INDUSTRIAL-SCALE WIND ENERGY DEVELOPMENT IN THE UNITED STATES:

PHYSICAL, LEGISLATIVE, AND ECONOMIC

CONDITIONS FOR SUCCESS

By

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A thesis submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

WASHINGTON STATE UNIVERSITY
School of Earth and Environmental Sciences

MAY 2009

To the Faculty of Washington State University:

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ACKNOWLEDGEMENT

I would like to thank the Washington State University faculty who served on my graduate committee including Dr. Andrew Ford, Dr. George Hinman, and Dr. Phil Wandschneider for committing their time and expertise in assisting me with my research and writing. I would also like to thank all of those who provided additional outreach and feedback regarding the topics discussed within this paper.

I could not have succeeded in completing my thesis without the guidance from my family and friends, and I owe them a great deal of thanks for their continued support.

INDUSTRIAL-SCALE WIND ENERGY DEVELOPMENT IN THE UNITED STATES:

PHYSICAL, LEGISLATIVE, AND ECONOMIC CONDITIONS FOR SUCCESS

Abstract

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May 2009

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This analysis is designed to educate stakeholders (including legislators, utility providers, and wind developers) interested in industrial-scale wind energy development about the most critical conditions influencing the industry.

Annual installed capacity for wind generation has risen dramatically over the past decade and will continue to grow in the future. However, various resource, infrastructure, and economic constraints have prevented turbine installations in many regions of the United States. Six "conditions" were identified as important for the commercial implementation of industrial-scale wind energy facilities, and were chosen based on current legislation, regulatory mechanisms, and economic climate. These include: Accessible development sites located in medium to high wind resource potential areas; Available federal tax credit incentives; Renewable portfolio standards (RPS) in conjunction with renewable energy certificate (REC) trading; Transmission infrastructure located within reasonable proximity to a wind resource so connection to the grid is economically feasible; Alternate generation sources within the service area able to firm the electrical load; And an encouraging sociopolitical climate at the state or local level. The more these conditions are met for a proposed wind project, the more certain the developer or investor

can be that the project will be a sound investment, properly located, and cost competitive over time.

A levelized cost comparison between combined cycle natural gas facilities and wind power facilities shows that the total cost of production (in 2006 dollars) is about $76/MWh for natural gas and $95/MWh for wind. The Production Tax Credit, currently valued at $21/MWh, is sufficient to accommodate this cost differential. Investment tax credits, cash grants, regulatory carbon pricing, or tradable renewable energy certificates could also reduce costs for generating electricity from wind.

The states with the highest potential for electrical output from wind are not always the states with the largest amount of installed capacity. This indicates that barriers for development exist due to other sociopolitical, physical, or economic conditions among states. California, Texas, Washington, and North Dakota provide high-quality cases for examining conditions that currently influence industrial-scale wind development. Total installed wind capacity; RPS target levels and deadlines, primary electricity generation sources, and availability of REC trading provide good indicators for a state's relationship with wind energy and are used in a fifty state comparison matrix.

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CHAPTER ONE

INTRODUCTION

Wind energy will play a key role in meeting green house gas (GHG) reduction goals, RPS mandates, changing consumer preferences, and an increasing energy demand in the United States and worldwide. Of the various alternative energy technologies commercially available, wind has achieved the greatest amount of growth, reaching over 5,000MW of installed capacity in 2007 alone (Figure 1). Electricity generation through wind has gained significant popularity with politicians, energy developers, utilities, and the public. The cost competitiveness, level of resource availability, potential for large-scale utilization, and low variable operating cost make wind the most attractive and economically feasible of the alternative energy generation technologies currently available.

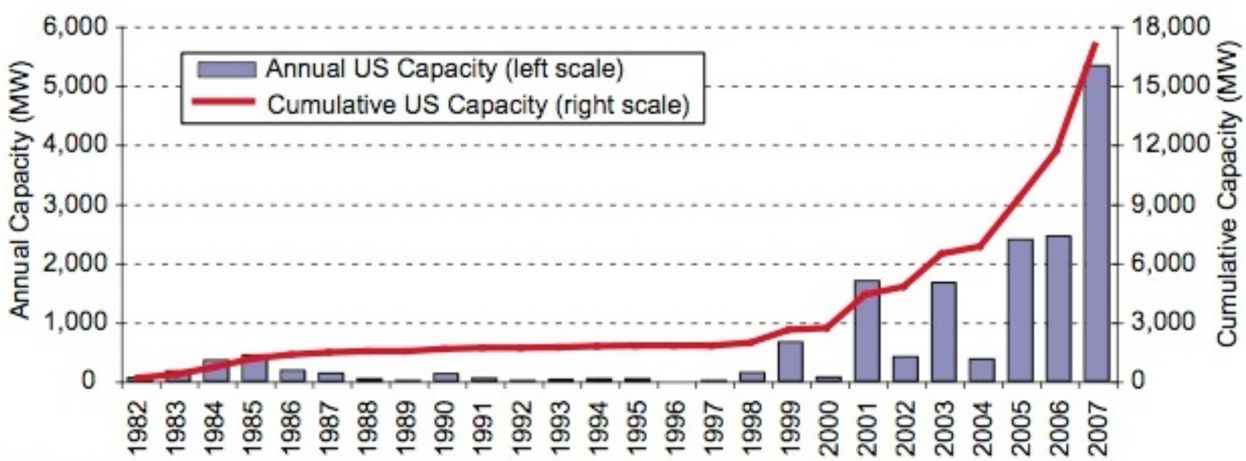

Figure 1: Annual Growth and Cumulative Capacity of Wind Energy in the United States. (Source: American Wind Energy Association 2008)

Recent improvements in technology have allowed for the construction of massive commercial turbines, with the capacity to produce up to six megawatts of power apiece and power over fifteen hundred American homes a year. The average lifespan of a commercial turbine has also grown dramatically, with most new projects expected to remain in operation for 20-30 years. Large wind "farms" have begun to appear across the nation, funded by a diverse mix of investors, utility companies, and private landowners. Wind power is operationally emission-free, does not rely on fossil fuel inputs, and bears extremely low operating costs. The benefits of harnessing wind energy are widely known, and advocacy for increasing its use has arisen from a variety of different interest groups. In order to achieve large-scale utilization of the country's wind energy resource potential, specific policies, regulations, and financial incentives must be in place (Simon 2007). The current wind energy paradigm in the United States provides an interesting opportunity to study the various physical, economic, legislative, and social factors that currently drive the industry.

The United States has instituted federal and state level policies to promote the addition of larger amounts of wind power into the nation's electricity grid. Legislation recently passed by Congress in 2008, titled the Emergency Economic Stabilization Act, renewed the primary federal incentive known as the Production Tax Credit (PTC) for one year. This tax incentive has proven vital to the growth and expansion of the wind industry in the United States, and has consistently been linked to the level of yearly investment and capacity additions in years following its renewal or allowed expiration (Figure 6). Federal incentives, such as the production tax credit, have helped wind energy remain cost competitive with the least-cost alternatives, which are generally coal-fired plants or combined cycle (CC) natural gas facilities. Although Congress has allowed these tax incentives to expire several times in the past decade, hampering investment and creating large drops in annual capacity installed, growth in the wind industry continued to soar with record growth in 2007 and 2008. Allowing the PTC to expire creates instability in the market for investors, and short-term renewals are not consistent with the large length of time it takes to plan and permit a new wind facility. The latest extension of the PTC was integrated into the American Recovery and Reinvestment Act (ARRA) of 2009, also known as the federal "stimulus package", and extended the credit for wind generators until 2012. This longer renewal period is a step in the right direction for policy makers in the U.S. The Act also gave wind developers greater flexibility in choosing the type of tax incentive they could receive by allowing them to utilized the federal investment tax credit (ITC) or review a cash grant instead of claiming the PTC for their wind facility. Additional provisions were added into the ARRA that address financing and tax options for wind developers and will be discussed later in this paper.

State level energy-supply mandates, known as renewable portfolio standards (RPS), have helped create a high market demand for new wind power and other alternative energies by forcing electricity serving utilities to obtain a certain percentage of their power load from renewables sources. Wind energy has become the primary means for meeting these targets, as it remains the most cost competitive compared to large-scale hydroelectric, nuclear, and traditional fossil fuel based generation methods, which are considered non-renewable under most states' RPS laws. More than 75% of all of the new wind capacity added in the United States in 2007 was within states that had a RPS in place (DOE 2007). There are currently twenty-six states in the nation who have self-imposed renewable portfolio standards. Each state has determined its own target percentages for the utilities within its borders and set the deadlines for when those percentages must be met. Although the federal production tax credit is most responsible for reducing the cost of producing electricity from wind, state level portfolio standards assist in maintaining a continuous demand for wind development and promote long-term purchasing contracts for the electricity produced by wind generators.

Renewable energy certificates (RECs) are the primary tool for tracking and monitoring the production and distribution of energy generated from renewables. These certificates are either sold along with the power produced by turbines, or independently (unbundled) to utilities that don't receive and distribute the actual electricity generated. The majority of states who have implemented a RPS target allow renewable energy certificates to be traded in an unbundled fashion in a market separate from electricity. Only four of the twenty-six states with an RPS target do not allow unbundled trading of RECs that are created by alternative energy production (Figure 2).

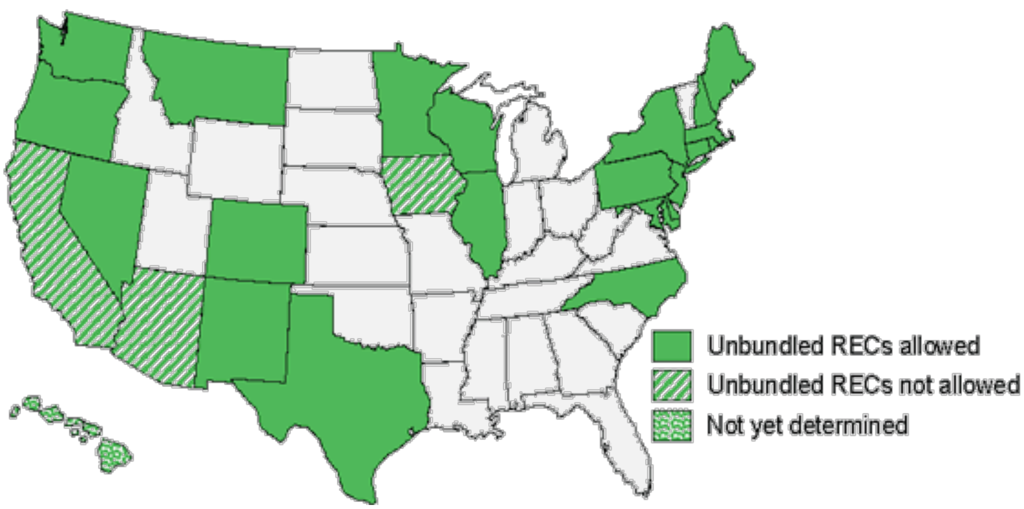

Figure 2. State Regulations Specifying the Trading and Use of Unbundled RECs Towards a State RPS Mandate. (Source: Berkeley Lab, 2007)

The ability to trade serves as a critical tool for utilities that are trying to meet their portfolio requirements and are not located within reasonable proximity to a renewable energy generation site. Allowing the trading of RECs can also help reduce transmission and transaction costs for utilities and developers. Revenue from the sale of RECs (or tradable green certificates; TGCs) will encourage wind energy development by providing an extra financial incentive for investment in new generating capacity (Ford et. al 2005). However, simulations of markets using modeling have predicted high volatility in REC trading prices.

Areas with high wind resource potential are commonly located in remote areas that are long distances from load centers or urban areas where a high demand for electricity exists. In order to access these wind sites, large transmission infrastructure must be in place that can handle the additional load generated by an industrial-scale wind farm, which can be upwards of 500MW at any given time. Because a large percentage of high resource areas exist in extreme environments, there are no transmission lines in place and they must be constructed. The need for transmission infrastructure can give rise to large additional costs for wind developers or utilities, and generally makes up 10-15% of the total construction costs for an industrial-scale wind facility (AWEA 2008). Disputes commonly arise between the developer, the utility that will be purchasing the power, and the state and regional governments in which they reside regarding who will bear the cost for new transmission capacity. The Department of Energy (2008) emphasizes the difficulty with transmission shortage stating, "as long as electricity demands grow, new transmission will be required to serve any new generation developed, and incremental transmission costs will be unavoidable". Long permitting times for building these new lines can also cause problems in areas virgin to development, and commonly delay projects and create insecurity for project investors.

One of the largest challenges for integrating large amounts of electricity into the grid that is generated by wind turbines is the intermittent nature of wind. Wind is typically strongest at night when electrical demand is low, and weakest during the day when peak-load demand burdens the grid. Even when there is a large supply of wind so generators can run at maximum capacity, the total load of electricity being provided to the grid must be monitored and adjusted using other generation sources, such as a hydroelectric power plant, in order to provide a smooth and steady supply to costumers. This process is referred to as “firming” the energy resource, and is achieved by providing an effective amount of back-up generation potential using sources which can be controlled in real-time with relative ease, thereby compensating for periods of low generation from wind generators. Hydroelectric dams have proved to work well in conjunction with wind turbines, as water in reservoirs can be withheld while wind is providing large amounts of electricity, and then released through hydro-generators to accommodate shortfalls in production from the wind turbines (NPCC 2009). Integrating intermittent generation sources such as wind into a region’s power grid creates additional costs and uncertainty that must be considered and planned for.

Even when an area has high resource potential, a sufficient market for wind power, and adequate transmission and firming sources there is still the need for a receptive local government and local population. Developers and utilities spend large amounts of time working with local governments to determine if citizens will allow wind turbines to be erected within their jurisdiction. Zoning regulations, special-use permits, and length of permitting time all come into play when developers are attempting to build a wind facility or even erect preliminary meteorological towers to determine if an area has adequate resource potential. The length of permitting time and language used in zoning laws are both good indicators of a county or city’s receptiveness to wind energy installations. Cooperation between developers and citizens living in the prospective area is imperative for success. The majority of high wind resource potential zones in the country are located in rural areas. Landowners in these areas have the potential to generate considerable amounts of additional income by allowing turbines to be placed on their property, while keeping their land in traditional uses such as farming or grazing. Local governments also have the potential to increase their tax base by allowing development within their jurisdictions, and create construction and maintenance jobs for the local population. These mutual benefits serve as the backbone for cooperation between wind developers, utilities, and local governments and residents.

There has been growing concern from the federal government about bottlenecks in the siting of new transmission infrastructure caused by resistance from local, county, and state governments. In March of 2009, the Federal Energy Regulatory Commission's acting Chairman John Wellinghoff made public testimony advocating giving federal agencies ultimate authority in the siting of transmission lines when local and state governments were unable to do so themselves. If new transmission is necessary to access a high wind resource potential area, and utilizing the energy resource is in the nation's best interest, then the federal government would step in and use its authority, similar to immanent domain, against those opposing the new lines. A strategy like this is bound to cause a large amount of discontent from local and state governments, and would most likely lead to many extensive legal battles in federal courts.

Combined cycle (CC) natural gas facilities are commonly used as the baseline standard, or least cost alternative, to wind when examining additions to energy generation capacity in the United States (Ford et. al 2005, DOE 2008). Natural gas plants have consistently provided the largest amount of new electrical capacity added to the grid in recent years, with 7,500MW installed in 2007, but the difference in growth over new wind capacity has been gradually shrinking over time (Figure 3).

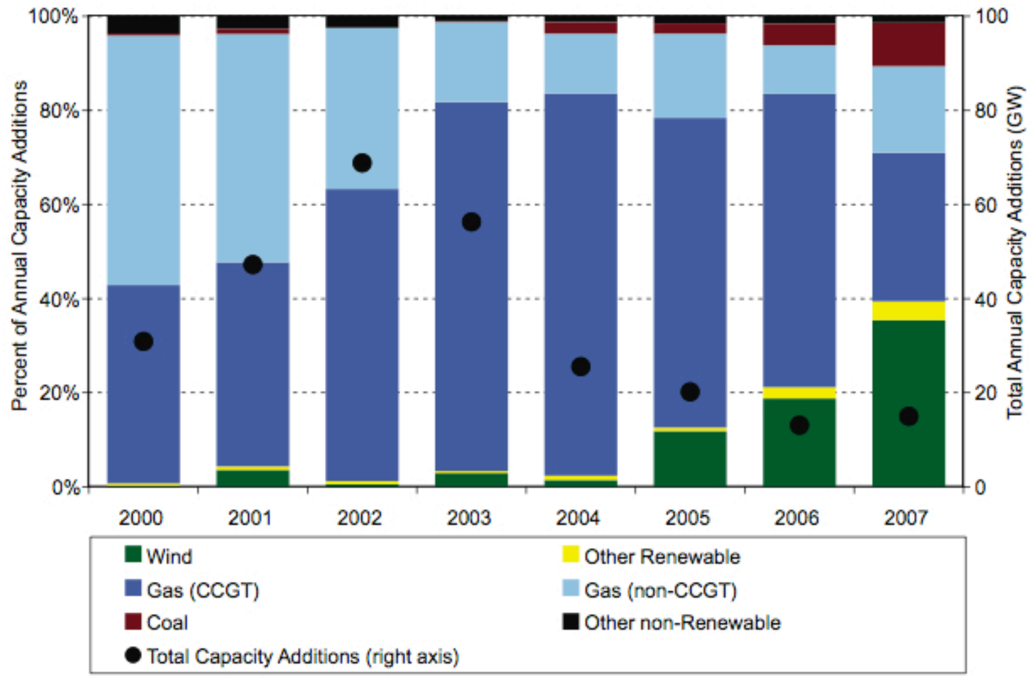

Figure 3. Energy Type and Relative Contribution to Annual Additions in Capacity (Source: EIA, Ventyx, AWEA, IREC, Berkeley Lab 2008)

The burning of natural gas for electricity generation provides a very high output of energy while releasing half of the green house gas emissions that a coal fired power plant produces (EIA 2008b). Gas facilities also provide greater control of load management and generally have lower maintenance costs when compared to coal or nuclear-based generation. Average variable operating costs have been on the rise due to the increasing price of natural gas. The levelized costs of a CC-natural gas plant are shown in comparison with a wind facility in Table 1. These types of comparisons have been made in the past and consistently show that total generation costs are lower for a CC-natural gas facility. The difference in dollars per mega-watt hour can be attributed to the high construction or capital cost of an industrial-scale wind facility. Due to the comparatively high variable operating costs of a CC-natural gas facility, and the rising cost of fuel inputs, wind becomes more cost competitive overtime as the facility operates. It is difficult to forecast the exact cost of natural gas in the near future, but trends in data have shown a steady increase in prices over the last 10 years (EIA 2008a). This increase in fuel costs may ultimately lead to a cost comparison scenario where wind is equally priced with CC-natural gas facilities for the generation of electricity. Unfortunately, based on the current economic recession worldwide, one may predict that natural gas prices will actually decline over the next several years. A large drop in gas prices will dramatically lower the operating cost for CC-natural gas facilities, thereby reducing electricity production costs making gas generation far less expensive than wind. Large investments in liquefied natural gas (LNG) transport across the globe may also lead to large declines in gas prices. Current analysis suggests that most of these new LNG facilities built in the U.S. were based on inaccurate price forecasting of domestic natural gas and supply from Canada. The comprehensive economic status of CC-natural gas generation is an important determinate for the success of wind generators as it remains the primary competition for new energy capacity added each year in the United States.

The American Recovery and Reinvestment Act of 2009, valued at approximately $760 billion dollars contains large allocations of funding aimed to address limitations in the nation's transmission infrastructure, research and development of renewable energy technologies, energy storage strategies, and increasing overall efficiency and conservation. Approximately $49.7 billion is allocated specifically for "energy related" projects and research, which include projects that span from creating a smarter transmission grid to cleaning up spent nuclear waste. These legislative efforts initiated by the government must be monitored and analyzed to be sure that resources and taxpayer dollars are being correctly allocated, and to also ensure the objectives set by public officials are actually being met. An analysis of the current federal funding strategy for energy related issues, such as in the ARRA of 2009, will be made in the policy recommendations section of this paper.

Each of the conditions discussed in this paper provide insight into what physical, legislative, economic, and social conditions are necessary for large-scale wind energy facilities to be successful in the United States. In order to meet the increasingly ambitious goals for energy supply from renewable in the United States, a holistic approach must be taken by states and the federal government to increase the efficiency, cost competitiveness, adaptive management, and proper siting of wind energy facilities. Further research is necessary that examines correlations between the different conditions and their effects on the success of wind energy facilities in the U.S. Experimental economics and modeling may help explain the effects of various financial incentives, potential REC and carbon market schemes, and different regulatory mandates on the growth of wind energy. Effective communication between researchers, developers, and political leaders is imperative to create a climate of success for wind energy. Utilizing the great potential of wind will help prepare for a world of increasing energy demand, limited supply, and an environment threatened by the traditional fuel based electrical system. The human health and environmental benefits of alternative energies are rarely accounted for in cost/benefit analyses regarding energy supply options. This is one major shortfall in economic analysis that needs to be adjusted. It is reasonable to assume that the marginal costs of traditional fossil fuel generators would dramatically increase if cumulative environmental damages were accounted for during price assessments and priced into operational markets through the use of carbon allowances.

1.2 Conditions

There are dynamic interactions that occur between the physical, economic, legislative and social variables described above with respect to large-scale wind energy development. Six "conditions" have been identified as critically important for the commercial implementation of a wind energy facility. Although it is not necessary for all of these conditions to be in place for a development to be successful, the more conditions that are in place the more certain the developer can be that the wind facility is a good investment, properly located, and will prove cost effective overtime. The conditions are as follows:

1) Adequate wind resource potential (minimum average wind speeds of 6 m/s (13 mph)) that is accessible for development

2) Available federal tax credit incentives (PTC, ITC, or cash grant)

3) State mandated renewable portfolio standards in conjunction with renewable energy certificate trading options

4) Transmission infrastructure where connection, or tie-in to the grid, is economically feasible and within reasonable proximity to the wind resource site

5) Alternate generation methods within the service area to secure reliability in energy supply and accommodate intermittency by firming the electrical load

6) An encouraging social and political climate at the state or local level

Predicting how all of the conditions above will react to changes in the U.S. regulatory structure, the implementation of a carbon market for example, is extremely difficult. The six conditions listed above were chosen based on current legislation, regulatory mechanisms, and economic climate. Forecasting potential changes in the interactions between the conditions listed above are offered in the policy recommendation and conclusion sections of this paper.

For those policy makers, energy developers, or utility companies that wish to pursue commercial wind energy it is imperative that all of the conditions discussed above are considered. It is very difficult to build wind projects that will be successful when the right physical, economic, legislative, and social drivers are not in place. Wind installations have been extremely effective in areas where only two of the six conditions have been in place, but higher success rates will arise as more conditions are met. Areas being considered for development should not be chosen solely on the level of wind resource potential, as many of these regions have proved inadequate for development because of other factors, including insufficient transmission infrastructure or a local population unreceptive to the installation of wind turbines. Short-term renewal of the federal production tax credit has proved to be extremely problematic for the wind industry, and has been correlated to dramatic drops in yearly investment and overall capacity installed (Figure 6). As a developer or utility interested in wind, it is important to monitor the status of the PTC and ensure that the project will qualify for the benefits of the tax credit. Smaller entities, or non-taxable institutions, may want to consider involving a third party developer whose financial portfolio is large enough to fully utilize the benefits of the PTC and would be eligible as a private entity for the federal incentive. The following analysis is meant to educate stakeholders interested in pursuing industrial-scale wind energy development about the most critical conditions influencing the industry today and in the future.

CHAPTER TWO

WIND ENERGY AND THE ENVIRONMENT

2.1 Climate Change and Green House Gases

There is an undeniable need for new methods of electricity generation in order to meet our growing energy demand and rebuild the current energy supply system. The largest percentage of the world's green house gas (GHG) emissions, 25.9% in 2008, come from the production of electricity. This percentage is even higher in the United States at 40% (EIA 2008b). The dramatic increase in life expectancy and productivity in the developed world can largely be attributed to the ability to produce and utilize large amounts of energy, generally from the burning of fossil fuels. Improvements to help care, advancements in technological and information systems, and globalization can have also contributed to increased productivity and life expectancy in the developed world, but each of these additional changes is directly connected to energy use and supply. A concern over atmospheric climate change and greenhouse gas emissions has begun to emerge worldwide. The Kyoto Protocol is direct evidence demonstrating the seriousness of the problem. Never before in history have the nations of the world come together to draft such a challenging and controversial piece of environmental self-regulation regarding energy-use and the harmful affects of industrialization. As countries continue to release their pollution into the global commons, which includes the ocean and atmosphere, the Earth's ecosystem has begun to lose its resiliency and may be approaching a critical tipping point of environmental irreversibility. Taking on the challenges created by climate change will become an "iterative risk management process", which will require both mitigation and adaption (IPCC 2007). Converting the way we produce energy to zero-emission sources is one way to help mitigate the production of greenhouse gases and simultaneously adapt to an environment in which traditional fossil fuels become limited. The Northwest Power Conservation Council has made addressing climate change the primary theme of its Sixth Power Plan, and will take on the difficult challenge faced by regions across the country of achieving emission reduction goals while continuing to provide an economical and reliable power system (NPCC 2009). Wind power has the potential to dramatically reduce the amount of emissions entering the atmosphere as a result of generating electricity.

2.2 Wind Energy Demand and Supply

Energy demand has skyrocketed worldwide over the last century, and the overwhelming majority of that demand has been met with the burning of fossil fuels. Most utilities in the United States assume a constant growth in electrical demand of about 3% per year, but there are regions where this value has been lowered due to improvements in efficiency and demand management. 2008 marked the third consecutive year that wind power was the second-largest energy resource added to the U.S. electrical grid in terms of nameplate capacity, behind the 7,500 MW of new natural gas plants, but ahead of the 1,400 MW of new coal (DOE 2007). The new 5,328MW of added capacity made up 35% of all new electric generating capacity in the U.S. in 2007, growing significantly from the 19% added in 2006 (DOE 2007). Between 1991 and 2006 wind energy increased as the percent of renewable generation by source from 4.2% to 26.7%, as shown in Figure 4. As of September 30, 2008 the United States had a total of 22,613 MW of installed wind energy capacity (AWEA 2008).

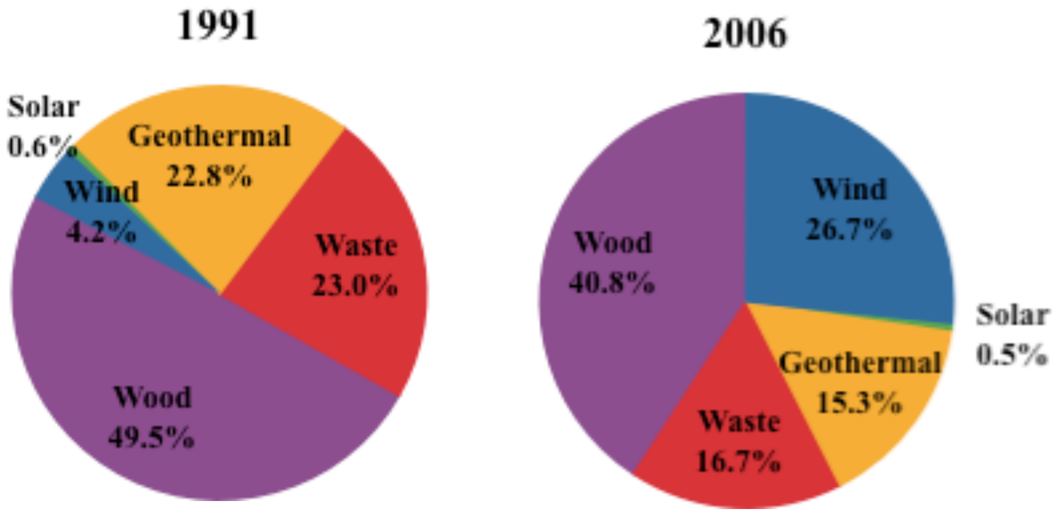

Figure 4. Percent of Renewable Generation by Source in 1991 and 2006

When using wind generator's nameplate capacity as a measure of additions made to supply, it must be considered that wind generation has a less consistent production capacity factor than some of the other renewable energy technologies, such as wood or geothermal, due to the variability of wind supply and intermittency. Capacity factors are meant to adjust generation potential for the influence of intermittency, average hours of facility operation, resource supply, and resource availability. Table 1 uses a capacity factor of 33% for wind generation in the Northwest United States, which assumes that turbines operating in the area will only produce 33% of the nameplate capacity if the facility were to operate twenty four hours a day all year long. Most values calculated for wind generation potential or total electrical output potential, such as those used in Table 3 for each state, take into account average wind speed and wind density in addition to average annual facility time in operation. These weighted values are a more accurate indicator of the actual service provided by a specific wind facility or cumulative electrical generation potential within a state.

Unfortunately the United States still receives less than 2% of its total electricity supply from wind power. The Department of Energy has conducted an analysis to examine the feasibility of achieving a 20% electricity supply from wind by 2030. A quick glance over the potential electrical output based on state wind resource potential in Table 3 indicates that this goal is realistic and achievable. Harnessing the wind potential in the state of North Dakota alone could meet nearly a quarter of the entire nation's electricity demand. The DOE's analysis concludes that reaching the 20 percent wind energy goal will require, "enhanced transmission infrastructure, streamlined siting and permitting regimes, improved reliability and operability of wind systems, and increased U.S. wind manufacturing capacity" (DOE 2008). A study by Elliot, Wendell, and Gower (1991) concluded that providing 20% of the nation′s electricity from wind would require only 0.6% of the land in the lower forty-eight states to be developed with wind turbines. In addition, the study explained that less than 5% of the required land would actually be occupied by wind turbines, electrical equipment, and access roads. Most existing land uses, such as farming and ranching, would remain unchanged.

One of the greatest challenges facing wind energy is that the areas with the greatest resource potential are commonly long distances from cities with high electrical demand. The distance between areas with high electrical supply and high electrical demand creates serious transmission barriers, and usually leads to higher transaction costs between utilities and for their customers. Efficiently bringing the nation's enormous wind energy supply from areas such as the Midwest to large cities will require new infrastructure and more effective management of the nation's electrical grid as a whole.

The Energy Information Administration (2008) has projected the amount of renewable energy in the United States to increase steadily through the year 2030 (Figure 5), with a large majority of that growth comprised of wind power. Of all the sources analyzed, only natural gas and liquid fuels are projected to decrease over the time frame analyzed. Coal is projected to have the highest amount of growth, but there are no assumptions used for the possibility of stricter carbon regulations through the implementation of a cap-and-trade market or tax based system. Carbon capture and sequestration is commonly mentioned when discussing the potential growth in the use of coal for energy production, but little evidence has been published regarding its overall effectiveness and its economic impacts in terms of cost-per-megawatt for power plants that choose to install the technology.

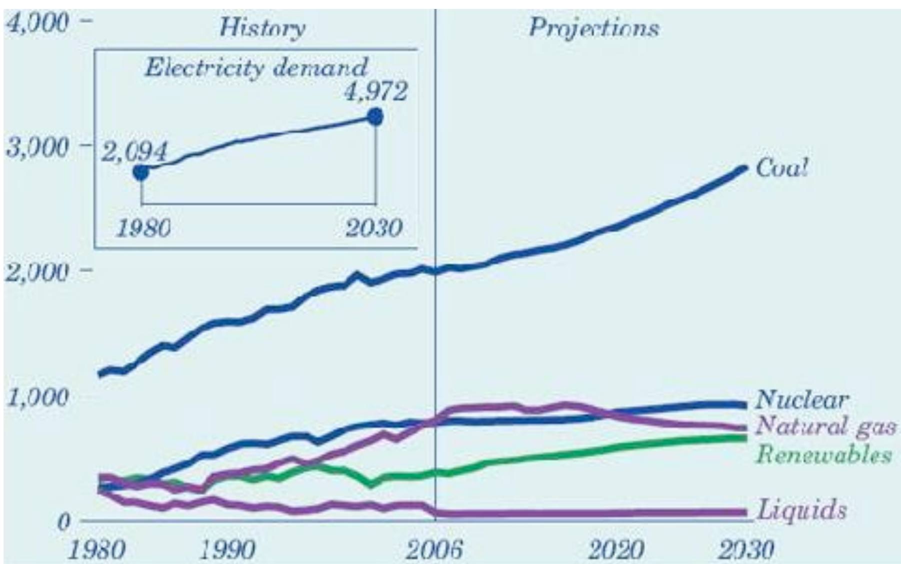

Figure 5. Projections for Energy Supply through 2030 in GW. (Source: EIA Energy Outlook 2008)

It will take time to determine if current manufacturing capabilities worldwide can handle a large surge in demand for wind turbine materials. Many wind advocates have voiced concern that bottlenecks exist in the manufacturing process and supply chain, and that obtaining turbine components from around the globe can create severe insecurities in supply. The DOE (2007) claims that no material restraints currently exist that would impair our ability to dramatically ramp up wind development. Their study was based upon assuming an increase in wind capacity to 20% of the total U.S. energy supply by 2030, which would be a thirty-fold increase from current supply and is a very aggressive prediction for growth. Even if no material barriers exist, skilled labor and manufacturing facilities will be required to create and assemble turbine components at a rate that can keep up with worldwide demand.

CHAPTER THREE

HISTORY OF WIND ENERGY

3.1 Federal Legislation

The history of environmental movement in the United States began in the 1960's and has evolved dramatically over time. Severe degradation of the environment inspired a social movement dedicated to regulating polluting industries and fighting to protect the remaining wilderness areas throughout the U.S. The creation of the National Environmental Protection Act (NEPA) in 1969 was one of the most historic pieces of environmental legislation, and established the environmental impact assessment process that is still used to this day. Any major project proposed by the federal government must complete an environmental impact statement for all activities that may impact the environment. Air quality was first addressed through federal policy with the Clean Air Act of 1963. In 1975 the Corporate Average Fuel Economy (CAFE) standards were in-acted to combat the cumulative impacts of fuel consumption, resulting from the large dependence on automobiles in the country, through tail pipe emissions standards and regulations (Simon 2007).

In the year of 1973 the United States experienced Oil Shock I that was a direct result of an oil embargo from OPEC. The dramatic decrease in fuel supply, along with skyrocketing costs, awoke the nation to the vulnerability of the United States energy supply. Heavy reliance on imported fuels was viewed as an economic and national security risk. Public opinion began to embrace the idea of domestic energy diversification, which spurred the first real interest in large-scale renewable energy technologies (Simon 2007). As a result, the National Renewable Energy Laboratory (NREL) was established in 1974, and began operation in 1977. The creation of the cabinet-level Department of Energy also occurred in 1977. To address growing concerns over domestic oil supply and security, the Strategic Petroleum Reserve was created in 1975. The United States experienced Oil Shock II in 1979 that led to a similar result in public opinion regarding alternative energy development but did not result in any landmark legislation or the creation of any new government agencies.

The first of a series of legislation aimed directly at energy related issues in the United States was the National Energy Act of 1978. In 1992 George Bush Sr. signed the Energy Policy Act into law, which was federal legislation that created a federal production tax credit system and encouraged diversification of the country's energy supply. The Energy Policy Act was amended in 2005 and 2007 and addressed accelerated depreciation rates for renewable energy projects, created special bond programs for financing, and included a renewal of the PTC. The 2005 renewal of the PTC was the first renewal to occur before the tax credit expired, which helped maintain consistent growth in the wind industry over the following two years (Figure 6).

Senators McCain and Lieberman introduced senate Bill S.139, titled The Climate Stewardship Act, in 2003 with the intention of regulating carbon emissions through a cap-and-trade market system. This innovative bill was the first of its kind, and has received thorough analysis by the Energy Information Administration and independent companies regarding its potential economic and environmental impacts. Although the Act has been through several revisions it has yet to pass through Congress and become U.S. law.

The two most recent pieces of federal legislation that concern wind energy development are the Emergency Economic Stabilization Act (EEST) of 2008 and the American Recovery and Reinvestment Act (ARRA) of 2009. The EEST renewed the PTC for one year for wind generation and eight years for solar-based energy production. The ARRA extended production tax credits for wind until 2012 and contained provisions that allow developers to choose between the PTC, an investment tax credit, or a cash grant option.

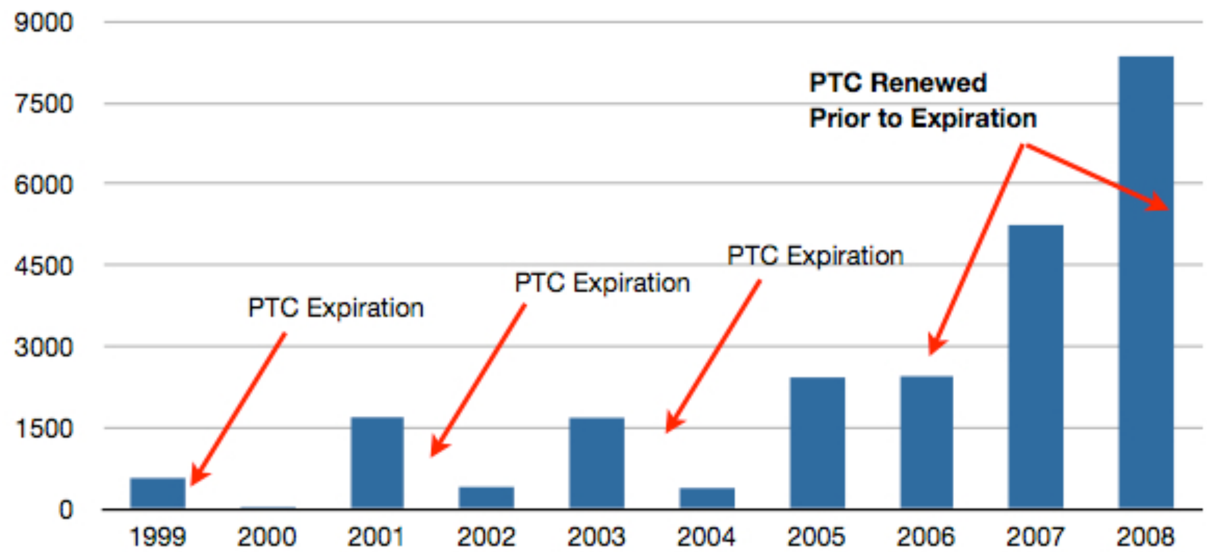

Figure 6. U.S. Wind Power Capacity Additions 1999-2008 in Megawatts and Points Showing PTC Expiration and Renewal.

3.2 State Legislation

Although most major environmental regulation has occurred at the federal level, many state governments have been more aggressive in setting their own environmental policy agendas and committing to proactively addressing the challenges of climate change. Initiatives such as the Governor's Climate Commitment, and efforts led by local governments, have moved closer to addressing the goals established by the Kyoto Protocol than any piece of national legislation to date. The best example of a state going above and beyond federal standards is California. California has been extremely aggressive in setting state-level policies to address energy related issues, air pollution, and climate change. Assembly Bill 32, titled the Global Warming Solution Act, requires California to reduce its greenhouse gas emissions to 1990 levels by 2020, leading to a reduction of approximately 30 percent, and then an 80 percent reduction below 1990 levels by 2050 (CEPA 2009). California has also made multiple attempts to increase regulations on vehicle emissions above the national standards. Assembly Bill 1493 passed in 2002, and an Executive Order established in 2005, call for reducing GHG emissions from California passenger vehicles by about 22 percent by 2012 and about 30 percent by 2016 (CEPA 2009).

Some of the most important mandates initiated at the state level have been renewable portfolio standards (RPS), with twenty-six states currently self-regulating their utilities with this policy mechanism. Nearly every RPS is unique, with varying load-percentage requirements and timelines for achieving those requirements. The type of energy generation technologies that qualify to count towards the RPS vary from state to states along with their specific definition of what is considered a renewable source. There are three energy sources that every state considers renewable in their RPS, including biomass conversion, solar photovoltaic and wind (Michaels 2008). It is unclear how states have chosen their specific percentage, and a great deal of variability exists between states even within similar regions of the country. In Michael's 2008 paper, "A federal Renewable Electricity Requirement", argues that a state's RPS is often determine by politics rather than science or economics, and that there are few indications that regulators have set their targets by using benefit-cost analyses. There is some truth to the argument that a RPS goal may be somewhat speculative, but there should be no debate about its effectiveness in forcing utilities to raise the percent of their electric load that comes from renewable sources. Economic incentives at the federal level such as the PTC help reduce the cost of installing the wind energy, but state RPS mandates are necessary in order to create a larger renewable energy market and increase demand for wind energy and other clean generation sources. These mandates may be necessary until market forces provide larger returns on wind development through some form of carbon regulation or a nationwide unbundled REC trading market. A federal RPS had been discussed but little legislative progress has been made for its establishment. Further analysis of the potential for a nationwide RPS target is discussed in the policy recommendations section.

CHAPTER FOUR

CONDITIONS FOR SUCCESS

4.1 Physical

Most of the large-scale wind energy development over the past decade has occurred in areas of moderate to high resource potential. The National Renewable Energy Laboratory has compiled a map of the United States that shows the geographic potential for harnessing wind energy and ranks each area from "excellent" to "poor". This type of easily accessible mapping system has allowed developers at all levels a simple first step for choosing ideal locations for wind turbine placement. If an adequate wind resource does not exist in the prospective project area that is accessible, then it is very difficult for developers and utilities in the service region to utilize wind energy as part of their supply portfolios. Resource maps such as these provide a very easy and inexpensive way for developers to conduct preliminary examinations to see if the right physical conditions are in place for turbine installation. Policy makers can also use these resource maps to determine where government funding and infrastructure development projects could be directed in order to most effectively utilize the nation's wind resources.

Once preliminary background research has been completed, one to two years of site-specific data collection is necessary so developers can confirm that there is sufficient wind speed, duration, and consistency at the chosen site. Utility-scale wind power plants generally require minimum average wind speeds of 6 m/s (13 mph) to be effective (AWEA 2009). When the peak hours of wind speed in an area coincide with peak demand hours, which normally occur during the middle of the day, the area becomes even more valuable for development.

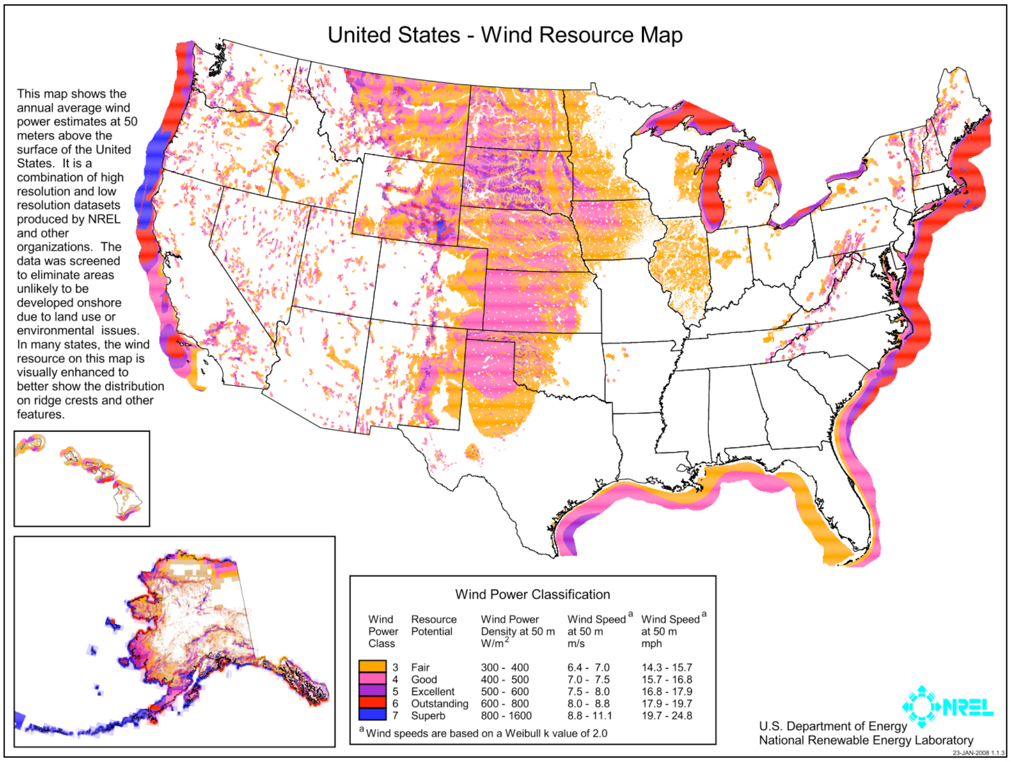

Figure 7. National Renewable Energy Laboratory Wind Resource Map of the United States. (Source: NREL, 2008)

The proximity of a wind facility to other sources of electricity generation is important to maintain a firm load and reliability in the service areas. These facilities can serve as "back-up" for wind generation and are ideally hydropower or natural gas plants, due to the ease of which their load can be adjusted quickly or additional generator capacity can be activated. New storage technologies may help solve some problems created by intermittency and off-peak load production, or help areas without a good "firming" energy generation source. It is important for utilities and developers to consider what other types of generation are near a proposed wind site, and to determine what type of extra capacity is available from these producers and the price that will be charged if shaping services are needed.

Limitations from transmission infrastructure can be viewed not only as an economic condition, but also as a physical constraint that may impede the development of more windpower facilities. Transmission is not only expensive; there are also many environmental concerns that arise when attempting to extend a high-voltage line to a project site. Extensive environmental analysis must be completed before laying new line, and the best access route is commonly not feasible because it runs through protected lands such as wilderness areas or a national park. The load capacity of existing transmission lines can be a physical restraint also. Quite often lines are already congested by existing generation and would be unable to maintain additional power added from a new wind development. Jacobs et. al (2005) makes an important argument stating, "the congested periods are often found during peak summer months, when power from wind generators is at its lowest monthly totals, while periods of maximum wind generation potential are found in periods when transmission is not physically congested".

Based on a study by the Department of Energy (2008), in order to achieve 20% electricity supply from wind energy approximately 12,650 miles of new transmission lines need to be built to handle the increase in load according to their WinDS models (Figure 8). WinDS is a powerful modeling system that can be used to account for a massive amount of variables influencing various aspects of energy generation, planning, distribution, and efficiency (DOE 2008). In the case of examining transmission, the model seeks to optimize for shortest line distance and smallest cost. The WinDS assumes the cost of new transmission to be split 50-50 between the developer and ratepayers in the service region. On top of additional costs, inadequate transmission has the potential to become a time barrier also. An industrial-scale wind farm can be built in less than 18 months, while a high-voltage transmission line can take five to 10 years to be completed.

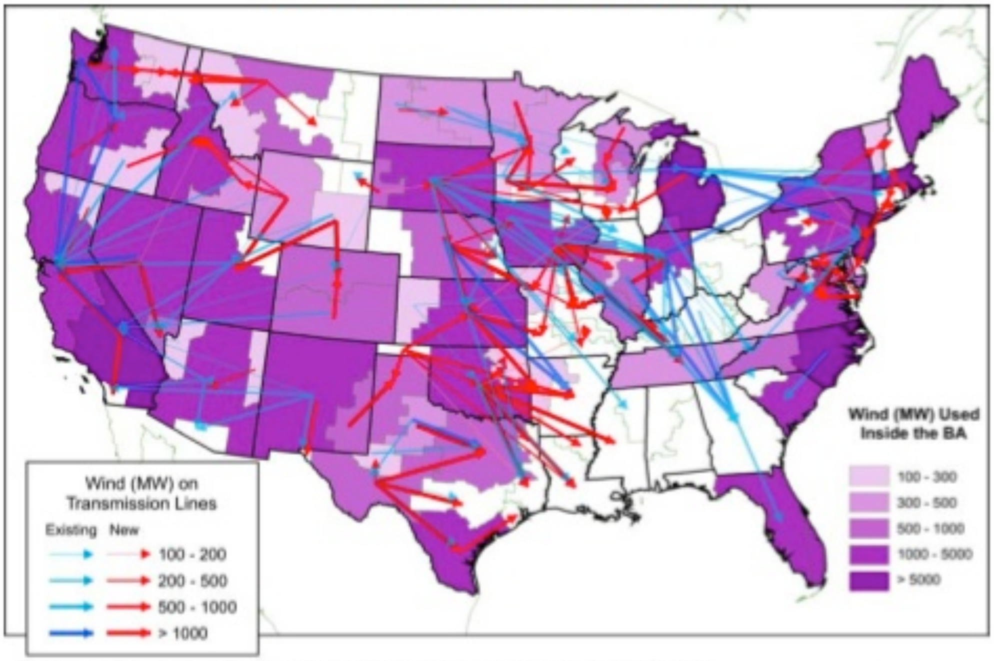

Figure 8. Proposed and existing transmission infrastructure by the year 2030 carrying load with electricity generated from wind. (Source: DOE 2008)

4.2 Economic

Electricity generated using wind turbines has become economically cost competitive with the help of government incentives such as the PTC and the rising cost of conventional fossil fuels over time. Shown below in Table 1a & 1b are levelized cost comparisons of electricity produced by combined cycle natural gas generation with wind generation in the Northwest United States. The Northwest region of the United States was chosen for the comparisons due to the large availability of data through the Northwest Power Conservation Council and the Energy Information Administration. The region serves as a great case study to examine the cost differences between combined cycle natural gas and wind-generated electricity. The difference in the average price of electricity between the Northwest region and the rest of the country has been gradually shrinking over the past 20 years. We are now looking at a less than 40% percent difference on average. The large difference in electricity price has been attributed to the massive amount of hydroelectric power in the region. There has been an overall increase in costs for all types of electricity generation, which the NPCC (2006) attributes to an average real increase in project construction cost of about 40 to 50% over the numbers published in the 5th Plan. The council also points out that improvements in energy capture and conversion efficiency of about 7% have helped offset these increases in cost.

It is reasonable to assume that the rest of the United States, the east coast in particular, would incur much higher costs for wind energy generation due to the smaller resource potential in the area and the higher shaping costs from lower availability of large-scale hydropower. The price of natural gas is also higher in this region, with the primary electricity generation for the Northeast being nuclear power and coal for the Southeast, not natural gas. These potential differences and their effects on total generation costs are examined in Table 2. Electricity generation form wind power in the Northwest may be far less expensive than most other regions in the country so it is important to consider the factors that may produce differences in total generation costs for both methods.

The economic comparison is designed as a project feasibility analysis, not a specific cost/benefit analysis, for the use of comparing wind and CC-natural gas generation costs. A more rigorous examination would require cost accounting or benefit/cost analysis to understand the social returns related to energy generation that are not covered in this study. The analysis is an update of a comparison completed by Ford et. al (2005) in a paper titled, "Simulating price patterns for tradable green certificates to promote electricity generation from wind". Since the original comparison (shown in Table 1a) was completed there has been a dramatic increase in the construction costs for wind facilities worldwide, primarily due to increasing turbine demand and rising costs of input materials such as copper, steel, and fiberglass. Operating and maintenance costs for CC-natural gas have increased only slightly, while fuel costs have increased dramatically and remain relatively unpredictable. The value of $8 per million Btu's was chosen based on the annual average price published by the Energy Information Administration for 2007. Although a final calculated average has not yet been released for 2008, it appears that the price will have risen well over $8/million Btu. Using data from 2008 and early 2007, and converting all values to 2006 dollars, final calculations show the total costs of CC-natural gas and wind generation have both increased to approximately $76 and $95 respectively. The difference in costs remains identical to the value of the federal PTC, which is currently at $19 (in 2006 dollars) per megawatt hour generated. The cost values calculated for wind are within the range predicted by the Northwest Power Conservation Council (2006), which ranged from $45 to well over $100/MWh. The $19/MWh cost differential between the two methods of generation in the Northwest, as seen in Table 1b, could be met through a federal tax incentive, revenue from REC trading, or through the implementation of a carbon market or regulatory mechanism.

This difference in price between CC-natural gas and wind calculated in the update is similar to the original results produced by Ford et. al (2005) that concluded the price difference to be approximately $12/MWh in year 2000 dollars, which was very close to the calculated value of PTC at the time (Table 1a). Converting the total cost values calculated from Ford's original comparison to 2006 dollars, using a Producer Price Index conversion factor of 0.76 for industrial electric power commodities, reveals that the costs for generation have risen in the Northwest by approximately $4 for CC-natural gas and $1 for wind per mega-watt hour (see Tables 1a & 1b) (Bureau of Labor Statistics 2009). The rise in natural gas prices has been the main influence on rising generation costs for CC-natural gas, while increases in capital costs has been the main influence on wind generation costs.

The fixed-charge rate, shown in Tables 1 & 2, is an industry standard accounting tool for incorporating interest rates and financing charges into total cost estimates for electricity generation. The value used by Ford et. al in their 2005 analysis was calculated upon an assumption that construction costs for new energy projects were funded through 60% debt financing, at a cost of 8% per year, and 40% equity financing at 17% per year. Taxes and insurance on the initial capital for construction were assumed to create an additional 2.9% in financing expenditures. The interest percentages used were based on capital markets and financing conditions from the year 2000. Since the original cost comparison was completed the financial system has changed dramatically, and interest rates and payments for debt and equity financing options have decreased so a lower overall fixed charge rate may be more appropriate for a current day analysis.

This method of using a standard fixed charge rate for both types of generation assumes CC-natural gas and wind generation facilities have identical project life spans and capital costs are depreciated at the same rate over time. This assumption is simplistic but reasonable, since technological improvements on wind turbines have allowed wind project life spans to grow to timeframes comparable to CC-natural gas facilities (~30 years), and almost all energy generation projects are allowed accelerated depreciation rates by the IRS. A more thorough cost/benefit analysis would take into account any site-specific differences in project lifespan, allowed depreciation rates, and any forecasted changes in interest rates and financing. The use of amortization schedules is another way to account for differences in project lifespan, depreciation rates, and costs incurred through financing capital costs. This strategy is more effective at accounting for the payback of principal for construction costs and not simply accounting for interest payments to project investors. Amortization methodology is beyond the scope of this analysis, so the levelized cost comparison relies on a uniform fixed cost rate for both CC-natural gas and wind generation.

CCs vs Wind Levelized Costs in the Northwest United States - *Original*		
(In Year 2000 dollars)	CCs	Wind
Fixed Costs		
Construction Cost ($/kW)	600	1,000
Fixed Charge Rate (1/year)	0.145	0.145
Annualized Construction Cost ($/kW-yr)	87	145
Fixed O&M ($/kW-yr)	10	20
Fixed Transmission ($/kW-yr)	15	20
Total Fixed Costs ($/kW-yr)	112	185
Capacity Factor to convert to $/MWh	0.9	0.33
Levelized Fixed Costs ($/MWh)	14.2	64.0
Variable Costs		
Variable O&M ($/MWh)	2.8	1
Cost of natural gas ($/million BTU)	5.5	
Heat Rate (BTU required per kWh)	6,900	
Fuel Cost ($/MWh)	38.0	
Shaping Costs ($/MWh)		5
Total Variable Costs	40.8	6.0
Total Cost ($/MWh)	55.0	70.0
Production Tax Credit ($/MWh)		(-)13
Total Investor Cost with PTC ($/MWh)	55.0	57.0
Total Cost in 2006 Dollars/MWh	72.3	92.1
Total Investor Cost with PTC in 2006 Dollars/MWh	72.3	75

Table 1a. Original Levelized cost comparison of combined cycle natural gas to wind energy generation in the Northwest United States from 2000.

CCs vs Wind Levelized Costs in the Northwest United States - *Update*		
(In Year 2006 Dollars)	CCs	Wind
Fixed Costs		
Construction Cost ($/kW)	780	1,500
Fixed Charge Rate (1/year)	0.145	0.145
Annualized Construction Cost ($/kW-yr)	113.1	217.5
Fixed O&M ($/kW-yr)	15	20
Fixed Transmission ($/kW-yr)	15	20
Total Fixed Costs ($/kW-yr)	143	258
Capacity Factor to convert to $/MWh	0.9	0.33
Levelized Fixed Costs ($/MWh)	18.2	89.1
Variable Costs		
Variable O&M ($/MWh)	3.0	1
Cost of natural gas ($/million btu)	8	
Heat Rate (btu required per kWh)	6,870	
Fuel Cost ($/MWh)	55.0	
Shaping Costs ($/MWh)		5
Total Variable Costs	58.0	6.0
Total Cost ($/MWh)	76.1	95.1
Production Tax Credit ($/MWh)		(-)19
***Current Condition* Total Investor Cost with PTC ($/MWh)**	76.1	76.1

Table 1b. Levelized cost comparison update of combined cycle natural gas to wind energy generation in the Northwest United States from 2006.

A brief sensitivity analysis was conducted to demonstrate how total generation costs in dollars per megawatt hour would be affected for CC-natural gas and wind generation when low, medium, and high cost scenarios were used for fixed charge rate, natural gas costs, and shaping costs. Variations in the fixed charge rate are not as dependent on geographic location similar to the way natural gas and shaping costs are. A fixed charge rate of 14.5% was used for the high-end since it was the industry standard in 2000 when interest rates were still relatively high, and total financing costs for energy developers have dropped dramatically since. Natural gas prices currently average around $8 per million BTU in the United States, so that value was used as the medium value. The values of $6/million BTU and $10/million BTU were chosen for the low and high because they have been the national average low and natural average high over the last five years (EIA 2008). Natural gas prices have demonstrated high volatility in the past and are predicted to continue to show similar behavior in the future. Although gas prices are inherently volatile, generators and utilities commonly use long-term purchasing contracts, which can help reduce the short-term variations in price. It is likely that natural gas prices will reach the high price assumption of $10/MWh over the next few years. The additional costs incurred from the shaping of energy fed into the grid are specific to wind and other renewable generation methods that cannot provide a firm and consistent electrical load like that of natural gas or hydroelectric generators. Since the Northwest has a clear advantage in terms of shaping costs, due primarily to the large availability of hydropower generation potential, the value of $5 per megawatt hour produced was used for the low assumption in the sensitivity analysis shown in Table 2. This value was calculated by the NPCC and used in its 5th and 6th Power Plans. Values for the medium and high estimates were chosen based on average costs for gas-fired turbine shaping services that are incurred throughout most of the United States where hydropower back up is not readily available. The California Energy Commission predicted that generation costs from gas combustion turbines would be $15.9/MWh in 2008, which was one of the highest cost estimates found, so the value of $15/MWh (in 2006 dollars) was chosen as the high-end value to estimate sensitivity for shaping costs and its effects on total costs for wind based generation. After adjusting for low, medium, and high cost scenarios regarding fixed charge rate, natural gas price, and shaping costs, the total cost range for CC-natural gas generation was determined to be between $59/MWh - $89/MWh. Sensitivity analysis for wind generation revealed a total cost range of $85 – $105/MWh before accounting for the production tax credit (Table 2).

CCs vs Wind Levelized Costs 2008 Update - Sensitivity for Fixed Charge Rate, Natural Gas Cost, and Shaping Costs						
(In Year 2006 Dollars)	CCs			Wind		
Fixed Costs	Low	Medium	High	Low	Medium	High
Construction Cost ($/kW)	780	780	780	1,500	1,500	1,500
Fixed Charge Rate (1/year)	0.125	0.135	0.145	0.125	0.135	0.145
Annualized Construction Cost ($/kW-yr)	97.5	105.3	113.1	187.5	202.5	217.5
Fixed O&M ($/kW-yr)	15	15	15	20	20	20
Fixed Transmission ($/kW-yr)	15	15	15	20	20	20
Total Fixed Costs ($/kW-yr)	128	135	143	228	243	258
Capacity Factor to convert to $/MWh	0.9	0.9	0.9	0.33	0.33	0.33
Levelized Fixed Costs ($/MWh)	16.2	17.2	18.2	78.7	83.9	89.1
Variable Costs						
Variable O&M ($/MWh)	2	2	2	1	1	1
Cost of natural gas ($/million BTU)	6	8	10			
Heat Rate (BTU required per kWh)	6,870	6,870	6,870			
Fuel Cost ($/MWh)	41.2	55.0	68.7			
Shaping Costs ($/MWh)				5	10	15
Total Variable Costs	43.2	57.0	70.7	6.0	11.0	16.0
Total Cost ($/MWh)	59.4	74.1	88.9	84.7	94.9	105.1

Table 2. Levelized cost comparison with sensitivity analysis for low, medium, and high cost scenarios for fixed charge rate, natural gas cost, and shaping costs.

When lower fixed charge rates are experienced for energy developers, wind facilities become more cost-competitive with CC-natural gas generators due to their high construction and capital costs. When market conditions and financing options lead to low fixed charge rates, CC-natural gas generators lose additional advantage and the price differential when compared to wind generation becomes smaller. As natural gas prices rise, costs for generators heavily reliant on those fuel inputs become dramatically more expensive due to large increases in total variable costs (Table 2). This cost increase for CC-natural gas generation makes wind generation much more cost-competitive as it relies on zero additional fuel inputs for generating electricity and wind generators have extremely low variable operating costs. As energy shaping costs increase from back-up sources, electricity generated from wind facilities becomes more expensive (Table 2). The increase in shaping cost does not have as n significant effect on total generation costs for wind as increases in natural gas supply have on CC-natural gas based generation, but it does have an impact on the overall cost competitiveness of wind generation and leads to an even larger difference in price between the two methods of generation.

One of the greatest challenges facing the expansion of wind energy is the distance between the majority of high resource areas and grid access points, or high-density urban areas with a large demand for electricity. Transmission costs can account for 10%-15% of a wind project's total costs and is generally around $300 total for each kW that is produced over the lifespan of the project (LBNL 2009). An article recently published in USA Today (2008) focused on a transmission study that concluded that the average cost of high-voltage line (<756kW) is $1.5 million-per-mile. "It is clear that institutional issues related to transmission planning, siting, and cost allocation will pose major obstacles to accelerated wind power development, but also of concern is the potential cost of this transmission infrastructure build out" (LBNL 2009). The values of $15/kW-yr and $20/kW-yr were used for CC-natural gas and wind generation in the levelized cost comparison in Tables 1a & 1b. As more wind sites are developed, more projects would be sited farther from load centers thereby causing the transmission costs to increase. At this point in time the difference in transmission costs for CC-natural gas and wind is only $5/kW-yr, but will most likely increase over time unless major infrastructure projects are completed that would provide easier transmission access for wind sites. This is primarily due to the fact that easily accessible sites are developed first, leaving remote sites and sites with lower resource potential to be developed last. Due to the large role that transmission infrastructure plays in the economic feasibility of a wind project, it is important for developers and utilities to consider it as a condition that may determine whether or not an area is suitable for development. Policy makers also need to consider the barriers created by insufficient transmission because of the direct relationship to potential for increasing installed wind energy capacity in a region. Further analysis regarding legislative action that should be taken in order to address transmission issues is offered in the policy recommendations section of this paper.

Another cost that is often mentioned when discussing the economics of wind energy is the additional resources needed to accommodate the intermittency of wind. The Department of Energy (2008) concluded that if wind energy were to reach 20% market penetration (which is currently only at 2%), it could be reliably integrated into the grid for less than 0.5 cents per kWh. Further research and development of advanced storage options could help reduce the problems with wind's intermittency and the related costs. These technologies and their average capital costs in 2006 dollars include; Advanced batteries at $390/kWh; Compressed air energy storage at $350/kWh; Flywheels at $750/kWh; Conventional pumped hydro at $1200/kWh, and super-capacitors at $180/kWh target (Electric Power Research Institute 2006). Advanced fuel cells, solar thermal storage, and molten salt technology also serve as potential storage options, but no cost studies have been conducted yet to determine their potential capital costs. Wind developers and utilities could consider these new storage options as a replacement for load firming generation in a service region when analyzing a project's feasibility. Accessing existing generation sources in a region that can serve as load back up for wind provides much greater security for developers and utilities than relying on the installation of new expensive storage technologies.

Advocates of advancing regulation on greenhouse gases, primarily to combat global climate change, have suggested institutionalizing some sort of price signal for emissions, particularly on carbon dioxide from electricity generators. An institutional change, such as the creation of a carbon market, could dramatically influence the current economic position of wind energy. Wind energy interest groups support pricing carbon emissions as it gives zero-emission generators a competitive advantage over fossil fuel based generation systems. Wind energy advocates also call for allocation of initial carbon allowances based on electricity generation, which would favor all generators, and not based on total CO_2 emissions, which would favor coal based generation. This method of market regulation would lead to additional costs that would be incurred only by those generators who emit carbon, and would help narrow the ~$21/MWh price gap between alternative and traditional generation sources.

4.3 Legislative

Political support for wind energy has risen and fallen over time, and is currently in a period of high support from the Obama Administration and the public. Instability in imported fuel supply in the past led to short bursts of investment and public focus on increasing the nation's reliance on renewables. Today, the concern is not only over dependence on foreign fuels, but also climate change and an environment that is being degraded by a dirty energy system. A large industrial process such as the generation of electricity can only be successful in the United States when there is sufficient support from politicians and a high demand from consumers. Wind energy is at a pivotal point in its industry's evolution when these two factors are in place and developers need to capitalize on the current sociopolitical climate.

The largest legislative influence on the wind industry was been the creation of the federal production tax credits in the Energy Policy Act of 1992. Before this legislation was in place there was only marginal growth in the number of wind projects being installed each year, and many were put on hold during lapse periods in PTC renewal. As described by the Union of Concerned Scientists (2008), "many renewable energy developers came to depend on the PTC to improve a facility's cost effectiveness and may hesitate to start a new project due to the uncertainty that the credit will still be available to them when the project is completed". The tax credit is provided to generators over a ten-year period, from the point of project completion, and is proportional to the level of generation from each wind facility. The current value of the PTC stands at $21/MWh and has been adjusted for inflation since its original implementation in 1992. Project owners are able to transfer the benefits of the credit to new owners if they choose to sell before the 10-year period is over which in turn provides more liquidity on their investment.

Federal legislation which implements a long-term renewal of the PTC has been recommended in order to secure investment in the wind industry until another legislative or economic mechanism is in place to counteract differences in cost between traditional methods of generation and wind. The PTC was most recently renewed as part of the ARRA in 2009 and will cover all wind projects that are completed until 2012. Developers and utilities constantly monitor the status of the PTC and corresponding legislation in Congress to insure that this primary condition is in place before undertaking a new development or expanding an existing wind project.

Recent provisional changes in the American Recovery and Reinvestment Act of 2009 have broadened developers' options for utilizing federal tax incentives relating to renewable energy. The federal Investment Tax Credit (ITC), which was initially unavailable to wind generators, can now be claimed by newly constructed facilities instead of the PTC. The ITC provides a tax credit to the developer worth 30% of the total project cost and is vested over a five-year period. The ARRA also states that any entity that is eligible for the ITC (which now includes almost all wind projects) can also receive the value in a cash grant format. Unfortunately these two new options are non-transferable if the project owner chooses to sell the wind facility, and can only be claimed by the initial developer.

State level legislation, known as renewable portfolio standards (RPS), have helped maintain a high market demand for wind power and other alternatives by forcing electricity serving utilities to obtain a certain percentage of their load supply from renewable sources. Wind has become the primary energy type for meeting these mandates as it remains the most cost competitive compared to nuclear, hydroelectric, and traditional fossil fuel based sources which are listed as non-renewable under most RPS mandates. There are currently twenty-six states in the nation who have self-imposed renewable portfolio standards. Each states has its own target percentages for utilities and dates when those percentages must be met. Meeting the new demand for renewable power created by these mandates would require 53GW of new non-hydro renewable electric production by the year 2020, which totals to $53 billion in capital investment (Knutson and McMahan 2005). Although the federal production tax credit is most responsible for reducing the costs for producing electricity from wind, state level portfolio standards assist in maintaining a demand for wind development and encouraging long-term contracts with utilities for the electricity produced by the facilities.

Wind energy facility developers should focus their attention on states with RPS targets in place, as these areas will have a more secure level of demand for the electricity produced. Monitoring states that are currently deliberating passing a RPS mandate would also be a good business strategy. Although it is not necessary that a state have a RPS in place for developers or utilities to invest in new wind capacity there, it is the second condition that suggests a good environment exists for wind energy development.

CHAPTER FIVE

INTERDEPENDENCE OF CONDITIONS

This chapter examines the interdependence of the conditions by focusing on the dynamic interconnectedness. Many of the incentives and regulations that will allow, or have allowed, wind development to be successful are mutually beneficial and require the others to achieve their ultimate goal of increasing installed capacity. The sum is truly greater than each of the parts when considering what has allowed wind energy to become economically and politically competitive with existing fossil fuel based energy sources. The initial condition that must be met before any of the others can be evaluated is whether or not the area being considered has an adequate wind resource potential with sites that are accessible for development. If there is not a sufficient amount of wind present, than other economic and legislative conditions are relatively unimportant. Once an area's resource potential has been deemed acceptable for wind installations then the other conditions can be evaluated.

Without the federal Production Tax Credit, most wind investors and developers would not be able to obtain the type of financial returns necessary to make their wind projects economically feasible, but without state implemented renewable portfolio standards a sufficient demand may not exist to drive the market for wind energy in most regions. Renewable portfolio standards may help create a market for wind energy, but without the ability to trade some type of renewable power certificate the transaction would be confined to one generator and one power purchaser. This would mean that the environmental benefits and clean power would not be able to cross state lines and would not transfer between generators, utilities, and third parties. A combination of all three conditions described above can help encourage expansion of transmission infrastructure in a region because not only will the wind energy production be profitable and flexible when sufficient demand exists, but a shared interest in its success will be established, thereby creating shared cost responsibility in the transmission projects. When local citizens and politicians observe the benefits derived from developing wind energy in their area, the entire sociopolitical climate can shift to embrace future development while encouraging similar behavior in surrounding communities.

Regions that derive most of their electricity from hydroelectric or natural gas generation have a competitive advantage when it comes to integrating wind energy because of their ability to firm the energy supply with relative ease and low cost (compared to other firming sources such as coal or nuclear generation). This leads to a reduction in costs for accommodating an intermittent energy source for generators, distributors, and customers. This unique advantage may encourage a state to adopt more aggressive renewable portfolio standards and foster a more encouraging climate between local utilities, citizens, and government officials.

5.1 Matrix of Potential Measures for Wind Energy Success by State

There are multiple ways to examine the level of success of wind energy across the country. Table 3 shows a mix of different quantitative and qualitative measures that were chosen to examine what conditions might be influencing the level of wind development for all fifty states. The American Wind Energy Association and the National Renewable Energy Laboratory both keep up to date records of the total installed wind capacity within each state. Total installed capacity is a good indicator for the magnitude of wind development, but does little to explain why that development is occurring. The matrix below lists states in descending order from highest installed wind capacity to lowest. Nine out of the top ten states in installed capacity have a RPS target in place, and six of those states allow the unbundled trading of RECs. This is a good indication that the implementation of a state-level RPS may lead to increases in development, thereby raising the total amount of installed wind capacity in the state.

The primary electricity generation source in 2008 for each state, as listed by the Energy Information Administration, was included in the matrix to determine if any connection exists with the level of wind development within the state. It has been suggested that high reliance to natural gas for electricity generation may lead a state to implement a RPS and develop more renewables, but there appears to be little evidence that this claim is true based on the data provided in Table 3. The top two states with highest wind capacity, Texas and California, both rely on natural gas as their primary sources of electricity generation, but experience gas prices that are about 15% lower than the national average. There appears to be an even distribution of primary sources for generation when compared to the level of installed wind capacity throughout the matrix. One noticeable difference to this general uniformity is that the four states using hydropower as their primary method for generating electricity are in the top half of the list, with Washington and Oregon ranked at 5th and 8th in terms of total installed wind capacity.

Resource potential rating is a very important variable that was included in the fifty-state matrix. Comparing a state's resource potential to its actual installed capacity reveals how well the wind resource is being utilized. North Dakota is a great example of underutilization, with the highest resource potential ranking in the country, but ranked 11th in terms of total installed wind capacity. Suggestions for why this may be occurring in North Dakota are offered in the following state case study section. Although the state of California has been ranked 17th in terms of total wind resource potential, it is the second highest state in terms of installed capacity, which suggests that it has been very successful in utilizing its wind resource through various legislative and economic mechanisms.

In addition to direct comparison between the measures shown in the matrix, four specific states are examined as case studies in the following section to provide further insight into what factors may influence the success or failure of wind energy at the state level.

	Total Wind Capacity Installed (MW)	Percentage of Electricity from Wind (%)	Average Price per kWh 2007 ($)	Renewable Portfolio Standard	RPS Mandate	Primary Electricity Generation Source	Un-bundled REC Trading Options	Resource Potential Rating	Wind Energy Potential Annual Power Output (MW)	Average Natural Gas Price for ElecGen in 2007 ($/million BTU)
Texas	6698	2	10.31	Yes	5880MW by 2015	natural gas	Yes	2nd	136000	6.77
California	2537	2.6	12.55	Yes	20% by 2010	natural gas	No	17th	6770	6.72
Iowa	1655	5.5	6.54	Yes	105 MW	coal	No	10th	62900	7.73
Minnesota	1438	4.6	7.02	Yes	25% by 2025	coal	Yes	9th	75000	Withheld
Washington	1367	2	6.57	Yes	15% by 2020	hydroelectric	Yes	24th	3740	6.15
New York	1078	0.6	15.5	Yes	20% by 2020	nuclear	Yes	15th	7080	8.09
Colorado	1068	1.3	7.87	Yes	20% by 2020	coal	Yes	11th	54900	4.35
Oregon	988	3.5	7.27	Yes	25% by 2025	hydroelectric	Yes	23rd	4870	6.10
Illinois	915	0.3	8.65	Yes	25% by 2025	nuclear	No	16th	6980	7.26
Kansas	815	2.3	6.72	No	-	coal	No	3rd	121900	6.31
North Dakota	714	1.8	6.63	No	-	coal	No	1st	138400	6.41
Oklahoma	689	2.6	7.66	No	-	coal	Yes	8th	82500	7.88
Wyoming	676	1.6	5.44	No	-	coal	No	7th	85000	Withheld
New Mexico	496	3.9	7.61	Yes	20% by 2020	coal	Yes	12th	49700	Withheld
Pennsylvania	374	0.2	9.05	Yes	18% by 2020	coal	No	22nd	5120	8.01
West Virginia	330	NA	5.37	No	-	coal	No	32nd	594	8.03W
Montana	272	1.7	7.78	Yes	15% by 2015	coal	Yes	5th	11600	Withheld
Indiana	228	NA	6.56	No	-	coal	No	NA	NA	7.48
South Dakota	187	2.6	7.03	No	-	hydroelectric	No	4th	117200	Not applicable
Missouri	163	NA	5.87	No	-	coal	No	NA	NA	Withheld
Idaho	138	1.6	5.18	No	-	hydroelectric	No	13th	8290	Withheld
Nebraska	117	0.7	6.2	No	-	coal	No	6th	99100	8.97
Hawaii	63	1.3	23.11	Yes	20% by 2020	petroleum	No	NA	NA	Not applicable
Michigan	60	NA	8.26	No	-	coal	No	14th	7460	6.63
Wisconsin	53	0.2	8.38	Yes	10% by 2015	coal	Yes	18th	6,440	7.56
Maine	43	0.6	12.87	Yes	10% by 2017	natural gas	No	19th	6390	withheld
Tennessee	29	0.1	7.29	No	-	coal	No	39th	186	Withheld
Utah	20	NA	6.61	Yes	20% by 2025	coal	No	26th	2770	Withheld
New Jersey	8	NA	12.98	Yes	22.5% by 2021	nuclear	Yes	29th	1200	8.17
Ohio	7	NA	7.75	No	-	coal	No	36th	410	7.88
Massachusetts	6	NA	14.98	Yes	4% by 2009	natural gas	Yes	25th	2880	8.11
Vermont	6	0.2	12.07	Yes	20% by 2020	nuclear	No	34th	537	7.72
Alaska	3	0.1	14.05	No	-	natural gas	No	NA	NA	3.58
New Hampshire	1	NA	14.09	Yes	16% by 2025	nuclear	Yes	35th	502	Withheld
Rhode Island	1	NA	13.23	Yes	15% by 2020	natural gas	Yes	NA	NA	8.06
Alabama	0	0	7.53	No	-	coal	No	NA	NA	7.19
Arizona	0	0	8.94	Yes	15% by 2025	coal	No	30th	1090	6.84
Arkansas	0	0	6.84	No	-	coal	No	27th	2460	7.04
Connecticut	0	0	15.72	Yes	23% by 2020	nuclear	Yes	33rd	571	7.81
Delaware	0	0	11.58	Yes	20% by 2019	coal	Yes	NA	NA	Withheld
Florida	0	0	10.38	No	-	natural gas	No	NA	NA	9.35
Georgia	0	0	7.46	No	-	coal	No	40th	171	7.54
Kentucky	0	0	5.57	No	-	coal	No	NA	NA	7.96W
Louisiana	0	0	8.61	No	-	natural gas	Yes	NA	NA	7.53
Maryland	0	0	12.03	Yes	9.5% by 2022	coal	Yes	37th	338	7.89
Mississippi	0	0	8.11	No	-	coal	No	NA	NA	7.43
Nevada	0	0	10.07	Yes	20% by 2015	natural gas	Yes	21st	5740	6.31
North Carolina	0	0	8.03	Yes	12.5% by 2021	coal	Yes	NA	NA	Withheld
South Carolina	0	0	7.13	No	-	nuclear	No	NA	NA	8.16
Virginia	0	0	7.09	No	-	coal	No	NA	NA	8.42

Table 3. Fifty state comparison of potential measures for wind energy success by state, listed in descending order by total wind capacity installed.

5.2 State Case Studies

Examining several states that are key players in the field of wind energy will help provide insight into how the conditions described above are influencing their progress. It is also useful to examine the state of North Dakota, which is relatively underdeveloped in terms of utilizing its wind energy potential. Figure 9 shows total installed wind power capacity for each state in the U.S. as of 2008. It is obvious that the southeast United States does not have sufficient wind resource potential to spur commercial development, or meet ambitious RPS targets that would rely on large-scale wind energy production (Figure 7). This region is not analyzed here specifically for this reason.

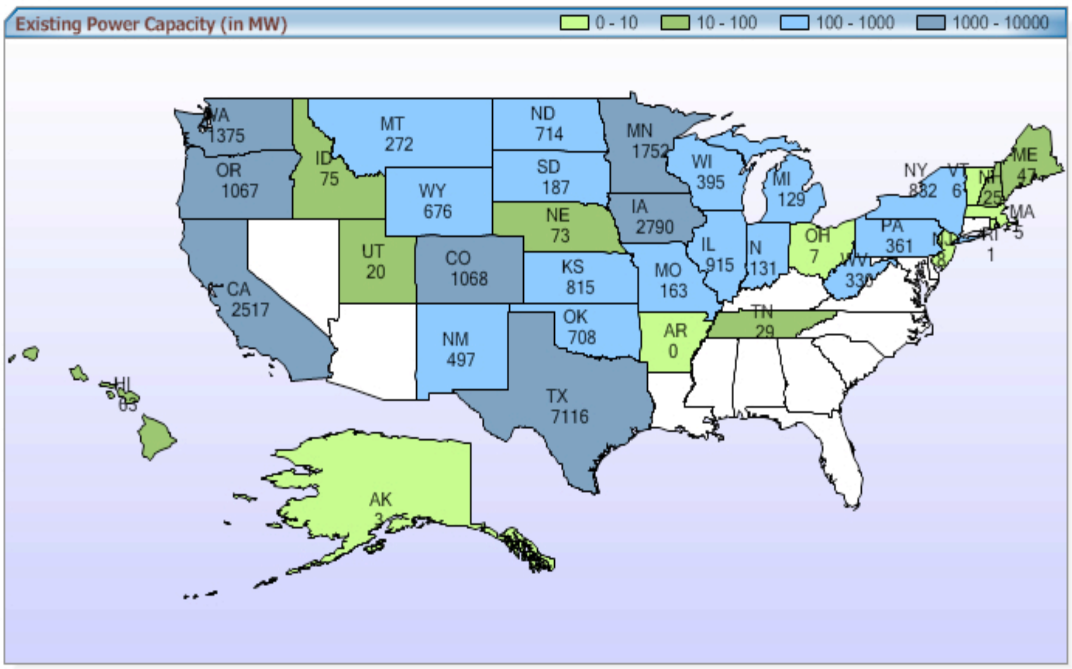

Figure 9. Installed Wind Power Capacity by State as of 2008. (Source: American Wind Energy Association 2009)

North Dakota

The state with the highest wind resource potential in the United States is North Dakota (AWEA 2008). NREL has rated the entire area within the state as fair to excellent in terms of wind resource quality. North Dakota has the potential to produce more than 1.2 trillion kWh of electricity every year from wind, which could power over a quarter of the United States (Figure 10). Unfortunately this resource is severely underutilized, with the total installed wind capacity in the state at 714MW, placing North Dakota 12th nationwide in terms of installed wind capacity. Wind power makes up only 1.8% of the state's total electricity generation. Elaborating on this point, one state official stated that North Dakota is "a rural state lacking the population and load growth needed to drive energy development". According to NationalWind and Windpower.com (2009), as of December 2008 there were no additional wind projects currently underway within the state. The apparent lack of installed wind capacity may be attributed to several factors. First, the state has not yet instituted a renewable portfolio standard and in turn also does not have any form of REC trading system in place. Although not a state mandated RPS, North Dakota did enact legislation in 2007 that establishes a voluntary objective asking that 10% of all retail electricity sold in the state be obtained from renewable energy and recycled energy by 2015 (NationalWind 2009). This goal is non-binding and therefore carries little weight for regulating the state's utility providers. Second, North Dakota has been continually cited as lacking sufficient transmission infrastructure to support large amounts of new generation from wind. Much of the transmission lines running through the state are 345 kilovolts or less, which is sufficient for intrastate movement of electricity, but insufficient to transmit power from large wind installations to other states in the region. This issue is currently being addressed through the creation of the North Dakota Transmission Authority, which was intended to be a "catalyst for new investment in transmission by facility, financing, developing and/or acquiring transmission to accommodate new lignite and wind energy development" (NDTA 2008). This authority, which is backed by state government funding, is meant to be a measure of last resort for transmission expansion only when private entities are not interested in building new transmission themselves, or are not providing the necessary grid expansion that is in the best interest of the state.

Expansion projects funded by private companies and utility providers are currently underway in North Dakota, including two lines by Basin Electric, which may help increase the speed at which wind energy is installed in the state. ITC Holdings Inc. has also proposed a "Green Power Express" transmission project that would build a $10 billion to $12 billion transmission network to move 12,000 megawatts of power from the wind-abundant areas in the Dakotas, Minnesota and Iowa to Midwest load centers, such as Chicago (Sustainable Business 2009). The proposed "Green Power Express" would consist of transmission lines capable of handling 756 kilovolts of power and would be a dramatic improvement to the state's transmission infrastructure.

Several state-specific tax incentives have been recently been put in place by North Dakota's government with the hope of spurring more small-scale wind energy installations in additional to commercial sized development. All taxpayers within the state that purchase and install wind energy equipment can claim a 3% income tax credit for up to five years for all projects installed after December 21, 2000 (NationalWind 2009). All or part of the credit can then be sold or passed on to the purchaser of the electricity generated by the project, in consideration with a "power purchase agreement" or for construction of a transmission line after August of 2007. Property taxes are reduced by 70% for 100kW wind facilities or larger and systems are also exempt from sales tax, but all wind projects must begin construction by January 1, 2011 to be considered eligible for the property tax exemptions (NationalWind 2009).

The EmPower ND Commission, an agency designed to oversee energy related issues in the state, has set a goal to increase wind capacity to 1,500MW by 2020, which would entail a doubling of current capacity (NDTA 2008). This value is extremely low considering the enormous resource potential the state has. A more aggressive target set by a state level RPS, similar to efforts in Texas, would be much more effective at encouraging wind development up to its full potential in North Dakota. Residents and politicians in North Dakota are making progress towards expanding the role of wind energy in the state, but annual additions in capacity have continued to show marginal growth, which suggests that a more drastic approach needs to be taken by the state government and utility providers.

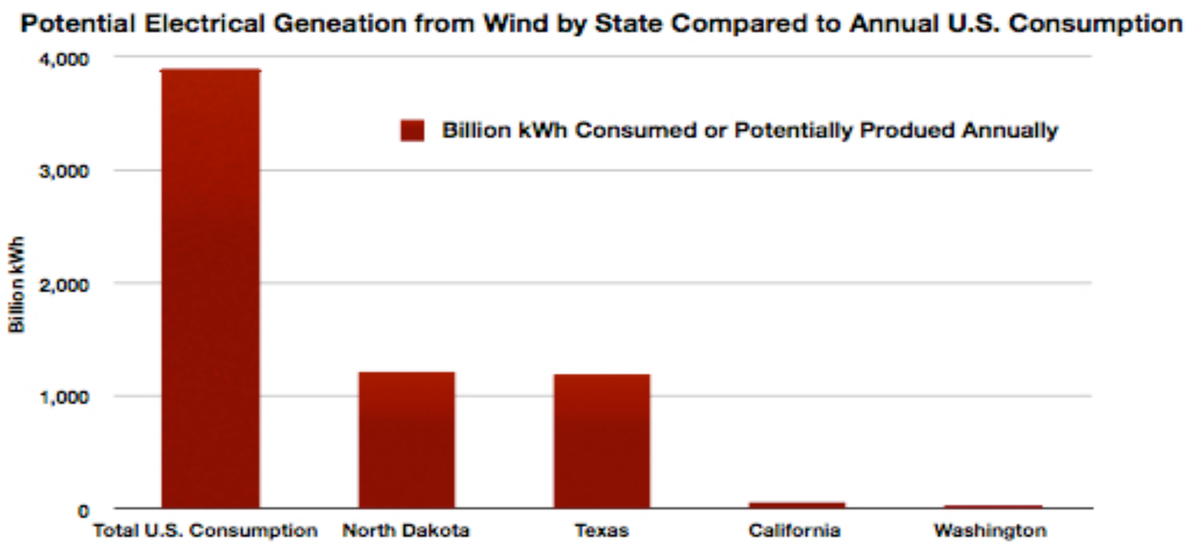

Figure 10. Potential electrical generation from wind by state compared to annual U.S. consumption in 2008.

Washington

Washington has proved an interesting exception to the argument that a state's installed wind capacity is directly dependent on its level of available resource potential. Although the state is ranked 24th overall in wind potential, it has 1367 MW of installed capacity, which places it 5th nationwide (Table 3). The state also has a low average electricity cost which can be attributed to the enormous supply of hydropower in the region. This hydropower supply may prove to be a critical link to the large number of wind installations in the state. These hydroelectric dams have massive reservoirs, storing large amounts of water for potential generation, and electrical output can be controlled with relative ease with little lag time.

Hydropower in the Northwest is traditionally used to meet the majority base-load requirements, but can easily be adjusted to meet peaking power when the load calls for additional generation. These characteristics, along with the fact that hydropower is inherently inexpensive, reduce the firming costs that wind generators face in the region and help create an economic climate that increases the cost competitiveness of wind power.

Another interesting feature that may make wind attractive in Washington is the local utilities' offering of "green blocks of power" to customers (Avista 2009). This option, which comes with a slightly higher premium, guarantees that a certain amount of power will come from renewable sources. These types of option programs foster increased demand for sources such as wind on top of the demand already being created by the state's RPS target. It is difficult to attribute the large growth in wind capacity in Washington to the state's RPS due to the fact that it is relatively modest (15% by 2015) compared to the other top-10 wind power generating states.

Lack of adequate transmission is rarely cited as a major barrier for the expansion of wind energy development in the state of Washington. Most of Washington's hydroelectric projects required the building of large transmission lines to remote areas within the state when they were being installed. The distance for tie-in to the grid is relatively short for new wind developers in Washington because of these lines, compared to other states that did not expand to accommodate similar hydropower development in the past.

Texas

The state of Texas has had the greatest success by far in terms of installing new wind capacity. Texas currently leads in the United States as the state with the most wind power, at 6698 MW of installed capacity, and has almost three times as much as the state of California which sits at number two. Based on wind resource potential rankings published by the AWEA

(2008), Texas has the second highest resource potential in the country. Similar to North Dakota, if Texas' generation potential from wind were fully utilized, the state has the ability to generate nearly a quarter of the electricity consumed annually in the United States solely from wind energy (Figure 10).

The states of Texas and California both consume electricity at a rate that is well over the national state-average due to their large populations and the multiple megacities located within their borders. This large electrical demand, which is constantly growing, and high prices for consumers have been the primary drivers behind the growth in wind energy and its popularity in the state. According to the State Energy Conservation Office of Texas (2008), "wind power development in Texas has more than quadrupled since the RPS was established.... due to its competitive pricing, available federal tax incentives and the state's immense wind resources, wind power is expected to remain competitive with coal- and gas-fired plants".

One unique characteristic of Texas's RPS target is that it is stated in terms of actual mega-watts required, not as a percentage of its utilities' total load. By doing so, the state created greater predictability in the actual amount of wind capacity that would result from the RPS implementation. The RPS currently states that 5880MW of electrical generation potential within the state must come from wind by 2015. Most state's set their RPS goals as percentages because it is assumed that electrical demand will grow constantly, and in turn the RPS will require the amount of renewable generation to continue to grow simultaneously. In the case of Texas, setting of their RPS in real mega-watts will only be effective in promoting long term increases in wind if the requirement is progressively raised over time. It is difficult to determine how the RPS has affected wind growth in the state due to the fact that growth has already surpassed the target by over 1000 MW of installed capacity, being the only state in the country to have met and surpassed its RPS target. Setting the RPS in terms of megawatts installed capacity also does not reveal how much electricity supplied customers will actually come from wind generation. Although implementing targets on installed capacity can help encourage more wind energy installations, this type of RPS mandate does little to influence how much of a utility's load actually needs to come from renewable generation sources.

The state's high electricity prices and large reliance on natural gas as its main electricity generation source were the two most likely drivers for the state to implement a RPS in the first place (Moseijord 2005). Even with the massive growth of wind based electricity generation in Texas, inadequate transmission is frequently cited as the most significant obstacle to wind power development (Public Utility Commission of Texas, 2006). The unbundled trading of RECs is permitted in Texas and has resulted in large volumes of certificates being traded amongst utility providers in the state. The Public Utility Commission of Texas maintains the authority to "cap" the price of RECs, and may suspend the RPS standard if it decides the reliability and operation of the grid is being compromised.

California

California provides an interesting case study because it currently has the second largest amount of installed wind capacity in the country, but has been ranked 17th in terms of total wind resource potential. When sixteen other states have greater amounts of adequate wind potential, how has California managed to implement such a large amount of wind power? The state's government has been extremely aggressive in setting an environmental agenda and has made increasing renewable energy supply a top priority. The state's RPS target has been updated three times since it was originally implemented, and remains the country's most aggressive target by requiring 10% renewables from its utilities by 2010 and 33% by 2025. Overall, the state consumes an extremely large amount of electricity due to its massive population, but the average per-capita electricity use is one of the lowest in the country.

One unique characteristic of California's RPS system is that is does not allow RECs to be traded in an unbundled fashion. This issue is currently under intense debate within the state government and between invested stakeholders. Many publications have been released declaring that California's utilities will not be able to meet the state's aggressive RPS targets, with some analysts suggesting that not allowing REC trading may be one cause. The majority of high wind resource areas are in northern California, with the largest electrical demand coming from the southern region of the state. Getting the wind power from the northern end to urban centers with large electrical demands leads to high transmission and transaction costs and puts utilities in southern California at a specific disadvantage in meeting the state's RPS mandate. Allowing REC trading between utilities in the state may help focus wind development in the areas with highest resource potential, but some officials are worried that the environmental and economic benefits of renewable energy will not be even dispersed across the state if this were to occur.

CHAPTER SIX

SUCCESSFULLY INTEGRATING WIND ENERGY

For those energy developers and utilities that wish to pursue wind energy it is imperative that all of the conditions discussed above are considered when choosing a potential site location or conducting a project cost analysis. It is very difficult to build projects that will be successful when the right physical, economic, legislative, and social drivers are not in place. Wind installations have been successful in areas where only two of the six conditions described above have been met, but higher success rates will result as more conditions are in place. Areas for development should not be chosen solely on the level of wind resource potential, as many of these regions have proved inadequate for developed because of other factors such as insufficient transmission infrastructure or an unwilling local population.

Short-term renewal of the federal production tax credit has proved to be extremely problematic for the wind industry and has been shown to cause dramatic drops in yearly investment and overall capacity installed (Figure 6). As a developer or utility interested in wind it is important to monitor the status of the PTC and ensure that the project will qualify for the tax credit. Smaller entities, or those that are ineligible for the tax benefits of the PTC, may want to consider involving a third party whose financial portfolio is large enough to utilize the full benefits of the tax credit or is tax eligible as a private entity. Long-term renewals in the PTC or ITC are good indicators for improved financial stability for wind developers, and should lead to a larger number of wind projects going online. Broadening flexibility for incentives, as done in the ARRA of 2009, is also a good indication that the renewable energy industry will experience growth and higher levels of investment in the future.

Wind energy developers should complete extensive cost-benefit analysis before choosing a site location due to the large number of variables that are involved. An area with high resource potential and a large demand created by the state's RPS commonly prove uneconomical due to a lack of transmission access and inability to handle new capacity. Developers must tailor analyses individually by project site; taking into consideration wind resource potential, electrical demand within the service area, the availability of state and federal financial incentives, siting regulations, and receptiveness of the local population to turbine installation.

The condition of the electrical load, with regards to regionally supply and demand for power, is critical for determining if new wind generation will be suitable. It is important for developers to consider the type of generation technology currently being used to meet base-load requirements and how peak-power demands are satisfied. Utilities generally keep a large amount of data regarding the load shape for their service areas, so that they can provide for peak load demands with a combination of base load plants and peaking plants. Wind facilities are normally used for base-load generation because of their low variable costs. Utilities will rarely depend on wind generation for peak-power production unless the facility is located in a service region where wind speed and duration are consistently highest during peak load demand periods. The low availability factor and intermittent nature of wind make it a more difficult generation method to account for when utilities are forecasting load supply with regards to their predicted demand. Conventional methods used for base-load generation such as coal-fired, oil-fired, nuclear, and natural gas-fired boilers, a much higher availability factor. Developers should look for service areas that are in need of additional base-load generation capacity, and have a large amount of electrical supply available from peaking power sources. Hydropower is the best peak-power backup for wind energy due to its low cost and ability to adjust production with relative easy.

An alternative for effectively meeting peak load demands at low cost when no surplus hydropower is available is the use of gas-fired combustion turbines. These turbines have a relatively low construction cost compared to CC-natural gas plants, but are more exposed to volatile natural gas price fluctuations as they are not as efficient as combined cycle plants and use more fuel.

The DOE's analysis "20% by 2030" concluded that no input material constraints currently exist for developers building wind energy facilities. The costs per kWh for wind turbines have risen dramatically over the last few years due to the increased size of turbines, the use of more advanced technology, and the growing demand for copper, fiberglass and other raw materials involved in the manufacturing process. Although costs are increasing, there are no physical resource constraints preventing a large-scale increase in wind development (DOE 2008). While clustered development in high resource potential areas would help to reduce transmission costs, there has been no evidence of economies of scale for wind projects as shown in Figure 11 (Berkeley Lab 2008).

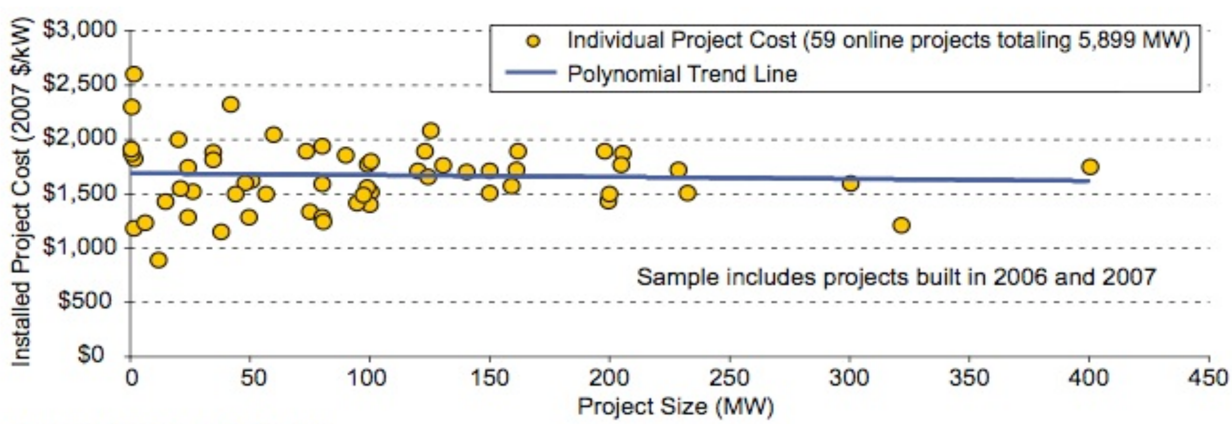

Figure 11. Installed Wind Project Costs as a Function of Project Size: 2006-2007 Projects.
(Source: Berkeley Lab database, 2008)

CHAPTER SEVEN

POLICY RECOMMENDATIONS

In order for wind energy to be utilized to its full potential in the United States it will take serious political will and innovative policymaking. Creating a stable supply of clean-energy, while promoting an ethic of conservation, can help address electricity prices, national security, and economic growth if it is declared as one of our highest priorities as a nation. Without sufficient legislation in place, where priority is given to wind and other renewable energies, there is no way to create the new energy system that is so badly needed. How a government allocates its financial incentives is a good indicator of where priorities lie for policy makers. If increasing wind in our energy portfolio is truly a national priority, then incentives must be strategically directed to developers who invest in projects that will provide clean, reliable, low-cost electricity. The negative impacts of green house gases have been externalized by electricity generators over time, and have become signs of a severe market failure. Based on current conditions, we cannot rely on the free-market alone to provide the guidance that will lead to massive increases in installed wind capacity in the United States. The U.S. vitally needs energy generation from technologies like wind turbines in order to reduce green house gas emissions and reduce dependence on important fuels.

Two of the most important tools that have been used to encourage investment and development of wind energy are the production and investment tax credit incentives. It is imperative that these incentives remain in place until other mechanisms are created that can accommodate the differences in cost between wind and traditional fossil fuel based electricity generation. Federal policy also has the potential to promote an ethic of conservation and efficiency improvement by allowing individuals to claim the money spent on these behaviors towards tax deductions. The nation's political leaders can lead by example, by returning to the days when President James Carter was installing solar panels on the roof of the White House.

Institutionalizing some form of carbon regulation, either through the use of allowances or creating a national feed-in tariff, could eliminate the need for a tax incentive as long as the value of the allowances of tariff equals the difference in cost between wind and CC-natural gas (currently ~$21/MWh). A national feed-in tariff for wind would provide the greatest stability in the industry and spur the largest amount of growth. This type of system has been used in Germany and proved to generate large amounts of growth in the country's wind energy supply for electricity.

Giving generators the ability to trade RECs in an unbundled fashion may help provide additional revenues from wind facilities if the price of the certificates is greater than the levelized cost differential between wind and combined cycle natural gas generation. The concern exists that markets for trading RECs may only promote growth in the wind industry up to the point where requirements established by the state RPS are met. Texas has proved to be an exception to this prediction by surpassing its RPS goals by over 1000MW of installed wind capacity even when unbundled REC trading was allowed.

One of the largest market challenges is figuring out how to make wind cheaper than existing high-emission generation methods so that old capacity is replaced with new zero-emission generation. Most of the current focus has been on how to make wind cost competitive with other sources so that new capacity added is from wind. A carbon regulation system where allowances become extremely expensive may promote this type of shift where the U.S. energy supply infrastructure begins to rebuild and high emission generators are retired.

7.1 Federal Policies

Under current market conditions a financial incentive such as the production tax credit, valued at approximately $21/MWh, is necessary for wind to remain competitive with combined cycle gas generation facilities. The PTC is based on revenue forgone to the Treasury, through the elimination of taxable income by generator companies, but no additional funding is needed in order maintain the incentive. The ITC operates in a similar manner, using a tax deduction mechanism, which ultimately lowers project costs for developers. The new provision in the American Recovery and Reinvestment Act that allows ITC eligible projects to instead receive cash grant options may have a slightly larger impact on the Treasury and when taking into account the time value of money. In the case of wind energy, only small-scale projects are eligible for the ITC or cash grant options so large commercial developments would not apply. Allowing commercial scale wind facilities to choose from the three incentives would help encourage more development, but it would no doubt come at a higher price tag for the Treasury, and the money would not be as spread out over time if a large number of owners chose the ITC or cash grant instead of the PTC. A recent study by NREL and the Berkeley Lab (2009) concluded that developers for most renewable energy types would favor the cash grant option as opposed to the PTC or ITC in the near future except for large-scale wind. Their analysis showed the expected valued from each incentive based upon project capacity factor and total installed costs taking into consideration multiple discount rates. Researchers also took into consideration additional quantitative factors that may affect a developer's choice such as availability of financing, project liquidity, and the availability of other government incentives. The majority of large-scale wind owners will continue to favor the PTC as long as the capacity factors for their facilities remains high and installed costs don't rise dramatically (NREL/LBL 2009). Once the nation's moderate to high resource potential sites are completely developed, leaving developers to prospect lower potential sites, there is a good possibility that there will be a shift to smaller-scale facilities in order to utilize the ITC or cash grant instead of the PTC which would provide better benefits for low capacity developments with high installed costs.

In comparison to a federal feed-in tariff for wind generation, the PTC is a low-cost way to encourage investment and the development of additional wind capacity without raising electricity rates for consumers. The economic downturn of late 2008 has left many renewable energy developers with insufficient profits to utilize the PTC to its full economic potential. As profits decline, renewable developers have less "appetite" for tax credits and as a result, the loss in potentail value of the PTC and ITC is expected to slow investments in renewable energy facilities (AWEA 2008). The new cash grant option for ITC eligible projects was intended to help combat this problem, since it is still obtainable for developers with insufficient tax bases to fully utilize the ITC or PTC. Creating a "refundable PTC" could also help ensure success of the wind industry even when the economy falls into a recession (Union of Concerned Scientists 2008).

If unbundled REC trading was chosen to be the primary mechanism for counteracting the levelized cost differential between wind and CC-natural gas based generation, a national market and trading system must be implemented. Allowing a nationwide unbundled REC trading market would create uniformity throughout the industry and allow states to meet their RPS mandates even if they don't have the highest resource potential in their service regions. Currently four out of the twenty-six states with RPS targets don't allow the unbundled trading of RECs (Figure 2), and there is currently no operational trading system that is run by the federal government or between states. There has been extensive debate over whether or not the banking and borrowing of RECs should be allowed by generators and utilities. A nationwide trading system might help reduce the need for these activities as there would be a larger market in which to buy and sell certificates, so temporary shortages and oversupplies can be mitigated. If it was decided that banking would be allowed by generators operating in a national market, then borrowing should also be allowed by electricity distribution companies to help lower price volatility and market uncertainty (Ford et. al 2005).

The Western Renewable Energy Generation Information System, a renewable energy registry and tracking system for the Western Electricity Coordinating Council, recently went online opening up the potential for RECs to be traded across the entire western region of the United States (WREGIS 2009). This independent tracking company is governed by a committee of various stakeholders and is in its preliminary stages. A national registry and tracking system similar to the WREGIS would be necessary to accommodate nationwide trading between generators, utilities, and third party trading entities. Large scale REC trading would allow all states to meet their RPS goals as long as renewable electricity generation was occurring somewhere in the country. Although the environmental benefits of zero-emission generation such as wind may not be as localized with this type of system, the greater environmental challenge of reducing climate change would still be addressed. Nationwide REC trading may also allow states such as North Dakota, who have an enormous amount of wind potential, to fully develop their wind resource and beyond any demand level that could be created through a state level RPS mandate.

7.2 State Policies

Renewable portfolio standards mandated by states are excellent policy mechanisms to increase the demand for renewable energy through regulating utility providers. Each state has the flexibility to individualize its own RPS, which can focus on energy sources that are most accessible in the region and also institute percentage generation goals that are achievable. RPS targets also help maintain a demand for alternatives energies even when the costs of production are higher than traditional generation methods. It is important that each RPS have an aggressive goal with a long "ramp period", or be updated continuously by increasing the percentage requirements on utilities. This will insure a continued demand for renewables and encourage investment in new projects. Ford et. al (2005) suggested that investors may be reluctant to sign on to new construction projects solely based on the supposition that a state's RPS target will be increased. The publication went on to compare this to the similar uncertainty caused by investors relying on the production tax credit renewal. For this reason, it is imperative that a state's RPS sets ambitious goals over a long time frame, or publicity announces its future intentions to increase target percentages and the dates they will become legally binding. It is reasonable to assume that a carbon pricing scheme would help minimize investor and generator reliance on utility demand solely based on RPS requirements. The extra revenue generated from carbon allowances would help provide security for new projects even when some uncertainty existed about a state's intentions to increase RPS targets.

State level RPS mandates have shown to create additional demand for renewable generation. Utilities that are bound by a state RPS target must invest in new capacity from sources like wind, solar, or geothermal. Even though RPS targets can help promote growth in renewables, one potential shortfall is that they do not necessary help reduce emissions from existing fossil fuel based generation sources. If the ultimate policy goal is to reduce GHG emissions, a regional cap-and-trade scheme may be more effective than a state-level RPS, but if the ultimate goal were to promote growth in renewables, then a RPS would be appropriate.

There is a large amount of flexibility for states to create their own incentives in order to promote the development of new wind power. Tax incentives are a great way to draw companies to a region, assuming there is sufficient wind resource potential for development in the state. State governments can also encourage their utilities to offer “green power block” options similar to those being offered by utilities in the Northwest. State incentives for individual consumers to improve energy efficiency and reduce demand on the region’s electrical load can also help improve the electrical system. Efforts like these can be based upon investment tax credits or direct payment plans to encourage conservation and efficiency measures such as installing “smart grid” technology or new appliances in homes.

In order to tackle the development restraints caused by transmission lines in regions of the United States, state governments could begin subsidizing, lending, or providing funding options for infrastructure improvements where private entities are unable to do so. The North Dakota Transmission Authority was created to serve a similar purpose and can be referenced to as a model for how states could go about addressing their own transmission infrastructure challenges. Decades of underinvestment into the grid must be accounted for and state entities can play a key role in overcoming this difficult challenge.

The potential for a federal RPS has been discussed but little legislative progress has been made towards its implementation. Creating a universal, nationwide target that is binding may not be the most efficient way to achieve GHG reduction as a country. There are many areas of the country, such as the Southeast, that do not have the resource potential for large-scale wind to be feasible. Technologies that may prove more productive for these regions, such as tidal or wave energy, are still in early stages of development and may not be ready for commercial use for another ten years. Until a greater number of renewable generation technologies are available that utilities could use to meet a federal RPS, it is not cost effective to require all electrical serving entities in the nation to use the same alternative generation methods that may not be compatible with their specific geographic characteristics.

7.3 Carbon Pricing

Many advocates of advanced regulation on GHG to combat global climate change have suggested institutionalizing some sort of price signal for emissions, particularly carbon dioxide from power plants. Wind energy interest groups support pricing carbon emissions as it gives zero-emission generators a competitive advantage over fossil fuel based generation systems. This method of market regulation would lead to additional production costs that would only be incurred by those generators who burn fossil fuels, and would help narrow the price gap between alternative and traditional generation sources.

The most recent Intergovernmental Panel on Climate Change Synthesis Report (2007) argues for placing a price on carbon stating, "Policies that provide a real or implicit price of carbon could create incentives for producers and consumers to significantly invest in low-GHG products, technologies and processes". A carbon price, either explicitly stated through a specific tax value or implicitly determined by a cap-and-trade market price, seeks to internalize the true cost of carbon dioxide emissions onto the producer and create a monetary incentive to reduce emissions and convert to low-GHG energy sources. The IPCC has also made claims based on modeling studies that CO_2 in the atmosphere could be stabilized at around 550ppm CO_2

equivalent by 2100 when institutionalized carbon prices rise to \$20-\$80 per ton of CO_2 equivalent (IPCC 2007).

The most recent data from the EPA states that the average carbon dioxide emission rates in the United States from natural gas-fired generators are 1135 lbs/MWh and 2240 lbs/MWh on average for coal plants. The emission levels from coal-fired generation are almost exactly two times the emission rate for gas. These numbers are nearly identical to those stated by Ford (2005), so using a difference factor of two between CC-natural gas and coal for carbon emissions is a reasonable assumption. The emissions differential factor between natural gas and coal may vary slightly depending on the type of coal being burned, but for the purpose of this assessment lignite is used, as it is the most common form burned for electricity generation. The value used to represent a potential carbon tax was chosen at \$100/ton of carbon, which is a price commonly used in most studies to model the economic implications of a carbon regulation program. A carbon tax at \$100/ton carbon would result in a \$25/MWh penalty for coal-fired generation (IPCC 2007). Since CC-natural gas facilities emit half the amount of CO_2 that coal plants emit, they would incur a penalty price of half the amount, or \$12.5 per MWh. This additional cost of \$12.5 incurred by CC-natural gas generators could narrow the price differential with wind generation. Since the current difference in cost between the two methods of generation is approximately \$19/MWh a carbon tax payment of \$12.5 per MWh alone would be insufficient to encourage development new wind generation capacity.

These incurred costs from carbon regulation may be considered extremely conservative by some energy serving companies. The PJM Interconnection, the biggest organized power market in North America (see Appendix), recently published a study to show the potential cost increase in wholesale power prices if carbon-regulating legislation similar to S.139 (The Climate

Stewardship Act) was passed in the United States. PJM determined that if carbon allowance prices were to reach $100/ton of carbon, it would impose a cost increase on coal fired electricity generation of nearly $80/MWh (EEnergy Informer 2009). Compared to the cost increase of $25/MWh mentioned before, the costs forecasted by PJM are on the very high end of cost predictions for carbon regulation, and may be due to the fact that the majority of PJM Interconnection's generation potential comes from coal fired power plants. According to Ford's (2007) "Quick and Clean Estimate of Carbon Prices", the variable costs of coal vs. CC-gas generation become equal at $80/MWh when carbon allowance prices reach $65 per metric ton of carbon. These assumptions are based on data from the 1999 DOE/EPA report on "Carbon Dioxide Emissions from Generation of Electric Power in the United States", and forecast the average emissions from coal to be 2.09 pounds of carbon for every kWh of generation and CC-gas to be at 1.17 pounds of carbon per kWh.

The most extensively debated and analyzed piece of legislation to be introduced in the U.S. dealing with carbon markets has been S.139, or the Climate Stewardship Act. Senators Joseph I. Lieberman (D-CT) and John McCain (R-AZ) introduced the bill in 2003 but it was never voted into law. Under S.139 (Climate Stewardship Act) the electricity sector would reduce its annual emissions by 75%. The Act has been revised several times since its origination, and was reintroduced in 2005 to a new Congress only to meet a similar defeat. The most recent update, now titled the Climate Stewardship and Innovation Act (S. 280), involved the provision for the emissions cap, immobile in previous Acts, to be gradually reduced based upon the theory of contraction and convergence. The most thorough analysis to be conducted on any of the stages of this Act was completed by the EIA in 2003 that examined the bill as originally introduced in Congress. The EIA determined that if a carbon market were to be institutionalized in the United

States, that $22 per metric ton of carbon would be the opening price for allowances in 2010. They forecasted that the price of allowances would increase to $35 in 2016 and head toward $60 in 2025. Additional variable costs that would be incurred by CC-natural gas generators were predicted to be $8/MWh in 2010, and $15/MWh in 2018 (This corresponds to the penalty price incurred by CC-gas generations, previously cited at $12.5/MWh, which is within a reasonable range but may be slightly high).

Andrew Ford completed a study in 2007, titled "Simulation scenarios for rapid reduction in carbon dioxide emissions in the western electricity system", that predicted the expected responses to carbon prices in the U.S. electricity sector if a bill similar to S.139 were to become law. The results, as shown in Figure 12, show that CC-natural gas generation with carbon sequestration technology would provide the largest amount of new growth in generation capacity. By 2025 a reduction in regular coal generation was predicted to exceed 2,200 billons of kWh. Surprisingly, although S.139 would increase the use of wind energy, biomass and demand reduction were expected to account for nearly double of the change in electricity generation by 2025.

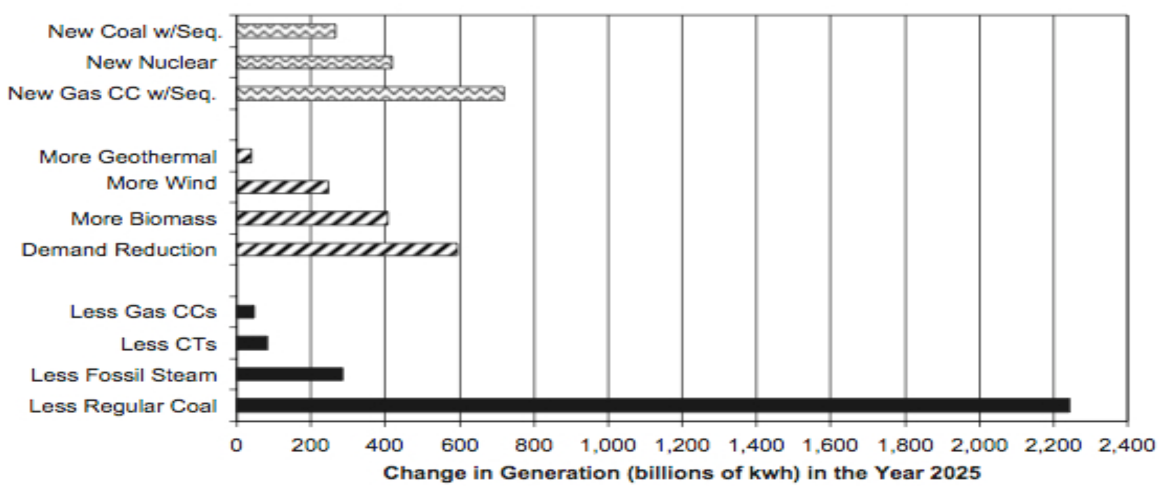

Figure 12. Summary of the expected responses to carbon prices in the US electricity sector (Source: Ford 2007).

CHAPTER EIGHT

CONCLUSIONS

The six conditions discussed in this paper are critically important for the successful implementation of a wind energy facility or for promoting a national energy policy that encourages growth in wind-based electricity generation. Although it is not necessary for all of these conditions to be in place for a wind project to be successful, the more conditions that are met the more certain the developers and investors can be that the wind facility is a sound investment, properly located, and will prove cost effective over time. There are dynamic interactions that occur between the physical, economic, legislative, and social conditions described in this paper while dealing with any large-scale wind energy development. Accurately predicting how all of the conditions will react to structural changes in the regulatory climate, with the implementation of a carbon market for example, is extremely difficult. The six conditions described throughout this analysis were chosen based on current legislation, regulatory mechanisms, and economic climate.

It is clear that a difference in cost exists between electricity generated by wind compared to traditional fossil fuel based generation that relies on natural gas or coal. The two main federal tax incentives that serve to address this difference, and help wind generation to be cost competitive, have been the PTC for commercial developments and the ITC for smaller-scale facilities. The extension of the federal PTC until 2012 in the ARRA of 2009 was a policy decision that will undoubtedly help increase the amount of wind development in the U.S. in the coming years. Maintaining these financial incentives over the next several years is critically important for the continued success of new large-scale wind generation. The new cash grant option, recently made available in the American Recovery and Reinvestment Act of 2009, will provide a similar subsidization mechanism for renewable developers on a shorter time scale with the intention to create more flexibility (NREL/LBL 2009).

There are several other options that would serve to balance wind generation costs with conventional methods, including a direct feed-in tariff paid by utility providers, a national unbundled REC trading market, and the implementation of a regulatory carbon market. Ford et. al (2005) stressed that "the main goal of [REC] markets is to increase the share of renewable generation at costs below the costs of direct subsidies such as the PTC". Carbon pricing may result in the same effect as a national market for trading unbundled RECs. Both options may help reduce the differences in cost between wind and fossil fuel based generation, but both market systems have proved to be high volatile based on real world trading experience in the European Union. It is nearly impossible to forecast the exact prices that will result from these two systems, but any costs that are avoided for wind generation, or added to conventional fossil fuel based generation, will help direct the market toward greater growth in emission-free energy sources. If the main policy goal is to increase the level of installed wind capacity in the country, a direct and reliable financial incentive such as the PTC or a direct feed-in tariff is the best policy option.

RPS mandates have been proven to create additional demand for renewable generation. Utilities that are bound by a state RPS target must invest in new capacity from sources like wind, solar, or geothermal. Even though RPS targets can help promote growth in renewables, one potential shortfall is that they do not necessary help reduce emissions from existing fossil fuel based generation sources. If the ultimate policy goal is to reduce GHG emissions, a national cap-and-trade scheme may be more effective than a federal RPS, but if the ultimate goal were to promote growth in renewable industries a RPS would be appropriate.

Renewables are still relatively expensive to install, and the added capacity from new renewable based facilities would take the place of the most expensive conventional method of generation, which would most likely be natural gas or nuclear generation. Since coal generation is still the least expensive means of generating electricity, it is the least likely method to be displaced under a federal RPS, leaving gas generation more vulnerable (Micheals 2008). This scenario is obviously not ideal for the overall goal of reducing GHG emissions, since natural gas generation emits half of the carbon dioxide as a coal plant and nuclear facilities emit zero carbon dioxide. A federal RPS is not recommended for this reason in addition to the fact that it may reduce a state's ability to reduce emissions in the most efficient and cost effective manner. Areas such as the Southeast do not have adequate wind resources to utilize commercial wind energy and would most likely rely on biomass, solar, or wave and tidal based electricity generation. These other renewable technologies are still extremely expensive and would put states with smaller wind resources at a disadvantage unless a national REC market was allowed and the national standard could be met through trading.

Combined cycle natural gas facilities will continue to serve as the primary least-cost alternative to wind energy due to increasingly strict emission regulations and the low cost of integration and load management of gas-generated electricity. It is reasonable to assume that very little if any new hydroelectric power will be added in the United States in the future due to low availability of sites for placement and strong opposition from environmental interest groups. There has been a return to interest in nuclear power over the past several years in the United States and worldwide due to the fact that it is a zero-emission energy generation source and fuel input prices are less volatile than natural gas or petroleum. Several countries in the European Union have begun to reverse the nuclear bans put in place after the Chernobyl disaster in order to open the door for new nuclear development with the hopes of reducing dependence on imported natural gas and lower the country's GHG emissions. New nuclear facilities may eventually be built in the U.S. to help supplement the growing demand for electricity, but due to the long construction time and extensive permitting process they cannot be considered as a low-emission solution for the near future (10-15 years) in this analysis. The Nuclear Regulatory Commission has worked to streamline the procedures for approval of several new standard nuclear plant designs, and has combined the applications for construction and operation licenses. The NRC and the industry contend that these improvements will greatly reduce the time required for bringing new standardized designs into operation, but it has not yet been determined how long it will take to bring one of these newly designed plants online. Although increasing nuclear energy would help reduce GHG emissions into the atmosphere while providing enormous amounts of generation potential, it still has the negative consequence of generating radioactive waste products. This additional cost is not incurred by wind generation, which is not only emission-free but produces no dangerous by-products that must be treated and disposed of.

Cost competitiveness, high resource availability, potential for industrial-scale facilities, and low operating costs make wind the most attractive and feasible of the available renewable energy generation sources in the United States. The difference in cost between electricity from a combined cycle natural gas plant and wind is approximately $19 per megawatt hour in 2006 dollars (Table 1). Energy markets can be adjusted by either incentivizing wind or by institutionalizing a price on emissions from GHG emitting sources. In order to compete with traditional fossil fuel based electricity generation, financial incentives such as the federal tax credits will remain necessary unless carbon becomes a regulated pollutant for which the price of production is internalized on the generator. Even with these differences in production costs between CC-natural gas and wind, the Department of Energy has concluded that electricity produced from wind is competitive with the cost of a "flat block of electricity" in wholesale markets.

The need to expand national transmission infrastructure is not an undertaking created solely by the push for new wind power. Any major additions to generation capacity, be it from coal or wind, will require new transmission or improvements to the existing grid. Many benefits are derived from building new transmission in the United States, including the ability to handle an increased electrical load, greater grid reliability, increased management flexibility between service regions, and reduced costs for new projects. Funding massive infrastructure developments such as transmission expansion will only be accomplished through a cooperative effort between the federal government, states, ratepayers, and independent energy resource developers. New approaches need to be taken to address the transmission problem that will create opportunities for innovative project financing options, streamline the siting processes, and provide the resources for construction. The amount of money required to expand the power grid to access and accommodate new wind capacity could be upwards of $100 billion dollars (DOE 2008). Building new transmission for the eastern half of the country alone, to accommodate 20% wind penetration, would require 15,000 miles of new lines and would bear a cost of $80 billion (EEnergy Informer 2008). As stated by Mills et. al (2009), "It appears that the unit cost of transmission for wind need not increase dramatically at higher levels of wind penetration". This is an important dynamic that a region must take into account when they are considering increasing wind development and the potential cost implications for new transmission lines.

The Pacific Northwest has a distinct advantage for firming wind energy and maintaining reliability in load due to the large regional reserve generating capacity provided by the system of generators at dams, together with the large amounts of water stored in the reservoirs. Unfortunately, the majority of the United States does not have this reserve hydropower capacity (only South Dakota, Washington, Oregon, and Idaho have this advantage) so other generation sources must be scaled up to complement new wind capacity if sufficient back up does not already exist in the service area. Most other service regions in the United States, particularly the Southwest, will most likely rely on gas combustion turbine based power plants as their firming source for wind new capacity. Advances in energy storage technology will help reduce integration problems and lower costs caused by the intermittent nature of wind. Compressed air energy storage (CAES) seems to be receiving the greatest amount of public interest and venture capital funding for research, but high capacity battery systems still remain the most practical method of energy storage and allow for the controlled release of electricity onto the grid. Investments directed towards building a smart electrical-grid and increasing transmission connectivity across the U.S. could also help to smooth out intermittency and fluctuations in electrical load, thereby relieving some of the management burden created by large new additions in wind generation capacity. These types of efforts may require changes in jurisdictional power due to the fact that FERC maintains interstate control, and state governments having intrastate control. The process of updating our electrical system with more advanced technology will most likely be completed through a piecemeal process and may take many years to complete due to its immense size and complexity.

Dramatically increasing the amount of wind penetration in the United States, along with the construction of new transmission infrastructure, would create an enormous amount of new jobs and economic growth. The need for increased domestic manufacturing of the raw materials and components used in turbine construction processes must be addressed. The majority of wind turbine components are currently built overseas, so simply increasing the amount of wind energy capacity in the United States will not necessarily create manufacturing jobs unless turbine-manufacturing facilities are located within the country. Federal stimulus money allocated through the American Recovery and Reinvestment Act of 2009, much of which was directed towards increasing the amount of electrical capacity from renewables, was also intended to stimulate the national economy and create jobs. This goal can only be achieved if measures are taken to increase the amount of wind turbine components that are manufactured domestically. Although the amount of maintenance that wind turbines require is relatively low compared to conventional power facilities, jobs will also be created to provide service to wind generators and new transmission infrastructure.

When determining the economic and social advantages of increasing electricity production form wind, environmental and human health benefits derived from the use of renewable, zero-emission energy sources must also be considered. The overall the consequences of developing a subsidized industry would be a loss to society unless the externalities are accounted for that tip the balance. Externalities from conventional generation methods could include: the release of green house gases into the atmosphere, human health impacts resulting from increased levels of particulate matter and exposure to noxious gases, disposal and placement of toxic waste outputs, and energy insecurity caused by reliance on a finite fuel input supply. Wind energy avoids all of these additional long-term costs that are commonly externalized onto the environment and the public, thereby justifying the current need for federal and state-level incentives.

The United States faces a future of increased demand for electricity, limited supply, and a threatened environment. Wind energy can play a critical role in addressing each of these three dilemmas, while simultaneously helping to create jobs, technological innovation, and real economic growth. Researchers must further examine the relationships that exist between the conditions discussed in this paper, and determine how they affect the wind energy industry. If a strong synergy exists between private research, government funded research, and research at independent institutions, information can be effectively shared and improvements in wind turbine technology can be made quickly and efficiently. Policy makers and utility providers must have access to the best information from all of these groups in order to make informed decisions that will represent the interests of their constituents and customers. When national priority is placed on formulating progressive energy legislation, an effective economic climate for alternative energy development and the mitigation of green house gas emissions will follow. Utility companies located in areas with high resource potential need to seriously consider using wind energy as their primary method for meeting the state's RPS targets and their consumer's demands for electricity. All electrical generators and providers should prepare for some form of federal carbon regulation and continued growth in the demand for green power. Installing wind power provides a low cost means of establishing a competitive advantage for energy developers who are willing to look to the future, and take proactive measures to meet a rapidly changing world.

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