is labeled WPRI in the model.
7. Restructuring (negative) – Due to economies of scale and the efficiencies of a single delivery system, electricity distribution is regarded as a natural monopoly. Its production, however, is not. Following 1992's EPAct, several states have restructured the electric

industry by forcing electric utilities to sell their power generation facilities. This has thus created a regulated monopoly regime for utilities that specialize in electricity distribution and a more competitive free market regime for electricity producers (Heiman 2006). In their 2004 study, Heiman and Solomon found that, under electric utility market restructuring, RE generation must overcome challenges such as price distortions, lack of storage capability, discriminatory transmission system access, and the end of linked utility rate hikes guaranteed to cover the additional expense of RE generation. Data was collected from the US Energy Information Administration's site on the status of electricity restructuring by states (2010). Note that the data is recorded as being restructured or not; for those states that have suspended restructuring, their data is recorded as being restructured since the process has begun. Restructuring is labeled RESTR in the model.

8. Gross Domestic Product (GDP) by State (positive) - A state's economic and financial situation is expected to impact policy choices that affect consumers and the industry. Consistent with the findings of Huang et al. (2007), each state's GDP is hypothesized to be positively related to the capacity installation of wind power. Data was collected from the US Bureau of Economic Analysis and is reported for the year 2008 (2010). GDP by state is labeled SGDP in the model.
9. Population Change (positive) – Because as a state grows more populous, the more energy it demands thus straining existing resources, population change is hypothesized to be positively related to the capacity installation of wind power. Data is the percent change from April 1, 2000 to July 1, 2008 and was collected from the US Census Bureau (2010). Population change is labeled POP in the model.

Table 4. Summary of Analysis Variables

Field	Description
TMFR	# of years between the date of adoption and the target year
TSINC	# of years since RPS adoption
TAMOU	% of the state's energy supply that is mandated to be renewable
MVSV	Dummy variable: 1 = Mandatory, 0 = Voluntary
WPOT	Total windy land area that has 30% gross capacity factor at 80 m (km^2)
WPRI	Wind energy price (2006) ($/MWh)
RESTR	Dummy variable: 1 = Restructuring has started/is complete, 0 = No restructuring
SGDP	Gross domestic product by state in 2008 (millions of chained 2000 $)
POP	% population change from 4/1/2000 to 07/01/2008

5.2.2 Wind Power Capacity Installation Determination Model

To determine the structure of wind capacity installation by states with an RPS, the wind power capacity installation determination model is specified. The model estimates the relationships between determinants of wind capability installation and installed wind power capacity (IWPC) using the above discussed data. The model is specified as follows.

$$IWPC = \alpha_0 + \alpha_1\, TMFR + \alpha_2\, TSINC + \alpha_3\, TAMOU + \alpha_4\, MVSV +$$

$$\alpha_5\, WPOT + \alpha_6\, WPRI + \alpha_7\, RESTR + \alpha_8\, SGDP + \alpha_9\, POP + \varepsilon$$

5.2.3 Descriptive Statistics

One of the most reliable sources of data on wind power capacity in the US is the Department of Energy's Wind Powering America program. Data is provided for the past ten years (1999-2009) in MW. Data transformation was conducted to appropriately integrate the data and modeling process, and the Ordinary Least Squares (OLS) estimation method is used in the wind capacity installation determination model.

Table 5 provides a list and description of the variables used in estimating the wind capacity installation equation. The model has strong performance, with R^2 of 79.3%, meaning that it explains 79.3% of the variation in state wind capacity installation. Table 6 provides an overview of the model performance indicators.

Table 5. Descriptive Statistics

				Model Estimates	
Variable	N	Mean	Standard Deviation	Coefficient	p-value
Dependent Variable					
IWPC	33	929.12	1768.17		
Independent Variables					
TMFR	33	16.55	5.82	-.009	.956
TSINC	33	7.39	5.68	.245	.066
TAMOU	33	18.54	7.09	.050	.659
MVSV	33	0.85	0.36	.032	.776
WPOT	33	61675.76	97127.64	.858	.000
WPRI	33	40.76	8.22	.278	.218
RESTR	33	0.64	0.49	-.117	.362
SGDP	33	273935.55	3.22E5	.365	.004
POP	33	7.87	7.44	.189	.164

Table 6. Model Performance Indicators

R^2	0.793
Adjusted R^2	0.713
F-value	9.819
F-Prob. Value	0.000

5.2.4 OLS Regression Results

Only one of the factors that characterize the RPS target was found to be statistically significant: the time since RPS adoption. As hypothesized, the relationship was positive illustrating that, with time, wind capacity installation will grow after RPS adoption. These findings are confirmed by plotting the number of states with RPS policies versus wind power capacity in the US (see Figure 4).

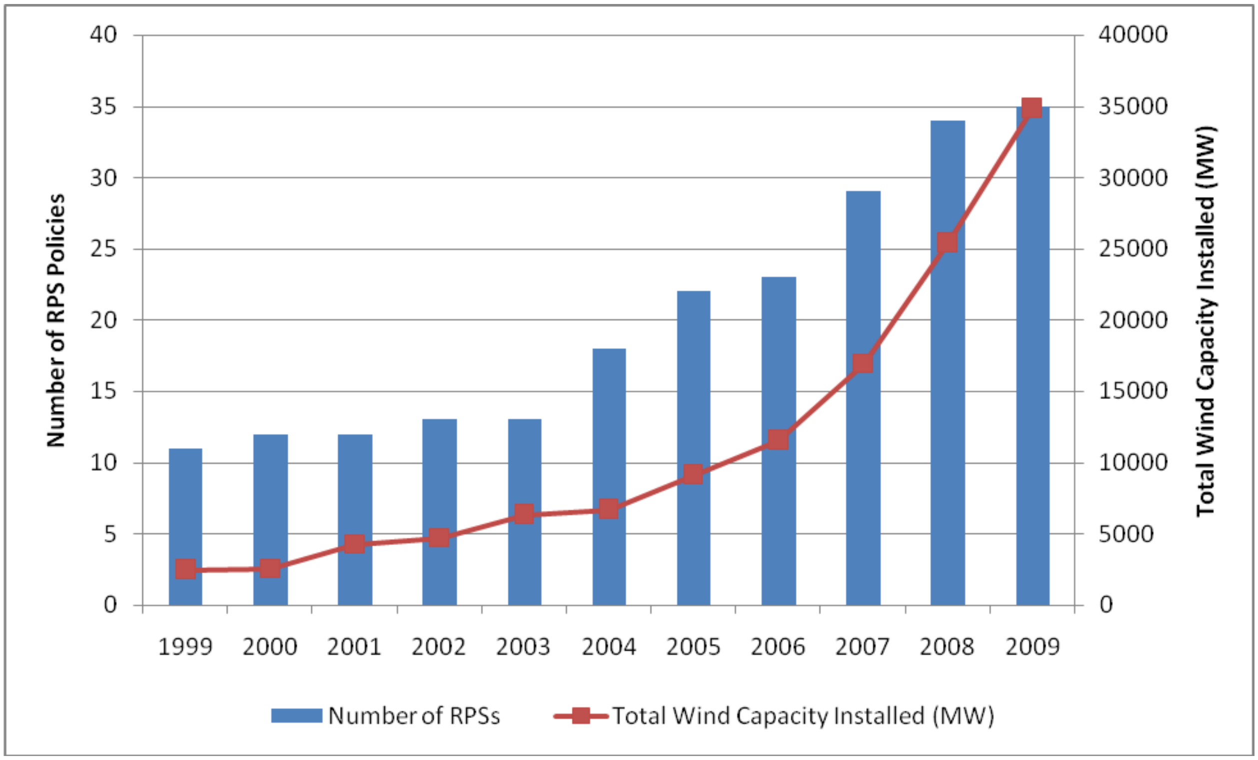


Figure 4. Prevalence of RPS Policies and Wind Capacity Installation

Wind energy potential was also found to be statistically significant. As hypothesized, the relationship was positive illustrating that wind potential provides a signal to the industry that there are wind resources to tap. Wind energy potential was the most important factor in determining state wind capacity installation. The results show that for a one standard deviation increase in wind energy potential, the state would expect a 0.858 standard deviation increase in wind capacity installation. This is nearly a one-to-one ratio which illustrates the significance of wind resources in a state for increasing capacity.

A surprising outcome of the analysis was the finding that wind energy price had a positive relationship with wind capacity installation. It appears that even if the price of wind power increases there is still a demand for it when an RPS is in place. This may be because, relative to other RE sources, wind power is still the least-cost option for meeting the RPS target. Another cause for this positive relationship could be that the PTC makes wind power desirable despite an increase in wind energy prices.

Both state GDP and population change were found to be statistically significant, and as anticipated, both factors had a positive relationship with wind capacity installation. The finding that the size of a state's economy positively impacts the growth of its installed wind power capacity may suggest that large states, in an economic sense, are faced with more pressure to implement policies that strengthen the gains from RPS adoption due to the high energy price tag and burdens and the potential gains from economies-of-scale (Adelaja and Hailu 2007). In terms of population change, it appears the hypothesis that as a state grows more populous, the more energy it demands thus straining existing resources, was correct. Because most states have already fully tapped into their significant hydropower resources, wind is the second-best RE source for states to progress towards as they try to shift away from fossil fuel-based sources.

Several variables were not found to be statistically significant determinants of installed wind capacity. Hence, a state's wind capacity installation is not affected by the RPS target size, the RPS target timeframe, whether the policy is mandatory or voluntary, and whether the state's electricity market has been restructured.

6.0 CONCLUSION

The world has seen global energy use expand at unprecedented rates to keep up with the demands of growing economies and populations. This growth process is complicated, however, by complex, interconnected issues involving climate change mitigation, economic development, and energy security. RE technologies have emerged as an answer for many countries' energy problems, satisfying the need for cleaner technology while still expanding energy supplies as a tool for further economic development. Unfortunately, these new technologies face several market challenges which have necessitated government intervention. The quota obligation (known as the RPS in the US) is one of the most popular policy tools for encouraging RE capacity expansion.

Evidence suggests that the RPS is a key driving force behind the growth in installed wind power capacity in the US (see Figure 4). The first analysis in the paper observed past regulatory policies and applied what was learned from their implementation to the RPS. The manner in which electric utilities responded was also examined to determine how they may respond to further regulatory mandates such as a federal RPS. The second analysis utilized data from the 35 states with an RPS in estimating a structural model of wind power development which accounts for particular characteristics of the RPS target and other drivers of wind power development such as state economic and population factors. This research adds to this evidence by showing that several other factors play a key role in increasing wind capacity within US states besides just the RPS. These factors include a state's wind energy potential, state GDP, and state population change. Additionally, it was found that there is a momentum effect associated with time since RPS adoption and that increases in wind energy prices do not negatively affect development in states with an RPS.

6.1 POLICY IMPLICATIONS

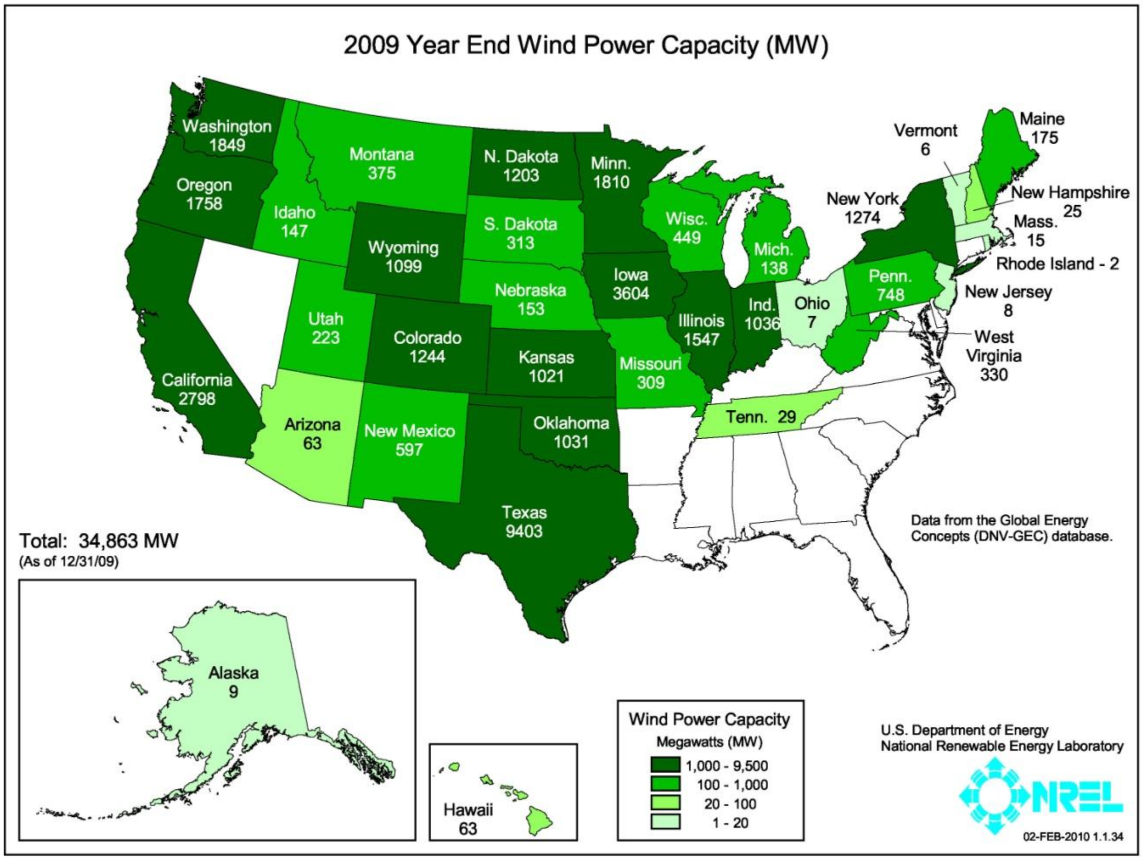
There are currently two main bills—The American Clean Energy Leadership Act (ACELA) by Senator Bingaman and The American Clean Energy Security Act (ACES) by Representative Waxman and Representative Markey—in Congress introducing a federal RPS. With a large number of US states already enacting such policies at the state-level, observing the experiences of these states with this policy and understanding how to best design and implement it should be a key goal for policymakers entering discussions on ACELA and ACES. This paper focused on the role of the RPS on one particular renewable resource—wind power—in the US.

The first stage of the research observed past regulatory policies in the electricity sector and analyzed the manner in which electric utilities responded to these policies. The key finding from this observation was quite obvious: electric utilities will respond to regulatory policies in the best manner which facilitates their budgets and will work to find exceptions, if possible, that allow them to practice least-cost methods of adaptation to the regulation. In relation to the RPS, this has already occurred with most states seeing wind power (currently the least-cost RE source in the US) increase rapidly to meet the demands of RPS targets. As was the case with the Clean Air Act and its amendments, policymakers have adapted policies to better specify the outcomes they wish to achieve with the regulatory mandate. Depending on the desired outcomes of the policy, this research indicates that regulation is best designed with specific implementation requirements.

The second stage of the research conducted a regression analysis to determine the indicators of wind capacity installation. Surprisingly, only one characteristic of the RPS target—the time since RPS adoption—was statistically significant. This illustrates the importance, however, of allowing sufficient time for a state to meet preliminary targets (if there are any). Furthermore, it shows that there are minimal trade-offs in the design of the target and that, in time, wind power will increase regardless of the stringency of the policy. Capacity expansion is instead more reliant on the availability of resources and the state economy. Also, the research indicates that as the population of a state grows, there is more likelihood to increase wind power installation. This is the probable result of increasing demands for energy placing a strain on current sources and creating a demand for new sources to come online. While this study demonstrates that the design of the RPS is not a critical factor for wind power adoption, it reasserts that RPS policies are nonetheless important to RE promotion. In all states that had adopted an RPS policy, either mandatory or non-binding, an increase in wind power capacity was observed. The differences in the growth of the capacity were better explained, however, by factors other than the target design features of the policy.

APPENDIX

TOTAL INSTALLED WIND POWER CAPACITY IN US STATES



BIBLIOGRAPHY

Abel, A. 1998. *Electricity Restructuring Background: The Public Utility Regulatory Policies Act of 1978 and the Energy Policy Act of 1992.* CRS Report for Congress. website

Adelaja, S. and Y. G. Hailu. 2007. *Projected Impacts of Renewable Portfolio Standards on*

Wind Industry Development in Michigan. Land Policy Institute at Michigan State University. http://www.landpolicy.msu.edu/modules.php?name=Documents&op=viewlive&sp_id=458.

American Wind Energy Association. 2009. *Annual Installed U.S. Wind Power Capacity*. http://www.ucsusa.org/assets/images/ce/AWEA-wind-capacity-graph.png

American Wind Energy Association. 2004. *American Wind Energy Association, 2004. Wind power: US installed capacity, 1981–2003.* http://www.awea.org/faq/instcap.html.

Avato, P. and J. Coony. 2008. *Accelerating Clean Energy Technology Research, Development, and Deployment: Lessons from Non-energy Sectors*. http://www.esmap.org/filez/pubs/78200895253_accelerating_clean_energy.pdf

Barr Engineering Company. 2008. *Water Conservation Plan Electric Utilities Sector Plan*. http://www.michamber.com/mx/electric

Berry and Jaccard. 2001. The renewable portfolio standard: design considerations and an implementation survey. *Energy Policy*. 29: 263-277.

Bird, L. et al. 2005. Policies and market factors driving wind power development in the United States. *Energy Policy*. 33: 1397–1407.

Bohn, C. and C. Lant. 2009. Welcoming the Wind? Determinants of Wind Power Development Among U.S. States. *The Professional Geographer*. 61:1: 87-100.

Bryant, T. 2007. Researchers find substantial wind resource off Mid-Atlantic coast. *University of Delaware Daily*, February 1, 2007. http://www.udel.edu/PR/UDaily/2007/feb/wind020107.html.

Calvert, S. and S. Hock. 2001. United States Wind Energy Growth and Policy Framework. National Renewable Energy Laboratory (NREL).

Copeland, C. 2008. *Clean Water Act: A Summary of the Law.* http://www.nationalaglawcenter.org/assets/crs/RL30030.pdf

Cory, K. and B Swezey. 2007. *Renewable Portfolio Standards in the States: Balancing Goals and Implementation Strategies*. NREL/TP-670-41409. Golden, CO: National Renewable Energy Laboratory (NREL). http://www.nrel.gov/analysis/pdfs/41409.pdf

Database of State Incentives for Renewables & Efficiency (DSIRE). 2009. *New York.* http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NY03R&re=1&ee=1

Database of State Incentives for Renewables & Efficiency (DSIRE). 2010. http://www.dsireusa.org

Deyette, J., S. Clemmer, and D. Donovan. 2003. *Plugging in Renewable Energy: Grading the States.* Union of Concerned Scientists: Cambridge, MA.

Environmental Protection Agency (EPA). 2006. Energy Supply Actions in *Clean Energy-Environment Guide to Action: Policies, Best Practices, and Action Steps for States*. http://www.epa.gov/RDEE/documents/gta/guide_action_chap5_s1.pdf

Gallagher, K. S., J. P. Holdren, and A. D. Sagar. 2006. Energy-Technology Innovation. *Annu. Rev. Environ. Resour*. 31: 193-237.

Gouchoe, S., V. Everette, R. Haynes. 2002. *Case studies on the effectiveness of state financial incentives for renewable energy.* NREL/SR-620-32819, National Renewable Energy Laboratory: Raleigh, NC.

Heiman, M. K. 2006. Expectations for renewable energy under market restructuring: The U.S. experience. *Energy*. 31: 1052–66.

Heiman, M. K. and B. D. Solomon. 2004. Power to the people: Utility restructuring and the commitment to renewable energy. *Annals of the Association of American Geographers.* 94 (1): 94–116.

Holdren, J.P. 2006. The Energy Innovation Imperative: Addressing Oil Dependence, Climate Change, and Other 21st Century Energy Challenges. *Innovations.* 1:2, 3-23.

Huang, M. et al. 2007. Is the choice of renewable portfolio standards random? *Energy Policy*. 35: 11: 5571-5575.

International Energy Agency (IEA). 1997. *Enhancing the Market Deployment of Energy Technologies: A survey of eight technologies*. OECD Press: Paris.

International Energy Agency (IEA). 2002. *Beyond Kyoto: Energy Dynamics and Climate Stabilisation.* Paris: IEA Publications.

International Energy Agency (IEA). 2004. *Renewable Energy: Market & Policy Trends in IEA Countries*. Paris: IEA Publications.

Langniss, O. and R.Wiser. 2003. The renewable portfolio standard in Texas: an early assessment. *Energy Policy*. 31: 527–535.

Lee, M. 2002. The effect of sulfur regulations on the U.S. electric power industry: a generalized cost approach. *Energy Economics*. 24: 491-508.

McCarthy, J. E. et al. 2007. *Clean Air Act: A Summary of the Act and Its Major Requirements.* http://www.cnie.org/NLE/CRSreports/07March/RL30853.pdf

Mendonca, M. 2007. *Feed-In Tariffs: Accelerating the Deployment of Renewable Energy*. Earthscan: Sterling, VA.

Menz, F. C. and S. Vachon. 2005. The Effectiveness of Different Policy Regimes for Promoting

Wind Power: Experiences from the States. *Energy Policy*. 34: 14: 1786-1796.

Sagar, A. D. and B. van der Zwaan. 2006. Technological Innovation in the Energy Sector: R&D, deployment, and learning-by-doing. *Energy Policy*. 34, 2601-2608.

Swisher, R. and K. Porter. 2006. Renewable Policy Lessons from the US: The Need for Consistent and Stable Policies in *Renewable Energy Policy and Politics*, ed. K. Mallon. Earthscan: Sterling, VA. Pages 185-198.

Swisher, R., C. Real de Azua, and J. Clendenin. 2001. Strong winds on the horizon: Wind power comes of age. *Proceedings of the IEEE* 89 (12): 1757–64.

US Bureau of Economic Analysis. 2010. *GDP by State.* http://www.bea.gov/newsreleases/regional/gdp_state/gsp_newsrelease.htm

US Census Bureau. 2010. *State and County QuickFacts.* http://quickfacts.census.gov/qfd/index.html

US Department of Energy (DOE). 2009. *States with Renewable Portfolio Standards*. http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm

US Department of Energy (DOE). 2010. *Installed Wind Capacity*. http://www.windpoweringamerica.gov/wind_installed_capacity.asp

US Department of Energy (DOE). 2010. *Wind Maps and Wind Resource Potential Estimates.* http://www.windpoweringamerica.gov/wind_maps.asp

US Energy Information Administration (EIA). 2007. *Electric Power Industry Overview 2007.* http://www.eia.doe.gov/cneaf/electricity/page/prim2/toc2.html

US Energy Information Administration (EIA). 2010. *Status of Electricity Restructuring by State*. http://www.eia.doe.gov/cneaf/electricity/page/restructuring/restructure_elect.html

Wiser, R. and G. Barbose. 2009. *State of the States: Update on RPS Policies and Progress.* Presentation to the State-Federal RPS Collaborative at the National Summit on RPS. http://www.cleanenergystates.org/Meetings/RPS_Summit_09/WISER_RPS_Summit2009.pdf

Wiser, R., and M. Bolinger. 2007. *Annual report on U.S. wind power installation, cost, and performance trends: 2006.* Washington, DC: U.S. Department of Energy, Energy Efficiency and Renewable Energy.

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[i] Unless otherwise noted, the information in figures and tables about state policies in this section comes from Wiser and Barbose's 2009 presentation to the State-Federal RPS Collaborative at the National Summit on RPS.