Wind energy development issues

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WIND ENERGY DEVELOPMENT ISSUES

by

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This is a professional paper aimed at assisting individuals in both the public and private sector who are interested in acquiring an introductory knowledge of the issues that surround the wind energy industry. The topic of wind energy is remarkably broad, encompassing major disciplines of philosophy, physics, economics, and political science and applied disciplines such as meteorology, engineering, and land use and municipal planning. A secondary goal of this paper is to reflect this breadth while making the topic of wind energy accessible to as many people as possible.

This paper is formatted as a guidebook, outlining the history of wind energy and discussing the five wind energy development issues; specifically: the wind resource analysis, the siting of wind turbines, the interconnection of wind turbines with the utility grid, the economics of wind energy, and the business of wind energy and its cost measures. The major sources used in this study range from scientific documents completed in correlation with research organizations such as the National Wind Coordinating Committee and the National Renewable Energy Laboratory to books on wind energy written by Gipe and Burton.

It is the focus of this paper to emphasize the importance of the wind turbine siting process. Only through the deliberate and thorough siting of wind energy facilities will the industry be able to thrive while achieving its goal of improving the quality of life of an area through developing its wind resource.
This project is dedicated to the two people who have given me everything I have, my parents.
Preface

Most Americans assume that when a light switch is thrown or computer turned on that there will be enough electricity to power their load. The electricity industry, which is the world’s largest and most polluting industrial enterprise (Asmus, 2001), remains largely a mystery to most Americans. The physics of electricity, by itself, is difficult to understand. When added to the complex disciplines of engineering, project finance and regulation industry, it becomes further obscured. It has taken an energy crisis in California as well as a persistent threat of climate change to spur people to attempt to make sense of this industry and look for alternatives to the accepted approaches to production. As a result, serious consideration of the harnessing of wind energy has emerged.

The basics of wind energy are simple. As Paul Gipe puts it:

For wind energy to work, a potential user needs ample wind, a place to put a wind turbine, a market for the energy it will produce, and some assurance that the product, electricity, will reach the market and fetch the price necessary (Gipe, 1995).

Using these simple terms, Gipe presents an easily understood vision of the fundamentals of this industry. However, a useful understanding of this intricate industry comes only through a much deeper investigation and analysis.

This paper is an introduction to the issues that surround wind energy development with the goal of being an aid to individuals and organizations, in the public and private sector, that are taking an active interest in wind energy.
The electric power industry has an enormous environmental footprint in the United States, and there is great potential to make a positive change to the environment if we were to increase our use of renewable energy. This sentiment is summarized by the European Renewable Energy Centers Agency, London:

The use of renewable energy sources and rational use of energy are the fundamental vectors of a responsible energy policy for the future. Because of their sustainable character, renewable energy technologies are capable of preserving resources, of ensuring security and diversity of energy supply, and providing energy services, virtually without any environmental impact (EUREC, 1996)

The energy industry in the United States continues to be buffeted by strong outside forces. Volatility in the price of oil, the collapse of the largest energy trader, and the electricity “crisis” in California in 2000 are just a few. People, now more than ever, are aware of the environmental, economic and political implications of energy and how they link to one another. This report aims to help individuals (environmental advocates, potential investors, landowners, people in public office, and interested companies) with their opportunities for choosing wind energy as a means of both meeting growing electricity demands and as a “fundamental vector of a responsible energy policy for the future” (EUREC, 1996). It should not be used as a stand-alone document but as a source of information about critical issues. The reader should be able to gain an introductory understanding of wind energy and the issues involved in its development in the United States.

The topic of wind energy is remarkably broad, encompassing major disciplines of philosophy, physics, economics, and political science and
applied disciplines such as meteorology, engineering, and land use and municipal planning. A secondary goal of this paper is to reflect this breadth. It is, however, the primary intent of this paper to introduce the reader to the issues of wind energy development as if he or she were a developer interested in learning how to begin a feasibility study for a wind farm. The paper starts with a history of wind energy, discussing its presence in both Europe and the United States. Next the wind energy development issues are presented. These serve as an introduction to the major issues faced by a wind energy developer. Last, attached as Appendix IV, will be an outline of a financial analysis of a wind energy development.

This project is to serve as a background/introductory aid to anyone interested in learning what goes into a successful wind energy development.
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Chapter 1

Wind Energy Background

“Pray, look better, sir,” quoth Sancho; “Those things yonder are no giants, but windmills, and the arms you fancy, are their sails, which, being whirled about by the wind, make the mill go”
-Faithful Sancho squire to Don Quixote

I. The History of Wind Energy

For 3000 years humans have harnessed the power of the wind. The earliest and most primitive application of wind power was to grind grain, pump water and power ships (Burton et al, 2001, p1). Civilizations that used the power of the wind to their advantage quickly prospered, leaving those without the technology in their wake. Historians have credited the windmill with everything from the birth of capitalism to developing the concept that the forces of nature are something civilization had the right to harness in order to meet its needs. The use of the windmill as a source of power quickly spread from the East before arriving in medieval Europe. Between the fourteenth and nineteenth centuries, wind provided as much as a quarter of Europe’s total energy needs; the waterwheel and human and animal labor provided the balance (Asmus, 2001, p25).

It is generally accepted that the history of Western wind energy begins with the appearance of the European or “Dutch” windmill in Normandy in 1180. This position accepts that the vertical-axis windmills of Persia spread across the Mediterranean to Northern Europe where they
were adopted and further developed. An alternative school of thought has been spearheaded by historian Edward Kealey, whose controversial thesis posits that the technology is native to Europe, specifically southern England (Gipe, 1995).

Regardless of its origin, harvesting the wind had an immense impact for a society. Capitalizing on wind power gave the farmers the opportunity to not spend their entire lives in their fields at work, thus allowing them to focus on education and other aspects of their society. In his book Reaping The Wind, Peter Asmus quotes historian Lynn White to describe the significance of wind power in medieval Europe:

The chief glory of the latter Middle Ages was not its cathedrals or its epics or its scholasticism: it was the building for the first time in history of a complex civilization which rested not on the backs of sweating slaves or coolies, but primarily on non-human power (Asmus, 2001).

Centuries ago, the classic Dutch windmill was used for water pumping. These machines were up to 25 meters in diameter, made almost entirely of wood and, like today, represented some of the most advanced form engineering and design of the era.

By the turn of the last century, the modern-day offspring of the Dutch windmill, the farm or ranch windmill, had become popular in the United States. The 1930’s and 1940’s saw 6 million of these all metal, multi-blade turbines come into use in the US, 30,000 of which are still in use today (Nelson, 1995). There is no question that wind generators were integral to the daily lives of pastoral Americans and Europeans. The water-pumping windmill was so essential to the life of the American
settler that a common phrase of the homesteader was that “no person should live in this country who can’t climb a windmill or shoot a gun” (Gipe, 1995).

The integration of a turbine into the design of a windmill (necessary to generate electricity) can be traced back to the late nineteenth century with the 12 kW DC generator constructed by Brush in the USA and the research done by LaCour in Denmark. For much of the twentieth century there was little interest in using wind energy other than for battery charging for remote dwellings. These low-power systems were quickly replaced once access to the electricity grid became available (Burton et al, 2001, p1).

Using turbines as part of the generating portfolio of an electric utility is a concept that is approximately seventy years old; the first of these turbines was developed by the Danish inventor Flettner in 1926. This 30 kW turbine contained four blades, each a vertical cylinder driving an electric motor (Nelson, 1995). Also in the 1920’s, the next stage of turbine design was being developed. This new phase attempted to capture the force of the wind by allowing it to rotate a turbine on a vertical axis, which is opposed to the horizontal axis turbine that is the accepted design of today. The French engineer D. G. M. Darrieus is renowned for his invention of the modern vertical-axis turbine which has often been described as looking like an oversized eggbeater. In comparison to conventional wind turbines, which must reorient themselves as the wind changes direction, vertical-axis wind turbines are omnidirectional.¹

¹Omnidirectional turbines have the ability to accept the wind from any direction (Gipe, 1995).
However, they are not as popular today due to the inefficiency of the larger moving parts inherent in their design.

The first grid-connected wind turbine in the United States was built in 1941 at a site called Grampa’s Knob, Vermont, and was connected to the Central Vermont Public Service’s transmission system. This prodigious 1200 kW Smith-Putnam wind turbine had a steel rotor that measured 53 meters in diameter and sophisticated blade speed control mechanisms. It remained the largest turbine constructed for the next four decades (Burton et al, 2001).

Despite the growing knowledge of the potential of wind energy in the U.S. in the early 1940’s, when an engineer with the Federal Power Commission named Percy Thomas studied the potential of wind energy and developed the first wind resource atlas for the United States, the bulk of the industry’s development took place in Europe for the next forty years (Nelson, 1995). In 1956, Gedser, a Danish inventor, developed a 200 kW turbine. Building on Gedser’s work, Electricité de France tested a 1.1 MW turbine in 1963. Throughout the 1950’s and 1960’s in Germany, Professor Hutter invented many lightweight utility-scale turbine designs. However, despite these technological advancements during this period, wind energy did not enter the public consciousness until a crisis brought it to the forefront in 1973 (Burton et al, 2001).

During the 1970’s, while the wind energy industry was rekindled by the 1973 oil embargo, both Europe and the United States renewable energy and environmental advocates developed a new view of wind turbines. Gone was the image of wind turbines as a simple
machine to create electricity; rather, they began to be seen as, in the words of Paul Gipe, “vehicles of social change.” Idealists quickly attached themselves to wind energy as a way to create a sustainable society by living within natural bounds rather than outside them (Gipe, 1995).

The U.S. wind industry, which was initially developed as a reaction to the world oil crises, was further stimulated by state and federal government policies. The majority of the projects were structured to take maximum advantage of concentrated wind resource, close proximity of high wind sites to major population centers, and economies of scale (Dunlop, 1996). The passage of the Public Utility Regulatory Policy Act (PURPA) in 1978 created a market for wind-generated power where none existed before (Guey-Lee, 1998). PURPA facilitated renewable energy development through provisions that required electric utilities to interconnect with, and to purchase the output of, qualifying power producers, wind energy providers included. Prior to PURPA, any interconnection or other cooperation was done at the discretion of the utilities (AWEA, 1992).

The early 1980’s witnessed a wind energy rush in California that was the direct result of an unprecedented tax credit law. Wind energy developments were quickly transformed into tax shelters, in which the basis for the tax write-off included not only what the investor had risked on the project but also what that investor had borrowed. Alan Duskin, a lead developer for United States Wind (an early California wind energy company), commented on the impact of the tax credit:

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*These policies, such as the federal Production Tax Credit and the Renewable Portfolio Standard, are discussed in Appendix I.*

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In essence the investor got all of his tax credit for nothing. The ‘profit’ became whatever income was sheltered from the IRS. Thanks to the tax breaks and depreciation schedule, it was as if wind farm investors never put up a dollar of their own money in the first place, and as if they never borrowed from the bank, but got to deduct from their income virtually all [of the value of the turbine]. Tax breaks made wind very attractive. The investor got a lot of potential value for basically zero risk (Asmus, 2001).

For years, the wind energy industry has been attempting to clear its reputation as an industry that could survive only with the aid of anomalous tax write-offs. By the 1990’s, wind energy facilities began to appear in other states such as Texas, Minnesota, Vermont, Hawaii, and Iowa. The 1990’s witnessed wind energy becoming the world’s fastest growing energy source with an annual growth rate of 40% per year. In both 1996 and 1997 the worldwide wind capacity increased by 24%; in 1998, more than 1500 megawatts of new wind energy was installed in the world, with European nations leading the way hosting three-fourths of the total (Parsons, 1998). In 2001, an additional 5,500 MW were installed worldwide bringing the total to 23,300 MW. This capacity has the ability to meet the needs of 23 million people. In the U.S., however, federal and state programs have continued to provide a broad level of support, ranging from various tax incentives to research grants, typical to many developing technologies (Guey-Lee, 1998).

In a paper presented at the North American Conference of the International Association of Energy Economists in 1998, Brian Parsons addressed the constraints faced by the wind industry:

Many energy analysts believe there is a major opportunity for wind

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3 This figure is the result of a study done by the Earth Policy Institute which assumed that 1 MW will satisfy the electricity needs of 350 households in an industrial society, roughly 1,000 people (Wind Energy Weekly, 2002).
energy in the US bulk power market. There appear to be few, if any, physical limits in the near term to wind penetration into the grid. Rather limits appear to be economic. Anticipated improvements in systems operations, energy storage, and wind forecasting will address these limits in the next few years (Parsons, 1998).

No longer the sole domain of political activists, wind energy (as Paul Gipe phrases it) “has come of age” (Gipe, 1995). The United States presently has 4,000 MW of wind energy capacity installed and in the past three decades the cost of wind energy has dropped from 20 to 30 cents per kilowatt hour to 3 to 6 cents per kilowatt hour, a price that is competitive with traditional fuels (Chicago Sun-Times, Editorial, 2001). In an interview with the Rocky Mountain News, John Nielsen, the energy project director for the Land and Water Fund of the Rockies (LAW fund) stated: “Our analysis indicates that this wind proposal is not only cost competitive with the gas resources Xcel [formerly Public Service of Colorado] is planning to acquire, but also will mitigate the environmental and public health impacts of burning fossil fuels such as natural gas” (Smith, 2001). The persistent effort of the LAW fund resulted in the Colorado Public Service Commission ruling to require Xcel Energy to construct 162 MW of wind turbines on the understanding that it was the most cost effective technology (Smith, 2001). This represents a major victory for the renewable energy advocates of the region as well as the United States wind energy industry as a whole.

II. The Renewable Energy Imperative

1 Information in this section was taken from, “The Major Market Drivers of Renewable Energy Development,” by Joseph Lerner, an independent research project written at the University of Montana, Summer, 2001.
How has an element that was once so important to our ancestors' lives been forgotten until only recently? Stated differently, what are the recent forces that have been driving wind energy into the world energy scene? As mentioned previously, the oil embargo of the 1970's woke the United States to the potential of wind energy to increase our energy security. Presently we are also choosing renewable energy for different reasons. The National Wind Coordinating Committee presents the following two points as important in driving our new attitudes:

1) There is growing agreement in the scientific community that air pollution, part of which comes from fossil-fueled power plants, poses a serious health risk. Whereas a 100-megawatt natural gas-fired power plant may emit 75-1,000 tons each of nitrogen and sulfur oxides per year, wind facilities emit no air pollutants.

2) The scientific community also sees the worldwide buildup of carbon dioxide from the combustion of fossil fuels and other "greenhouse gases" in the atmosphere as a likely contributor to global climate change. Unlike fossil-fueled power plants, wind facilities emit no greenhouse gases (NWCC, 1998).

The knowledge that burning fossil fuels is bad for both the natural environment and human health is far from a new discovery. As early as 1306, King Edward I of England banned the burning of coal in London in order to reduce the heavy air pollution already choking the city (Flavin and Lenssen, 1994). Unfortunately, we have yet to fully learn this lesson, and fossil fuel combustion is continuing to affect our physical and human environments. In 1998, the EPA warned that during the previous year, 107 million Americans lived in counties where the air failed health standards for at least one of the six criteria pollutants^6 (Serchuk, 2000).

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^6 Those six criteria pollutants include heavy metals such as lead, mercury, cadmium, as well as arsenic and other toxic chemicals.
Such pollutants, released into the air by power plants, oil refineries, and other facilities, often enter food and water supplies. They spread disease and in the worst cases, threaten life. The full long-term health consequences of this are still unclear (Flavin and Lenssen, 1994).

Electricity generation is a major source of these toxins as well as greenhouse gases (GHGs) that contribute to global warming. Electricity use accounts for about 36% of total U.S. GHG emissions, while U.S. power plant emissions account for 64% of total SO2, 26% of total NOx, and smaller quantities of other pollutants (Serchuk, 2000).

Carbon Dioxide, the most significant greenhouse gas emitted in the U.S., currently accounts for 85 percent of the total U.S. GHG emissions, the combustion of fossil fuels being responsible for 99 percent of that (Greenhouse Gas Inventory, 1997). Electric utilities rely on coal for over half of their energy requirements and account for about 87 percent of all coal consumption in the United States. Consequently, changes in electricity demand (or production) can significantly affect coal consumption and associated CO2 emissions (Greenhouse Gas Inventory, 1997). Unfortunately, the rate at which the United States is releasing these GHG’s is increasing. Overall, 1999 U.S. greenhouse gas emissions were about 10.7 percent higher that 1990 emissions (EIA, 2000).

Steven Clemmer, of the Union For Concerned Scientists, describes how U.S. power generation continues to affect the environment throughout the nation:

Power plants produce almost two-thirds of the sulfur-dioxide emissions in the United States- the main cause of acid rain. They generate more than one-quarter of the emissions of nitrogen
oxides, the primary contributor to smog. They release nearly 41 percent of U.S. emissions of carbon dioxide, emit mercury and other toxic chemicals, produce tons of solid and radioactive wastes, and consume enormous quantities of water (Clemmer, 2000).

It is clear that there are short and long term effects of the world’s, and more specifically the United States’, addiction to burning fossil fuels that release GHG’s. To answer the question of what impact the release of GHG’s has on the natural environment, the National Assessment conducted by the US Global Research Program released in the Fall of 2000 provides a good indicator. What follows is the predicted result of the anthropogenic or human-caused greenhouse effect at the current rate of GHG emission:

Long term observations confirm that our climate is now changing at a rapid rate. Over the 20th century, the average US temperature has risen by almost 1 degree F and precipitation has increased nationally by 5 to 10%, mostly due to increases in heavy downpours. Scenarios examined in this Assessment, which assumed no major intervention to reduce continued growth of world greenhouse gas emissions, indicate that temperatures in the US will rise by about 5-10 degrees F on average in the next 100 years, which is more than the projected global increase (National Assessment, 2000).

The National Assessment predicts the impact of climate change on the landscape of the United States to be dramatic, ultimately threatening the natural habitats of many species:

Our Nation has a variable climate, diverse topography and ecosystems, an increasing human population, and a rapidly growing and changing economy. The Nation’s water resources are vulnerable to climate change. Vegetation models suggest an increase in plant growth, a reduction in desert areas, and a shift toward more woodlands and forests in many parts of the country. The diverse topography coupled with landscape fragmentation and
other development pressures in the nation will likely make it difficult for many species to adapt to climate change by migrating (National Assessment, 2000).

Climate change, which is caused by, among other things, the persistent release of GHG's from fossil fuel fired electric generation facilities, will alter the balance of the Earth's natural systems. The exact response to such change is difficult to predict due to various and compounding elements. In particular, it is difficult to predict how species whose habitats are threatened by rising temperatures will respond to the changing availability of fresh water or nutrients in their home ranges. It is accepted among many scientists that the Earth is going to react to this blow; just how it is going to react is, however, not known. It must be accepted that the current method of energy production in our nation is one of the largest contributors to the Global Warming problem; alternatives to the burning of fossil fuels are presenting themselves and should be further utilized.
Chapter 2

Wind Resource Analysis

An accurate wind resource analysis is the backbone of a productive wind energy development. The goal of the wind resource siting process is to locate the site or sites which have the highest opportunity of being economically viable as well as publicly accepted (AWEA, 1993).

Stated simply, the primary requirement of a successful wind energy development is a lot of wind. As Michael Tennis of the Union of Concerned Scientists has stated, “The wind resource powering a wind project is as fundamental to the project’s successes as rainfall is to alfalfa production.” This point, as obvious as it may be, is what separates successful from unsuccessful wind developments. Stated more technically, the amount of electricity that a wind turbine produces is dependent upon the wind power density (NWCC, 1997). The key aspect behind this is that the power generated by a wind turbine is proportional to the wind speed cubed. Therefore, the annual average power output or annual energy output (kWh/yr.) from year to year will vary with a margin larger than that of the variation of the wind speed. A slight change in wind speed drastically alters turbine performance, and thus the amount of electricity generated. For example, with an annual wind speed variation of 15%, a turbine estimated to generate 100,000 kWh/yr. may produce between 61,000 and 150,000 kWh/yr. (Rohatgi and Nelson, 1994).

The first question when beginning a wind energy feasibility study

Wind power density is defined as the amount of energy in the wind passing through the area swept by the wind turbine blades in a unit of time (Gipe and Canter, 1997).
must be: where is the best wind resource within our area of interest?

In order to answer this question fully, developers should complete a two-step wind resource assessment. There are many approaches in determining the wind resource of a specific area, both expensive and less costly.

The two stages involved in a wind resource assessment are first, the preliminary area selection, and second, the wind resource evaluation for an area. The preliminary area selection entails looking at the big picture or macro-scale of a project. This stage should start with a regional look at development, then move to a state or utility service area analysis. The second stage in a wind resource assessment, the area wind resource evaluation, takes place after a specific site has been selected. During this stage, it is common to conduct a site-specific wind speed monitoring program. This process results in a more accurate understanding of the wind resource available at specific sites within an area (AWS Scientific, 1997).

Because wind is the result of the uneven cooling and heating of the Earth, its prediction is never absolutely certain even after thorough research. The wind blows stronger and more often in some areas than others, stronger during a few months of the year, stronger during a few hours of a day, and sometimes when it is predicted, it does not blow at all (Rohatgi and Nelson, 1994). The inability to absolutely control the resource is a concession that must be made early on by individuals within the wind energy industry.
I. Preliminary Area Identification

Possessing one of the largest wind energy resources in the world, the United States has the potential to supply anywhere from 10 percent to 40 percent of the U.S. electricity demand with wind power (NWCC, 1997).

A prospective wind energy developer’s first priority is to create reliable estimates of the wind resource on the land of interest. When beginning a search for the best wind resource of a region, it is helpful to understand the earth’s natural systems. As heat from the Sun is transferred into the air, the differences in air temperature, density and pressure create wind. On a large scale, the temperature differences between the tropics, and the poles drive global trade winds. On a more site specific scale, local winds are generated from the differences in temperatures between the land, sea and the features of the land. The earth’s rotation causes air to move through topographical features (NWCC, 1997).

Winds are put into two classes: general/planetary and local. The general winds are those that move in the upper atmosphere, whereas local winds are nearer the earth’s surface (Rohatgi and Nelson, 1994). The names of the major wind currents, the area and time scale they encompass are outlined below:
### TABLE 2.1  
**Time and space scale for atmospheric motions**

<table>
<thead>
<tr>
<th>Name</th>
<th>Time</th>
<th>Length (km)</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>General circulation stream</td>
<td>weeks to years</td>
<td>10,000 to 40,000</td>
<td>trade winds, jet</td>
</tr>
<tr>
<td>Synoptic scale</td>
<td>days to weeks</td>
<td>100 to 50000</td>
<td>cyclones, anticyclones, hurricane</td>
</tr>
<tr>
<td>Mesoscale</td>
<td>minutes to days</td>
<td>1 to 100</td>
<td>tornadoes, thunderstorms, land and sea breezes</td>
</tr>
<tr>
<td>Microscale dust devils</td>
<td>seconds to minutes</td>
<td>&lt;1</td>
<td>turbulence, gusts</td>
</tr>
</tbody>
</table>


To gain an effective understanding of the general wind currents of a region, researchers begin with meteorological charts and existing wind maps. This information is the most valuable resource for preliminary area identification. Archives and data centers that house information such as the National Climatic Data Center (which distributes National Weather Service information), the U.S. Forest Service, Universities, air quality monitoring networks, and electric utility companies, can be used to get an understanding of where, when, and how measurements were or are being taken, and what information is reliable (AWEA, 1993). Meteorologists generally accept that it takes 30 years of data to determine long-term values of weather or climate and that it takes at least five years to arrive at a reliable average annual wind speed at a given location (Rohatgi and Nelson, 1994). Wind atlases, which represent a synthesis of wind speed data, are often utilized to facilitate the beginning stages of a development.

Wind maps can give a quick introduction to the wind resource of a
region. The oldest and most proven of these is the Wind Energy Resource Atlas of the United States, published by the Battelle Pacific Northwest Laboratory for the U.S. Department of Energy in 1983. The Atlas used information from 1,245 wind monitoring stations across the United States to display the annual and seasonal average wind resource by region and by state. Also included in the Atlas were the wind resource certainty rating and the aerial distribution based on variation in land-surface form (Pacific Northwest Laboratory, 1987). Estimates of the wind resource are expressed as wind power class ratings on a scale from class 1 - class 7. Areas designated class 4 and above are generally acceptable for most wind energy applications (AWEA, 1993) (see appendix I for a map and wind class chart).

Certain states have undertaken their own wind resource monitoring sponsored by their independent Public Service Commissions. The Minnesota Wind Resource Assessment Program (MNWRAP), the Western Area Power Administration (WAPA), and the Northern States Power Company (NSP) each have committed resources to monitoring programs (Tennis, 1999). In 1999, the National Renewable Energy Laboratory (NREL) developed a state computerized mapping program. NREL’s goals were to reduce the human effort in creating a wind resource map and to produce a wind map that reflects a consistent analysis of the wind resource distribution throughout a region of interest (Elliott, et al., 1999). The next generation of these GIS maps will represent wind data along with transmission lines, bird patterns and other geographic

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7 NREL should be contacted to inquire if a GIS map is available of the state that is being studied. www.nrel.gov.
information (Lee, 2002).

The non-uniformity of the Earth’s surface ensures the global circulation of wind. Thus, an analysis of the small-scale variations in the land (i.e., topographic features) can be the most cost effective exercise of the siting process (Burton et al., 2001). An analysis of topographic relief maps should take note of high elevation plains, exposed ridges, exposed coastal sites, upwind and crosswind corners of islands, and areas of a high pressure gradient such as long valleys, mountain passes, and gaps. Although limited in its accuracy, wind-deformed vegetation on a landscape is also an indicator that should be considered during the preliminary siting process (AWEA, 1997).

A final and oftentimes expensive source of accurate wind resource estimates are wind energy consulting firms. There are many in the United States that maintain banks of proprietary wind data and, for a fee, are willing to consult on a project. Their price aside, consultants have often been involved in the wind energy industry for decades and often bring valuable experience to a project.

II. Site Specific Wind Resource Evaluation

Once a general area is selected for a wind development, a further in-depth study of the wind resource is necessary. The goal of this second stage is to acquire data about the wind resource in order to achieve the following objectives:

• To determine if a sufficient wind resource exists within the area to justify further study;
• To compare specific areas to determine their relative development potential;
• To obtain data for estimating the performance and/or economic viability of selected wind turbines;
• To screen for potential wind turbine sites (AWEA, 1993).

Ultimately, this second stage of analysis should result in wind speed data to be used in the ongoing calculation of a project’s feasibility. For the most efficient projects, monitoring equipment should be installed to measure the wind speeds for two to three years. The towers that hold the anemometers, or wind speed measuring devices, should be located as close as possible to the actual future location of the wind turbines. Multiple anemometers should be placed at varying heights on the tower to measure wind shear\(^6\) (NWCC, 1997).

The fundamental purpose of a monitoring program is to acquire data on wind speed, wind direction, and air temperature.

• Wind Speed - Multiple measurement heights are suggested to aid in determining a site’s wind shear characteristics, for simulating turbine performance at different turbine hub heights, and to act as a data backup. Recent NREL measurement programs have collected data at 10 m, 25 m, and 40 m.

• Wind Direction - Wind vanes allow prevailing wind direction to be determined. Wind direction frequency helps identify land features and optimize the layout of wind turbines in a wind farm.

• Temperature - An indicator of the turbine operating environment, measured at ground level. Air temperature is a variable required while calculating wind power density and, thus, wind turbine output (AWS Scientific, 1997).

A clear monitoring plan should be established even prior to the installation of the anemometer towers. This plan should be specific to

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\(^6\) Wind shear is defined as the change in wind speed at varying heights above the ground (Gipe and Canter, 1997).
the goals set by the developer. For example, does the developer want to quickly analyze the area for its windiest sites or is a long term measurement program on specific sites desired? A good monitoring plan can ensure that the design and execution of the monitoring program successfully meets the developer's siting objective (AWEA, 1993).

The monitoring program also recognizes the variable nature of the wind and the turbulence created. The wind blows in gusts, some days all day, some months all month, and other times not at all. These short term variations, whether they are spikes in wind speed or excessive turbulence, not only place the turbine's equipment under excessive stress but alter the productivity of the turbine. Wind monitoring programs should thus collect data on two short-term time intervals: 10 minutes and 3 seconds.

- The ten minute interval is estimated using a sampling rate of around one second and averaged for a 10 min. interval. The mean of the 10 min. interval is used to estimate performance of a wind turbine in terms of energy output.

- 3 second intervals give peak gust and turbulence data. The turbulence in the wind is used to estimate fatigue life of wind turbines, especially the blades (Rohatgi and Nelson, 1994).

**After the data collection process is complete, or once there is sufficient data to work with, the analysis of the annual mean wind speed must be considered when comparing the suitability of a site.** As stated earlier in this report, the energy available in the wind is proportional to the wind speed cubed. Annual mean wind speed could be from as low as 1 m/s to as high as 10 m/s (1 m/s = 2.2 mph). For wind energy purposes, a site with 5 m/s is desirable: however, 6 m/s would be
more attractive. The annual wind speed variation is an important factor to be analyzed and provide data by season and/or by month (Rohatgi and Nelson, 1994).

Wind resource analysis data is important to both the wind energy developer and the financier of a wind energy development. Developers need to be confident that they understand the energy production on a 15 - 20 year time frame as well as the economics of the development, to be assured that their risk will generate an acceptable rate of return. The financier needs to be assured that the revenues generated by the project month-to-month and year-to-year will be sufficient to cover the payments due on any loan that is made (Tennis et al., 1999). Thus, wind resource analysis at the beginning of a project is crucial not only to its initial development but also its long-term survival. An accurate wind analysis should be able to predict, with some certainty, the likelihood of a specific turbine producing electricity over the course of its life. Again, slight variations in site selection can be the difference between a successful project from one that is not so successful.

III. Wind Resource Analysis

In 1978, early in the development of the United States wind energy industry, the Battelle Pacific Northwest Laboratory of Richland Washington received a contract from the U.S. Department of Energy to publish a document entitled, A Siting Handbook For Small Wind Energy Conversion Systems. One of the first papers printed specifically to target U.S. wind energy development, it presents three approaches to site
PNL Approaches to Site Analysis

1. Use only mean annual speed from a nearby station to determine average annual power output.

- **Advantage** - Little time or monetary investment required, can be accurate.
- **Disadvantage** - Only works well in large, flat areas where an average annual wind speed is 10 mph and greater.

2. Limited onsite wind measurements used to verify data from nearby station. A combination of the data is then used to compute the site power output.

- **Advantage** - More accurate than first method. Can be applied to all sites with little topographic features.
- **Disadvantage** - Time is needed to collect data the period of which must be representative of typical wind conditions. Additional cost of the wind monitors. Not accurate in mountainous terrain.

3. Collect wind data from the site and analyze it to obtain annual power output.

- **Advantage** - Most accurate method, works in all types of terrain.
- **Disadvantage** - Requires time to collect data (at least 1-3 years). Additional cost of the wind monitors. Data must also represent typical wind conditions (BPNL, 1978).

Of the three methods presented above, the final approach offers the most accurate view of a wind resource. Wind turbines are large investments; however, the time and expenses incurred during the site analysis will be worthwhile if they lead the developer to selecting a proper site. The type of equipment used will also dictate how the data is analyzed. Presently, sophisticated recording equipment is able to gather the type of data that is useful to wind summaries. Monitoring equipment can cost a developer anywhere from $1,000 for the basic monitoring technology, to $15,000, depending upon how sophisticated the developer wants the
technology to be.

Government-sponsored monitoring agencies such as the National Oceanic and Atmospheric Administration (NOAA), the National Climactic Data Center (NCDC) or the National Data Buoy Center (NDBC) all hold records of archived wind speed data and should be consulted whenever possible. In an analysis of the offshore wind resource for the New England Coastal region, data was gathered from a variety of sources including:

- National Data Buoy Center
- U.S. Navy and Coast Guard facilities
- Mean Sea Surface Index
- Ship Log Data
- Surface and upper air observations from National Weather Service-affiliated weather stations
- State Agencies
- Maritime Research
- Other Government and Private sources (Manwell and Bailey, 2001).

The more sources that enter a resource analysis, the more accurate the conclusion. Many of the State and Federal weather monitoring programs, such as the one maintained by the NCDC which has stations at over 1,000 airports across the country, have archived data that goes back 20 and more years depending on the age of the facility. Databases such as the NCDC are invaluable to the wind energy industry.

Finally, as the industry matures, wind speed data will become more readily available. It is becoming more common for monitors to be set up specifically for wind turbines, when before, the majority of data was collected to aid aviators. The most useful monitoring programs have anemometers at multiple levels on a monitoring tower and thus can obtain any differences in wind shear.
Wind Resource Analysis Conclusion

In order for a wind energy development to be successful, it is imperative to complete a thorough and accurate wind resource analysis. A wind developer has a variety of resources to gain an understanding of the wind resource on a given piece of land. By first looking at their site on a large scale, and then following up with specific monitoring programs, a wind farm is more likely to succeed in a shorter timeframe. Finally, through the creative use of resources like archived data from government agencies, and undergoing site specific monitoring programs, a solid understanding of the wind resource can be gained, allowing the next step of the development to proceed.
Chapter 3

Siting

One of the principal differences between siting wind turbine generators and siting conventional power plants is that the performance of a wind turbine generator (the total energy produced by the machine over a given period as well as the temporal behavior of this energy production) is completely governed by the turbine’s location. This sensitivity makes the site-selection process for wind turbine generators even more critical than the site-selection process for conventional power plants (BPNL, 1981).

The successful siting of wind power projects may appear to be straightforward, but it is one of the most critical challenges facing the wind industry today (NWCC, NO.3, 1997). The major consideration in siting a wind turbine is the essential wind resource. The wind resource is not the only factor, however, that enters into the siting equation; other considerations include land ownership, proximity to suitable power lines for interconnection, state and local tax incentives, and zoning and building regulation within specific towns and counties. Furthermore, the wind energy developer is also required to take into account the visual impact the turbines will have once constructed, the environmental impact cutting roads for the construction and building large foundations will have, the noise pollution created by the turbines, and the impact the turbines will have on the bird population (Asmus, 2001).

The siting process can be an arduous task. Like any other utility-scale energy project, a wind power plant must go through the siting review process in order to acquire the permits and approvals needed to allow construction and operation. The goal of this process, which can
occur in a variety of federal, state, and local jurisdictions, is to ensure that
the plant will be safe, environmentally sound, and make appropriate use of
land (NWCC, NO.3, 1997).

By following predetermined guidelines, the initial search for a
potential wind energy site can be organized. Once a preliminary area has
been identified\(^\text{\textsuperscript{8}}\) the basic approaches to the siting process include:

\begin{itemize}
\item **Analyze Region of Interest.** A large region, perhaps 200,000 km\(^2\),
is screened for candidate resource areas (~10,000 km\(^2\)) that
appear attractive.

\item **Evaluate Candidate Resource Areas.** A candidate resource area is
screened for potential candidate sites that experience usable wind
and satisfy pertinent land use and accessibility criteria.

\item **Screen Potential Candidate Sites.** The potential candidate sites are
reviewed for candidate sites.

\item **Evaluate Candidate Site.** Wind Data are collected at the candidate
sites and the sites are evaluated.

\item **Develop Site.** A site is chosen and the best locations for individual
machines are identified (BPNL, 1981).
\end{itemize}

When comparing the siting process of a wind energy development to
that of traditional electricity generating facilities, which can be hidden
from view and do not need to be constructed in specific areas, unique
siting issues arise. For example, the success of a wind energy facility is
directly related to its ability to capture the wind resource on a particular
site, wind farms are quite often highly visible on the landscape. Ridge
lines and open plains, which are often visible for many miles, represent a
properly sited development from a meteorological point of view (DWIA,
1999). Other potential issues include:

\(^{8}\) See chapter 1 for a discussion of preliminary area identification.
• **Visual and noise impacts** in scenic areas or near residential communities. Wind turbines are highly visible structures that generate noise and often are located in conspicuous settings.

• **Potential impacts on birds and other wildlife.** Wind turbines can pose a threat to the environment and wildlife. Studies may be required to devise strategies for mitigating negative impacts on birds, soil erosion, and wildlife habitats.

• **Land owners’ rights.** Wind power plants often pay substantial rents and royalties to land owners, but the rights of neighboring land owners also must be considered.

• **Staged development.** Wind projects have the advantageous option of multiple stage construction; however, this also complicates siting proceedings and poses economic complexities. (NWCC, NO.3, 1997).

**To facilitate the siting process, both siting issues typical to any major facility as well as those unique to a wind energy facility must be identified from the outset.** Including as many parties as possible in this process will limit any last minute surprises to a developer. The National Wind Coordinating Committee, a non-governmental organization that prides itself on its collaborative approach to wind energy development, presents the following list as an example of the groups that should be included in the siting process:

- The wind developer
- State government
- Local government
- Federal agencies
- Community groups and activists
- Environmental organizations and activists
- The general public (NWCC, 1997).

Understanding the issues that typically surface during the siting process of wind turbines will aid a developer. What follows is an
introduction to some of the issues unique to siting wind energy facilities.

Visual Impact: An Issue of Aesthetics

“I think windmills are neat,” he said in his living room, as the wind outside turned a little snow into a blizzard. “When you’re out there in the fields, and you look up, they’re sort of mesmerizing.” -Conrad Schardin of Lake Benton, Minnesota (Jehl, 2000).

The most frequently mentioned objection to the use of wind energy is the perceived aesthetic impact that wind turbines have on a rural vista. Difficulties arise because opinions of wind turbines on the landscape will differ from one person to the next (Gipe, 1995). Some are intrigued by how they work and see them as an inspirational approach to electricity generation while some are repelled, viewing them as eyesores that destroy a rural vista. Many support the concept of wind energy in the abstract as a means of conservation or as a source of sustainable energy but object to specific projects when they are proposed to be built in their local area (Gipe, 1995). This has been termed the NIMBY (Not In My BackYard) syndrome. Although it is not unique to the wind energy industry, this phenomenon should be recognized by the wind energy industry as a challenge to development.

Efforts to educate and inform nearby communities about wind energy and its benefits can help lessen this aesthetic opposition (NWCC, NO.2, 1997). It is understood that the level of public support will vary with peoples’ local experience with wind power (DWIA, 2000). For example, in Denmark, a country that has a high level of public understanding of wind energy, there is a large amount of support for wind
power as a renewable energy source.

Public education programs are not a sure thing, however. Amazingly, the sight of wind turbines spinning on a hill side has the ability to offend and rally a very vocal opposition. These aesthetic concerns can be modified with modern turbines, tubular towers, and sleek, minimalist features that contribute to a more attractive appearance. Further, some developers try to arrange a wind plant’s turbines in an orderly fashion, giving a more purposeful and efficient appearance (Dale, 1997).

Cleaning the cluttered appearance of wind farms is necessary to increase the acceptance of wind energy. Part of the task of wind energy development is to improve the reputation of the wind energy industry in the United States:

Part of the problem here is that in the history of American wind energy, there has seldom been a wind farm that is sensitive to the visual landscape. One of the results of the initial wind energy boom in California in the 1980’s was, yes a large amount of wind turbines installed, but more like some of the best examples of how not to arrange a wind farm. As the [California] state tax incentive was winding up, turbines were slapped up on road cuts, on ridge lines and in disarray on the flatter terrain (DWIA, 2000).

Present wind developers in the U.S. are continuing to receive backlash from the public as a result of the aesthetic carelessness of wind energy developers in the 1970s and 1980’s. Given the lasting scars of the older facilities, it is understandable that residents reject their local areas turning into the wind energy waste lands of California. The Danish Wind Turbine Manufacturers Association offers the following guideline as one way to avoid obtrusive wind turbines on a landscape:
In flat areas it is often a good idea to place turbines in a simple geometrical pattern which is easily perceived by the viewer. Turbines placed equidistantly in a straight line work well. In hilly landscapes it is rarely feasible to use a simple pattern, and it usually works better to have the turbines follow the altitude contours of the landscape, or the fencing or other characteristic features of the landscape. (DWIA, 1999).

Another approach to countering the aesthetic argument is to use larger turbines in the development, which allows for the same amount of energy to be produced with a fewer number of turbines. From an aesthetic point of view, large turbines have a lower rotational speed than smaller counterparts, resulting in a less visually intrusive development (DWIA, 2000). There are also economic advantages to this approach such as lower maintenance costs.

Without detrimental affects to wind generating potential, steps can and should be taken to reduce the number of complaints by local residents through making wind turbines less obtrusive on the landscape and more pleasing to the eye. If careful attention is given to how a wind turbine array is set against the landscape, the aesthetic impact of wind turbines could be lighter.

Noise

As the turbine blades spin through the air, noise is created. While wind farms are typically constructed in remote locations, and in these instances noise would not a major problem for the industry given the distance to the closest neighbors (DWIA, 2000), there are cases where the site is located near homes or buildings. In those instances, the noise issue is often heavily debated, and it must be considered when siting a facility.
How the noise of the turbines is interpreted is subjective. Some people want absolute silence on the landscape while others gain a feeling of excitement when they hear a turbine spinning. However, even nature emits sound. At winds speeds of 4-7 meters/second and up, the noise from the wind in leaves, shrubs, and trees will gradually mask the actual spinning sound from the wind turbines (DWIA, 2000). For this reason it is difficult to quantify the exact contribution a wind turbine has to the noise of a windy landscape. Additionally, advancements in design have lessened the noise created by a spinning turbine. As with all issues that enter into the siting equation, the impact turbine noise has on the neighbors of the site needs to be considered. Noise issues may be mitigated through zoning ordinances that specify allowable noise levels and distances between turbines and residential areas (Dale, 1997).

**Zoning/Building permits**

Before a site is chosen for a wind farm, it is important to understand the legal requirements of the municipality where the wind farm will be constructed. Zoning laws are created to protect the public's general health and welfare and are the responsibility of local governments. When constructing a wind energy development, local officials will want to be shown how the use will conform with present restrictions. The United States wind industry has had few issues with zoning restrictions, mainly due to the fact that clearly defined zoning laws can easily be acquired at county building offices. Also, many of the windiest areas are rural, which in many cases have no restrictions on
States and communities that are interested in wind energy should develop laws, ordinances, and regulations for siting wind projects. The advantage of this planning for developers and the public is that many important questions can be discussed and resolved without arguments over specific elements of a proposal. Standards should be set in the following areas:

- **Wind turbine size**, including maximum rotor size, minimum and maximum height, tower height and base.
- **Installation and design**, including tower, rotor and electrical safety, utility notification, warning signs and tower access.
- **Siting**, including setbacks from plant boundaries and neighboring facilities, aesthetic design (such as tubular or lattice towers) and clearances from electrical lines.
- **Nuisance concerns**, such as noise regulations and television or radio interference.
- **Other regulations**, including insurance, public access to wind facilities, and repair, maintenance and decommissioning requirements (NWCC, 1997).

By establishing such regulations, zoning committees are able to convey a message to prospective wind energy developers regarding what type of projects they will consider within their jurisdictions. These clear regulations assist both the developer as well as the overseeing agency in that it establishes the law on what development a specific municipality will or will not allow. A wind energy permitting process is established to ensure that projects comply with existing laws and regulations, providing for necessary environmental protection at a reasonable cost. This process
also defines a time period for potential court challenges. Knowing these codes, developers can avoid making proposals in nonsympathetic counties and wasting both the developer’s as well as the managing committee’s time.

**Ecological Impacts**

The construction of a wind energy facility is a major undertaking; roads need to be built, towers erected, and turbines assembled. The presence of heavy machinery, such as large cranes and trailers, during construction will undoubtedly disturb the bird and animal life of the area. Wind energy opponents argue that the turbines have a lasting negative impact on the area.

Ecological studies have shown that birds and other animals avoid nesting or hunting in the immediate vicinity of wind turbines. Further, road construction and tree clearing can disrupt habitats and allow the introduction of unwanted species. The problem is compounded because some of the best prospective wind sites are located in remote, mountainous areas that support many different plant and animal species (Dale, 1997).

The occasional disregard shown by wind energy developers in the 1980’s has resulted in a split in the environmental community over the use of wind energy. A final push in the 1980’s to take advantage of an expiring tax credit caused developers to erect turbines quickly where the wind blew without regard to the environmental impact they were causing. Today, if wind energy is to develop into a substantial contributor to the United States’ energy portfolio, developers need to recognize the mistakes of twenty years ago and show great sensitivity to environmental issues.

Because a wind farm will have a considerable impact on its
surrounding environment, development should not take place in ecologically sensitive areas. In an attempt to mitigate the impact of wind farms, an Environmental Impact Statement (EIS) is necessary. An EIS is required to ensure that the project is in compliance with various state and federal laws, and while occasionally expensive and time consuming, the EIS process is required to obtain the necessary permits for construction.

The EIS process of a wind energy facility will summarize:

- The physical characteristics of the wind turbines and their land-use requirements.
- The environmental character of the proposal and the surrounding area.
- The environmental impact of the wind farm.
- The measures which will be taken to mitigate any adverse impact.
- The need for the wind farm and provide the details to allow the planning authority and general public to make a decision on the proposed project (Burton et al., 2001).

**Birds**

The expansion of wind energy developments has been accompanied by concerns over unforeseen bird deaths caused by striking turbine blades and turbine support structures (Morrison, 1998). Unfortunately, many of the traits that characterize good wind sites also are attractive to birds (Dale, 1997). The presence of a wind farm may be detrimental to bird life due to collisions, noise disturbance, or habitat loss (Burton et al., 2001). However, taking proper precautions during the siting process can help prevent the majority of wind turbine associated bird deaths.

10 For a detailed outline of the topics covered within an EIS see Appendix III. It should be understood that it is a required step of the development process.
The increased mortality of raptors, especially federally protected golden eagles and red-tailed hawks, killed by wind turbines and high-voltage transmission lines near California’s Altamont Pass, brought the issue to the surface (Dale, 1997). The fact that raptor populations are typically small in size raised concern in avian advocacy groups. Further, raptors are protected by state and federal laws, which raises potential regulatory barriers to wind-energy developments. Concern has also been raised regarding potential negative impacts to other groups of birds, including waterfowl and migratory birds (Morrison, 1998).

During the siting process, it is necessary to consider potential impact on the local and migratory bird populations. A model has been established in an effort to limit that impact. It is predicted that with proper planning during the siting process, many of these bird deaths could be avoided. The following list outlines steps that, once taken, will increase the bird friendliness of wind energy developments:

- Baseline studies should be undertaken at every wind farm site to determine which species are present and how the birds use the site. This should be a mandatory part of the Environmental Impact Statement for wind turbines.

- Known bird migration corridors and areas of high bird concentration should be avoided unless site specific investigation indicates otherwise. Where there are significant migration routes the turbines should be arranged to leave suitable gaps (e.g., by leaving large spaces between groups of wind turbines.

- Micro habitats, including nesting and roosting sites, of rare/sensitive species should be avoided by turbines and auxiliary structures.

- Particular care is necessary during construction and it is proposed that access for contractors should be limited to avoid general disturbance over the entire site. If possible, construction should
take place outside the breeding season. If this is not possible then
construction should begin before the breeding season to avoid
displacing nesting birds.

- Tubular turbine towers are preferred to lattice structures.
  Consideration should be given to using unguyed meteorological
  masts.

- Fewer large turbines are preferred to larger numbers of small
  turbines. Larger turbines with lower rotational speeds are probably
  more readily visible to birds than smaller machines.

- Within the wind farm the electrical power collection system should
  be underground (Colson, 1995).

The impact of wind turbines on bird populations is an especially
important issue for many environmentalists. As with most scientific
studies, ongoing research is needed to clarify the extent of the impact.
What is known, however, is that the wind energy industry is losing the
much needed support of individuals within the environmental community,
not only from the avian advocacy groups, but from other groups as well.

**Tax Incentives**

During the site selection process, another key factor is the
availability of tax incentives in a particular area. Some state and local
municipalities are presently using incentives to attract wind energy
development in their region. Specifically, investment tax and sales tax
incentives and reductions in property taxes can cause certain sites to be
much more attractive to developers than other sites.

Investment tax credits (ITC) have been widely used to encourage
wind energy development. On the state level, these credits can lessen the
state income tax burden of the investors. Established by state legislatures,
the tax reduction is often given as a proportion of the overall investment. Although opponents of the ITC argue that it gives an incentive for the investment in renewable energy rather than for the actual energy produced, its more definite financial breaks can make one site more appealing than another.

States and local municipalities often reduce sales taxes to encourage wind development in their jurisdiction as well. This credit is calculated as a reduction on the tax payment per kWh of production. In general, since renewable energy facilities have relatively high capital costs and low operational costs when compared to fossil fuel powered facilities, the per-kWh sales tax burden is also high. Thus, sales tax reductions are likely to be appealing to larger wind developers once other factors such as the available wind resource has created an interest (Rader and Wiser, 1999).

Property taxes on renewable energy facilities are also high when compared to those of traditional energy facilities. This is another result of the high capital cost and low operating cost of the facility. Property taxes, which depend on rates and assessment methods, are often higher than sales taxes. Thus, the overall cost of a wind energy facility can be greatly impacted by the local property tax rate. Certain municipalities, which set their own property taxes, have recognized this and have crafted taxes to encourage wind development.

The specific tax policy of a region will never be so attractive as to be the sole factor of where to site a wind energy development. It can, however, be a deciding factor when comparing the feasibility of
developing sites with comparable wind resources.

**Land Requirements**

A general rule of thumb for the siting of turbines is that the entire rotor should be 30 feet above any obstruction within 300 feet (Gipe, 1993). The basic land requirement is that a site needs to be able to hold a turbine large enough to satisfy that rule, as well as permit heavy construction equipment access to erect the towers and install the rotors. Certain sites may prevent wind development due to access restrictions.

More often than not, the operation of wind turbines is compatible with the present use of the land. Specifically, renewable energy and agriculture can coexist on the same land in a symbiotic relationship. Not only do the lease payments add an influx of money to rural economies, but the turbines require little space once constructed and allow for farming or ranching practices to continue. Accomplishing both, cattle grazing and wind energy on the same land is becoming a more and more common. The cattle are unfettered by the turning turbines, grazing right up to their bases.

**Proximity to Transmission**

During the preliminary site selection process, transmission maps should be consulted to locate the nearest transmission lines to the site of interest. These lines should be than checked for their voltage and their compatibility to what will be produced by the wind turbine. Most wind

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11 For more on this issue, see Chapter III. of this paper which discusses the transmission and interconnection of wind energy.
farms are connected to rural, overhead distribution lines which tend to limit wind energy development. By consulting a transmission map, a developer can quickly estimate the available transmission potential of an area and the cost the wind farm would incur in upgrades in order to meet its needs rather quickly. These maps are found either through an engineer or through contacting the utility that controls the transmission in the region.

**Siting Conclusion**

Wind energy siting is a detailed process with a compound goal to benefit the developer as well as the people and ecology of a particular region. Once completed, a thorough siting inquiry will help limit the visual and noise pollution of a site and lessen the impact on birds and other wildlife, while placing the turbines in the best location to capture the available wind. Once the siting process is complete and the developer obtains the proper permits, the next step is to finance the wind farm.
Chapter 4

Interconnection and Transmission

Now that generating is being opened to competition, it is important that transmission access rules and pricing be designed with new market entrants in mind, including wind energy. Unless transmission policies become sensitive to those needs, in the same way they are sensitive to the unique characteristics of more established technologies, then transmission policies will favor continued reliance on more polluting technologies and the promise of [renewable] power will not be fully realized (AWEA, 2001).

As the regulations that surround the electric power industry changes, so to will the way traditional utilities operate. Under ideal circumstances this change in regulation will force utilities into greater competition for customers. This could result in the increased reliability of power delivery, plus the supplier will also be subject, on a greater level, to customers’ preferences to particular types of power. Significant change in regulations will increase the number of independent power providers (IPP) that are connected to the electricity grid. These power providers will have many options for how they get their electricity; they could use traditional fossil fuels such as coal or gas or they could follow the lead set by many IPPs in the industry and choose wind energy as their generating source (NWCC, 2000).

New wind generating capacity in California topped 1,600 MW during the past decade. As the wind energy industry focuses on other regions of the country, many with better wind resources than California, lessons learned from past experiences have proven valuable. For example, while many of the barriers to connecting wind energy to a utility grid are
either structural or procedural, one of the largest barriers is rooted in the nature of the wind itself. The intermittent quality of the wind as well as the large distance between the major wind resources and the population bases are seen as major hurdles to the wind energy industry (NWCC, 2000). These specific barriers that continually prevent the integration of wind energy into the electricity grid thus differ from the barriers of conventional generating resources. Wind energy development, as it relates to the transmission of electricity, is currently restrained by this reality:

- Wind is an intermittent energy source.
- Wind development must occur where the wind resource is, which may or may not be near customer load or transmission systems.
- Wind systems have a lower capacity factor\(^{12}\) (20% to 40%) than conventional resources, meaning that wind has fewer kilowatt-hours of electric energy over which to spread fixed transmission costs (Brown et al, 1999).

Adding to the limitations for using wind turbines are the physical constraints of the existing utility grid. In most situations, wind resources are not located near accessible transmission lines. Plus, since transmission lines have a limited capacity, in the rare cases where a good wind resource does have nearby transmission, those lines may not be able to transport additional electricity anyway. Transmission facilities throughout the country are strained and are in need of upgrading; wind energy developers often find themselves required to commit to those costly upgrades in order to secure an interconnection contract with a

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\(^{12}\) The quotient of the actual energy generated to that possible if the generator had operated at its rated capacity (power) over the time interval of interest, most often that of one year (8,760 hours) (Gipe and Canter, 1997).
utility (NWCC, September, 2000).

The next section discusses issues that are pertinent to wind energy interconnection and transmission, beginning with a basic description of the present structure of the transmission and distribution systems of a utility. Then the discussion moves to the technical, economic, and regulatory barriers that exist for wind energy developers.

I. Transmission and Distribution

Once electric power is generated, it must be delivered to consumers. The transmission and distribution (T&D) systems allow this to take place. The T&D system carries the generated electricity from a power plant to a utility’s customers and is responsible, through a network of components, to deliver the exact amount of electricity needed by a particular customer at a given time (Warkentin, 1998). A typical T&D system is made up of a switchyard, transmission lines, a substation to transform the power to transmission grade electricity, and distribution lines. On the transmission side of a T&D system, transmission lines and a utility’s switch yard are the major components:

**Transmission lines**
- Carry high-voltage electricity from switch yards to substations
- Link the switch yards of individual utilities to power grids

**Distribution lines**
- Carry power from a substation to consumer areas
- Deliver power to consumers (Warkentin, 1998).

As the overall demand for electricity grows in the United States,
transmission facilities are continually being stressed. Rather than building new or upgrading existing transmission lines, many utilities are discovering the virtues of distributed generation. The traditional format of a utility, where distribution facilities move electricity from central power plants to the consumer, are being reconsidered by utilities such as the Sacramento Municipal Utility District to find ways of producing power closer to the customer through small power plants. Small generators like micro natural gas turbines, wind turbines, fuel cells, and photovoltaic can be located near customers to provide power where it is needed, unclogging overloaded power lines and deferring the need for upgrades in the distribution system (Smeloff and Asmus, 1997).

II. The Three Major Barriers to Wind Energy Interconnection

• **Technical Barriers.** Technical interconnection barriers include utility requirements intended to address engineering compatibility with the grid and grid operation. These barriers include specifications relating to power quality, dispatch, safety, reliability, metering, local distribution system operation and control. Examples include engineering reviews, design criteria, engineering and feasibility studies, operating limits, and technical inspections required by distribution utilities.

• **Economic / Business Practice Barriers.** Business practice barriers relate to the contractual and procedural requirements for interconnection including contract length and complexity, contract terms and conditions, application fees, insurance and indemnification requirements, necessity for attorney involvement, identification of an authorized utility contact, consistency of requirements, operational requirements, timely response and delays.

• **Regulatory Barriers.** Regulatory barriers are specific policies that fall within the jurisdiction of state utility regulatory commissions or the Federal Energy Regulatory Committee (FERC). These are issues that arise from or are governed by statutes, policies, tariffs,
or regulatory filings by utilities, which are approved by the regulatory authority. Regulatory prohibition of interconnection, unreasonable backup and standby tariffs, local distributions system access, pricing issues, transmission and distribution tariff constraints, independent system operator (ISO) requirements, exit fees, “anti-bypass” rate discounting, and environmental permitting were put into this category (Alderfer et al., 2000).

**Technical Barriers**

In December 1998, the Institute of Electrical and Electronic Engineers (IEEE) began drafting the standards for the interconnection of distributed resources with the electricity grid. Once developed, these standards will encourage the construction of new wind power by clearly outlining the requirements of the industry. As they become more widely used, these standards should further increase development providing uniform technical requirements will reduce the costs of interconnection hardware, and reduce the time and expense associated with acquiring an interconnection agreement with the host utility (Green and Wind, 2000).

Technical requirements for interconnection are established to:

- Ensure the safety of utility personnel
- Regulate the flow of electricity on and off of the grid
- Simplify and lower the costs of connection requirements
- Allow for manufacturers to clearly understand what is being required of them which will enable them to develop appropriate equipment and software (Green and Wind, 2000).

**Economic / Business Practice Barriers**

The large utilities can be daunting institutions for an independent power provider to approach. From a bureaucratic
perspective, utilities appear to have layer upon layer of procedures to follow before anything is accomplished. Some procedures seem to be created just to make the connection of a distributed generation product more difficult.

The stages required by a typical utility prior to interconnection:

- Initial utility contact and requests for interconnection
- Application and interconnection fees
- Insurance and indemnification requirements
- Utility operational requirements
- Final interconnection requirements and procedures (Alderfer et al., 2000).

While studying these barriers, a National Renewable Energy Laboratory group found that utilities justify their interconnection procedures differently. Brent Alderfer led the study which completed interviews with project owners and developers. Cases ranged from a utility representative telling a customer that interconnection was not possible, to another utility that purposefully choosing not to follow state regulatory commission laws, to a third utility that wrongly telling an independent power provider that its project was not, under the Public Utility Regulatory Policy Act (PURPA), categorized as a Qualifying Facility (QF). After negotiations, the utility in this third example gave in stating that it would make an exception and go out of its way to allow interconnection while all they were being asked to do was follow the law (Alderfer et al., 2000).

In the past, utilities have clouded the interconnection process with lengthy procedures and ambiguous rules that they use to discourage interconnection. Many utilities are increasingly seeing
proposed wind energy interconnection cases and have begun to move through the process with some consistency. Knowing both the federal and state laws surrounding interconnection as well as making a contact within the utility itself will prove to be invaluable to a potential developer.

**Regulatory Barriers**

The third and final group of barriers are of a regulatory nature. By and large the transmission systems of the United States remain under a monopoly service. This structure places the control of the system in the hands of one utility. When the industry was under strict regulations this monopoly service was at least predictable. Under the present structure, however, an IPP can either be denied access to transmission or presented with unfairly high rates to interconnect, both of which can affect the competitiveness of a generation technology. The American Wind Energy Association (AWEA) views certain policies as significant hindrances to further wind energy development. In a paper outlining these barriers, the AWEA offers five approaches to change the present transmission policy:

1. Remove discriminatory connection requirements.

2. Charge the embedded costs of the transmission system to the customers rather than the generators.

3. Avoid multiple levies when power is transmitted through several transmission systems.

4. Allocate capacity fairly among all generators when the system is congested.

5. Base penalty costs on actual market values for spot market power purchases of power delivered to the system rather than on theoretical costs incurred (Wind Power Monthly, MAY 2000)
In short, effective transmission policies should take into account the different circumstances of the generators that are attempting to meet them (AWEA, 2001).

**Regulatory Barrier 1: Discriminatory Connection Requirements**

Interconnection to the electric transmission grid is a necessity. However, even in states where transmission operations have been made independent from electric utility generation interests, interconnection policies often remain in the hands of vertically integrated utilities that have financial incentive to limit the market integration by competitors such as wind energy interests. Also, when presented with contract, tax, financial, permit, or other such development deadlines, project developers often have little time to challenge interconnection costs that they feel are unfavorable. Lengthy litigation over an interconnection contract is not always an option. Instead, to ensure the project remains on schedule, they are forced to pay these unfair costs. *Obtaining timely interconnection at reasonable costs is critical to the success of a wind energy development* (AWEA, 2001).

**Regulatory Barrier 2: The Allocation of Embedded Costs**

The capital invested in the construction and operation of transmission facilities are referred to as embedded costs. A transmission organization has three methods of recovering these costs: by charging the consumer, charging the generator of the electricity independently or
splitting the charge between the two parties. The approach a transmission organization takes to recover their embedded costs can greatly impact the development of a wind farm (AWEA, 2001).

**When the embedded cost is charged solely to the generation facility, remote projects, such as a wind facility, are greatly impacted.** Historically, transmission organizations charge a generator embedded costs in proportion to the miles needed to transmit the electricity from its generating source to a “load center.” The result of this is that remote technologies pay a greater share of the embedded costs than those located closer to the “load center.” Transmission policies require wind energy and other site dependent energy facilities to pay more for their transmission services than those that are easily sited near load centers (AWEA, 2001).

**Regulatory Barrier 3: Multiple Transmission Fees or Pancaking**

In a paper entitled Fair Transmission Access For Wind: A Brief Discussion of Priority Issues, the American Wind Energy Association summarizes the problem of “rate pancaking” as follows:

When a generator seeks to deliver energy to a distant load, it may have to use the transmission system of multiple owners/operators. In such cases, the access charges of each owner/operator accumulate to a collective access charge which can far exceed an equitable access rate. This is not merely a function of using more transmission and therefore having to pay for more - it is a function of crossing ownership lines and having to pay multiple access rates that were each developed assuming only a single rate applies. This phenomenon is referred to as rate pancaking (AWEA, 2001).

Again, due to the remote nature of wind energy facilities, it is common for them to be subject to these multiple layers of transmission of fees. This excess charge can often be so significant as to undermine the
success of a wind energy facility.

**Regulatory Barrier 4: Congested Capacity Allocation**

*Congestion in transmission lines results from the demand for transmission exceeding the physical capacity of the lines.* To prevent this from occurring on a regular basis, transmission operators contract out the available capacity among generators who need to transmit their energy to their customers. Another result of remote wind energy facilities is the limited transmission options a generator can use. Policies that regulate the transmission system’s ability to eliminate congestion impact wind technologies (AWEA, 2001).

*A common approach to solving transmission congestion is to cut back on the allotted transmission of the most recent market entrant.* In other words, the newest generator to enter the picture loses the ability to access the transmission lines. This can be a devastating blow to an emerging wind energy facility which, more often than not, lose transmission access. Under this format the older, less efficient technologies are given greater transmission access (AWEA, 2001).

**Regulatory Barrier 5: Schedule Deviation Policies**

In the contract made with the transmission operator, the transmission users are asked to schedule their use of the system. This process necessarily entails predicting the amount of electricity a certain facility will produce within a given time frame. However, the reality of wind energy is that the actual generation of electricity often is not as
predicted, and the generator is penalized according to the amount of the deviation.

These penalties were established based on the understanding that the deviation is both harmful to the system and controllable by the generator. A contrary argument, presented by the American Wind Energy Association, asserts that these deviations can benefit the system as often as they harm it, and that the generators should be penalized only for the harm they cause the system. As far as predicting the exact amount of electricity generated is concerned, this is a near impossibility for wind projects. Given the current regulation, however, the most common approach in dealing with this issue for wind generators is to estimate a wind farm’s production close as possible and to take the penalties when they come as a cost of doing business (AWEA, 2001).

Thoughts on Reducing Regulatory Barriers

There are two flaws with the current system that hinder wind energy development. In the words of American Wind Energy Association’s legal counsel Chris Ellison: “One is that [the current rule] presumes everyone has control of how much they generate, and that is no longer true, especially as new resources like wind come on-line. The other is that it always assumes there is a negative impact associated with getting a delivery forecast wrong” (Windpower Monthly, September 2000). Under the present policy, if a generator either over or under-predicts its generation, something it must predict accurately under the long-term contract with the transmission facility for a given timeframe, it
is penalized. This penalty is delivered regardless if this deviation from the contract helps the overall system by stabilizing the voltage at a specific time or hurts it.

At the center of this issue is the fact that it is difficult to match the availability of wind energy with customer demand because of the distance, the lack of available transmission capacity between the generation and load, or differences in timing between when the energy is available and when it is needed (NWCC, 2000). This is an important issue for wind developers because, as discussed above, the exact timing of the output of a facility can rarely be predicted. To remedy this situation, the AWEA recommends the creation of a “real-time balancing market,” which would penalize a generator only if it hurts the system; if it helps the system out, the generator would get paid at a rate based on the market value of the excess electricity its turbine created in excess of the predicted output (Windpower Monthly, September 2000).

Generators that utilize intermittent and/or remote resources such as wind energy are interested in policies that penalize wind energy for its intermittent nature (Brown et al., 1999). The National Wind Coordinating Committee sees a potential answer to this issue.

This problem can be addressed in several ways. At the local level, wind energy can be accommodated by backing off fossil generation\(^\text{13}\) when the wind energy is available and replacing the displaced energy at a later time. This concept can also include storage. At a regional level, this concept can be extended to include delivery of the energy at another place and time by the same entity that purchases the energy, or by another entity through the purchase of a green energy credit. At the national level, one can imagine a purely financial transaction in which green energy credits are

\(^{13}\text{Natural Gas fired facilities make for a good match with wind energy in that they have a faster response time in either backing off or increasing a facility’s production.}\)
bought and sold (NWCC, 2000).

The National Wind Coordinating Committee and the American Wind Energy Association are leading the policy battle in the interest of the wind energy community. They should be contacted directly with further questions.14

**Interconnection and Transmission Conclusion**

Transmission and distribution systems are designed for one-way flow of electric power from large, central generating plants to electric customers. A structural change in which there is a continuous flow of power from many distributed sources, including wind generators, raises concern within the utilities for the safety of their personnel and for grid regulation, stability, and protection (Green and Wind, 2000). Understanding the barriers presented above will help potential developers get a better grasp of the system within which they are attempting to operate, thus opening the door to an increased and more efficient use of wind energy in the future.

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14 National Wind Coordinating Committee can be found at www.nationalwind.org, the American Wind Energy Association at www.awea.org.
Chapter 5

Wind Energy Economics

Will a wind machine pay for itself? Will it be a sound investment? Or, more simply, is it worth the trouble? The answers to these frequently asked questions are elusive. They depend on a number of speculative variables not subject to precise calculation, such as inflation, interest rates, and the desired rate of return. Nor is there just one straightforward way to look at the economics (Gipe, 1993).

The growing uncertainty surrounding future energy costs has become one of the major forces driving development of renewable energy in the United States. “Attempting to predict energy costs is a hazardous endeavor, as the cost of energy is driven primarily by the cost of oil, which, considering the present geopolitical state of the world, is liable to shift daily” (Nelson, 1996). Nonetheless, the continued progress made within the wind energy industry has decreased its overall cost of producing electricity and increased its competitiveness with traditional forms of energy production.

Proponents of wind technology claim that wind energy will do even more than present a clean form of sustainable electricity; it will also create sustainable jobs for some depressed rural economies. To get to that point, however, it is necessary to understand the basics of how the wind energy business works. Even if the concept of wind energy meets the ideals of both environmentalists and energy engineers, the wind energy industry will not last if the technology is not financially viable.

Wind-generating electricity has dropped in price by more than 80% since the early 1980’s. Modern, utility-scale wind turbines generate
electricity for about 4 cents/kWh, a level which has made wind energy appealing to power producers (AWEA, 2001). “There is growing consensus that wind energy offers a way to meet the needs of both the economy and the environment by providing a source of clean, competitively priced power” (NWCC, 1997).

The following discussion of wind energy economics will take two separate but directly related approaches to the issue. First will be an outline of the potential for the economic development of wind energy and the significance it may hold for the United States. Next will come an introduction to the economic factors that enter into the wind energy equation and what is needed to have a profitable wind energy development.

I. **The Economic Development Benefits of Wind Energy**

The wind is unarguably a potential source of clean sustainable energy for the United States. As this reality becomes recognized throughout the country, a rising trend in wind energy development will follow. As wind becomes harnessed on a more regular basis, a portion of the economy will begin to rely on it. Discussed previously was how wind energy is able to benefit the United States economy through creating a domestic source of clean and affordable energy; this section will focus on the potential wind energy holds for rural economies. The main question is how to capitalize on this potential.

It is estimated that if every megawatt (MW) of installed wind energy generates about, “60 person-years of employment or the equivalent of 15-
19 jobs. A typical 50-MW wind farm would then represent 3,000 person-years of employment” (AWEA, 2001). These new jobs would be created directly from the installing, operating and maintaining of the wind facilities as well as indirectly from local businesses supplying goods and services to support these activities. In some cases, manufacturing jobs would be created resulting from the relocation of a manufacturing plant to an area. For example, these plants could produce the components of the turbines, the tower sections, as well as the turbine blades. In a study done for the Union of Concerned Scientists, Steven Clemmer found that developing 800 MW of wind energy in Nebraska would create more jobs, earnings, and growth in gross state product than developing natural gas and coal facilities to produce an equivalent amount of electricity (Clemmer, 2001).

As mentioned above, many rural areas have premium wind resources. While a lack of transmission opportunities holds back development in these areas, once that barrier is overcome, these rural areas could benefit greatly from wind energy development. On a local level, the development will provide jobs as well as lease payments and royalties resulting from the use of the land. In high wind areas, developers may pay as much as $2,000 per year for each turbine installed (UCS, 2001). Turbines require only one quarter acre of land so there is little disturbance to the amount of land available for planting or livestock grazing.

The addition of a wind energy development to a region can have a beneficial impact. Studies by the American Wind Energy Association
conclude:

- Alameda County California, for example, collected $725,000 in property taxes during 1998 from wind turbine installations valued at $66 million.

- The 240 MW of wind capacity installed in Iowa in 1998 and 1999 produced: 2000 six month-long construction jobs and 40 permanent maintenance and operations jobs; $2 million per year in tax payments to counties and school districts; $640,000 per year in direct lease payments to landowners.

- LM Glasfiber, a Danish wind turbine blade manufacturer, became at a single stroke, one of North Dakota’s largest (private) employers in March 1999 when it opened a new factory in Grand Forks, ND that will employ 130 workers (AWEA, 2001).

A Department of Energy study found that renewable energy technologies offer up two basic economic advantages over traditional generating facilities: First, they are labor intensive, so they generally create more jobs per dollar invested than conventional electricity generating technology, and second, they use indigenous resources, so most of the energy dollars can be kept in the local area (DOE, 1997). A New York study, for example, found that producing 10 million kWh of electricity from wind energy generates 27 percent more jobs in the state than producing the same amount of energy from an advanced coal plant and 66 percent more jobs than from a natural gas combined-cycle power plant (NWCC, NO.1, 1997). In Nebraska, Clemmer found that these benefits usually go to those who needed it the most: the rural communities with the wind resource. The average income of the ten windiest communities in that state are, on average, 21 percent below the state average, and the poverty rates are higher than the state average in all but one of those windiest counties (Clemmer, 2001).
The sale of wind rights represents a significant potential income for landowners in windy areas. A Lake Benton, Minnesota farmer received a payment of $40,500 for the sale of the wind rights on his 90-acre farm, a figure that represented nearly the going rate for the land itself (Jehl, 2000). On top of that, the farmer now collects $2,000 per year per turbine as a lease payment. This is significant income for farmers who grow grain that rarely yields more than $40 per acre per year (Jehl, 2000).

In the wind energy debate, clear socioeconomic benefits and costs have been presented for and against its development. In such lists, how to analyze certain points can be subjective; what some people see as a positive, others may view as a negative. The benefits and costs of wind power development range from quantifiable economic and financial impacts to effects that are difficult to calculate and thus rely on an individual’s impression of the technology.

**Socioeconomic Benefits.**
- Landowner revenues
- Site Infrastructure
- Construction Jobs
- Procurement of local goods and service during construction
- Operation and maintenance jobs
- Procurement of local goods and service during ongoing operation
- Property, sales and income tax revenue
- Reduction in energy imports
- Air quality Improvements (relative to fossil fuel sources)
- Community distinction / tourism

**Socioeconomic Costs.**
- Land requirements
- Site infrastructure
• Visual impact
• Noise
• Avian impacts (BBC, 2000).

Three-fourths of the states in the U.S. have wind resources that could be used for commercial generation of electricity (AWEA, 2000). In other words, many state economies could potentially benefit from its development. Wind energy alone could provide $1.2 billion in new income for farmers and rural landowners by 2020 and 80,000 new jobs (UCS, 2001). The calculated use of our country’s wind resources represents not only a source of domestic renewable energy, but also a sustainable form of economic growth.

II. The Business of Wind Energy

Regardless of recent advancements made in the construction and design of wind turbines and how they may benefit the economy of a community, for wind energy to be accepted as a viable means to generate electricity, wind farms need to meet the requirements of a successful business. An understanding of how wind energy can work as a business and the factors that differentiate a profitable development from a not so profitable development is essential. This being understood, producing and selling electricity from the wind is similar to any other energy business that is attempting to get its share of this large sector of the economy. As a first step, to be economically viable, the cost of making the electricity has to be less than its selling price (EWEA, 1998). The European Wind Energy Association, in a paper entitled “The Economics of Wind Energy,” lists the
elements that make up the cost of generating electricity:

1. **Capital cost** - building the power plant and connecting it to the grid
2. **Operating cost** - operating, fueling and maintaining the plant

This section deals with the economics of wind energy by detailing the elements of the capital cost, operating cost, and financing of a project, and by presenting specific models for project analysis.

**Basic Wind Energy Economics: Capital Cost**

The capital cost or the initial installation cost of a project is made up of the cost of securing the land and the purchasing, shipping and installation costs of the wind turbines (Nelson, 1994). By following the basic theory of economies of scale, it would be assumed that as the size and number of turbines increases, the cost of producing a kilowatt hour would decrease. Unlike a thermal power plant (which can be viewed as a giant tea kettle, taking proportionately less material to cover a larger and larger volume kettle than to cover a smaller volume one), however, economies of scale are not as much of a factor with wind energy facilities. While technological improvements are making machines more efficient, they are out weighed by the cost of design and installation of the turbines themselves. The manpower needed to design and build a 150 kW machine is roughly a third of what goes into a 600 kW machine (DWIA, 2000). With technologies like wind, the forces that require more expensive reinforcement increase at a rate nearly equal to that of increased energy production (Gipe, 1995). An example of this is that machines with larger
rotor diameters need more expensive towers (e.g., taller, stronger) to safely hold them compared to machines with a smaller rotor diameter.

The Danish Wind Industry Association predicts that the average price of a large, modern wind farm is around $1,000 per kilowatt of electric power installed (DWIA, 2000). What must be noted is that this estimate, which is discussed later as the specific capital cost, does not represent the price per kilowatt of energy produced but rather the average cost of getting an installation online. The DWIA reaches this figure through using a simple model for the installed price of a 600 kW wind turbine:

<table>
<thead>
<tr>
<th>TABLE 5.1</th>
<th>Basic calculation of Capital Cost $/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 kW wind turbine</td>
<td>$400,000 - 500,000</td>
</tr>
<tr>
<td>Installation costs</td>
<td>$100,000 - 150,000</td>
</tr>
<tr>
<td>Total</td>
<td>$500,000 - 650,000</td>
</tr>
<tr>
<td>$/kWh</td>
<td>$830 - 1,080/kWh</td>
</tr>
</tbody>
</table>

(DWIA, 2000)

The turbine cost represents the largest portion of the overall cost of a wind farm. Installation costs that factor in to the economics of a wind farm (which vary due to the specifics of individual projects), include:

- Foundations - reinforced concrete
- Road construction - substantial roads necessary for delivery of turbines and construction teams. Price/mile can be high due to being in remote terrain.
- Transformer - necessary to convert (690 V) current from the turbine to 10 - 30 kV current for the local electrical grid
- Telephone connection - for remote monitoring
- Transmission Line - to transport the electricity from the turbines to the local utility grid (DWIA, 2000).

A commonly used measurement of the performance of a wind
The specific capital cost represents the cost incurred while generating a unit of energy (one kilowatt-hour is the commonly used unit) per year. This specific capital cost, measured in cents per kilowatt-hour per year (C/kWh/Yr.), is simply the installed capital cost divided by the annual energy production and is calculated through the following equation (NWCC, 1997):

\[ C_{kWh/Yr.} = \frac{\text{Installed Capital Cost}}{\text{Energy Production per Year} / \text{Turbine Size}} \]

The annual energy production of a wind turbine can be predicted by estimating the performance of a specific turbine under a certain wind regime. This calculation takes into account the shape and strength of the wind resource and the wind turbine power curve in an attempt to predict the degree to which they overlap. It should be noted, however, that the actual production of a turbine is always less than the production value of the wind turbine due to specific loss factors. These include the array\(^{16}\) losses associated with distortion of the flow downwind of operating turbines, losses associated with the electric power collection network and departures from ideal performance of the wind turbine blades (NWCC, NO. 11, 1997).

**Operating Costs**

For newer machines, the estimated range of operating cost is around 1.5 to 2% per year of the original turbine investment. The

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\(^{16}\) A wind energy array is defined as: An “orderly grouping or arrangement of multiple wind turbines in relative proximity” (Gipe and Canter, 1997).
Danish Wind Industry Association estimates that modern wind turbines are designed to work for some 120,000 hours of operation throughout their 20 year lifetime. Compare this estimate to the average life span of an automobile engine, *(generally lasting for some 4,000 to 6,000 hours)*, and the design of a wind turbine is impressive. However, what concerns wind farm owners is the cost of operation and maintenance of their turbines. *(DWIA, 2000).*

**Research has shown that maintenance costs are generally low while the turbines are brand new and increase as turbines age.** Studies done on the 5,000 wind turbines installed in Denmark since 1975 show that newer generations of turbines have relatively lower repair and maintenance costs than the older generations. Maintenance cost is usually presented as a fixed dollar amount per year for the regular service of the turbines. There are investors who use a standard number in their calculations; this figure tends to be around $0.01/kWh of output. Newer turbines are on average substantially larger, which would tend to lower maintenance costs per kW of installed power *(DWIA, 2000).*

A detailed breakdown of the elements that enter the wind energy economics equation is presented in the spreadsheet in Appendix IV.

**Financing**

Before approaching financial institutions to secure a loan for the project, other contracts need to be negotiated. These contracts are important to have from the outset, as they allow everyone involved in the process to agree on issues of the costs and feasibility of the project and
help ensure the lender that the project can actually happen. Burton presents a list of these required agreements:

- **Power Purchase Agreement** - to sell the output electrical energy of the wind farm. To reduce risk, this should be at a defined price for the duration of the project.

- **Loan Agreement** - with the bank(s) to provide the debt finance for the project. An accurate and verifiable assessment of the wind resource is an essential prerequisite for this agreement although there is also likely to be an additional due diligence investigation of the whole project to ensure all major risks are addressed.

- **Construction Agreement** - to purchase the wind turbines and construct the wind farm. To reduce risk this may be done on a “turn key” basis with the wind turbine manufacturer taking responsibility for the entire wind farm construction.

- **O & M Agreement** - with a management company to operate and maintain the wind farm for the first 5-10 years of the project.

- **Site Agreement** - to define the relationship with the landowners and to ensure access to the site and the wind resource for the duration of the project.

- **Connection Agreement** - to allow the wind farm to be connected to the electrical power system and export its output. In a deregulated power system this is separate from the power purchase agreement.

- **Shareholders Agreement** - between the owners of the project to define their rights and obligations. (Burton et al., 2001).

From the above list, it can be inferred that a large number of agreements need to be solidified before a project can materialize. During this time, which can take between one and five years, the developer is operating at a risk. However, such expenditures and use of resources is necessary to determine a project’s feasibility, and thus must be committed prior to initiating the financial phase of the project (Burton et al., 2001).

Due to the large capital investment required by a utility scale wind
energy development, the majority of those being built today are financed and owned by large companies such as utilities or large energy companies. They have the distinct advantage of being able to finance at least the beginnings of a $100 million project using internal financial capital. It is common for a utility to reinvest its earnings into project development.

It is not uncommon, however, for even a large company to raise money for a project. They raise capital for such developments through receiving loans secured by the existing assets of the company. The interest rates that these companies are required to pay on their loans, which is a major factor in determining the project pay back timeframe, depends on the overall strength of the company. Often these companies have existing relationships with financial institutions and are given beneficial treatment and discounted financing. This allows cash-rich energy companies to easily secure the necessary financing for wind energy projects.

Projects developed by smaller energy companies or independent investors will almost always require a loan which is obtained from a bank or other financial institution. This has the advantage of reducing the requirement for capital on the developer. Most contracts with the financial institution designate that the loan repayment will have priority for the income of the project (Burton et al., 2001).

As wind energy becomes more sophisticated, so too will domestic financial institutions in their approach to wind projects. In Europe, where there is a greater acceptance of wind energy as a viable means of generating electricity, financial institutions provide long-term loans
specifically to wind energy developments with low interest rates. The fact is that the United States trails the Europeans in terms of the number of financial institutions interested in loaning money to such projects. In recent years, however, this has begun to change. As European financiers have entered the United States wind energy market, U.S. institutions are beginning to see the potential for the financial growth that wind energy holds as well.

**Specific Financial Elements to Wind Energy**

When considering the profitability of a wind energy project, there are two significant elements of the financial equation that are unique to the industry. The Production Tax Credit (PTC) and the Green Pricing programs can have a large impact on the bottom line of a wind energy project.

**The Production Tax Credit**

2001 saw an unprecedented boom of wind energy development in the United States. The total installed new capacity of 1,694 MW is more than double the previous record year of 1999, which saw 732 MW of new wind (AWEA, 2002). In commenting on this record setting year, Randall Swisher, Executive Director of the AWEA, said that:

2001 was an astonishing year for our industry in the U.S. More new wind generation was installed in a single state -- Texas (over 900 MW) -- than had ever been installed in the entire country in a single year. We are finally beginning to tap into wind energy’s enormous potential (AWEA, 2002).

It is generally believed that the scheduled expiration of the Federal
Production Tax Credit (PTC) on December 31, 2001, was a major driver of this development. The PTC provides a 1.5 cent per kilowatt-hour tax credit for wind-generated electricity installed before the above “sunset” date. Uncertain as to the fate of the PTC, developers were charged with building their facilities and getting their wind farms on line to capitalize on the PTC. During this period, the AWEA and other wind energy interest groups successfully lobbied Congress to extend the PTC. In February 2002, it was announced that the PTC has been extended for two years retroactively from its previous expiration date to December 31, 2003, as part of an economic stimulus and unemployment insurance bill approved by the U.S. House of Representatives and the U.S. Senate. Randall Swisher of AWEA commented:

> The American wind energy industry welcomes Congressional passage of a two-year extension of the wind energy production tax credit. This action by Congress and the expected signature of President Bush means that about $3 billion in wind energy investments forecast over the next several years are now back on track across the country (RET, 2002).

The PTC is presently one of the major drivers of wind energy development through its ability to make wind energy development appealing to companies with large tax bases.\(^\text{16}\)

\(^{16}\) See Appendix II for further discussion of the PTC.

The Intermittent Nature of Wind Energy

A key factor in the economics of wind energy is its intermittent, non-dispatchable nature. As mentioned previously, under the present regulatory structure, wind turbines are penalized for the amount they deviate from their scheduled production contracts. Many wind turbine
operators take these charges as a regular expense of doing business. In an attempt to minimize these penalties, there is a movement within the industry to, through utilizing various meteorological resources, predict the wind speed each hour and sell wind energy on the spot-market. Comparatively, this latter method is more labor intensive as it places the electricity on the volatile energy spot-market.

Green Electricity: Pricing Programs and Credits

So-called “green electricity,” such as wind energy, is becoming a hot commodity. Across the country, Green Pricing Programs are being established and encouraging the development of wind energy. In a paper for the National Renewable Energy Laboratory, Swezey and Bird define Green Pricing Programs:

Green pricing is an optional service that utilities can offer to those individual customers who want to increase the utility’s reliance on renewables beyond that level which the utility considers to be “cost effective” to serve all its customers (Swezey and Bird, 2001).

These programs are significant in that they represent the public’s valuation of wind energy. Oftentimes, individuals or businesses sign up for 100 kW blocks of green electricity in an agreement in which the purchasers indicate their willingness to pay a premium for the electricity. A Green Pricing Program in Colorado is the result of a settlement in which the price of the wind energy was negotiated. Public Service of Colorado, the utility, agreed to a premium of $.025 (Mayer, Blank and Swezey, 1999). Independent wind energy developers should be aware of established Green Pricing Programs and whether the utility they are
dealing with is the benefactor of the wind energy they are placing under contract. Presently there are over 80 Green Pricing Programs in the United States (Reicher, 2000) that are directly responsible for the development of over 110 MW of renewable energy capacity (Swezey and Bird, 2001).

Green emission credits are a source of potential revenue for wind energy developers. It is estimated that by placing an appropriate monetary value on the environmental benefits of wind energy (i.e., emissions not produced) hundreds of millions to billions of dollars could be earned by the wind energy industry for service they are already providing (Rickstraw, 2000). Green emission credits are calculated on a per kilowatt-hour basis and reflect the emissions offset by generating the electricity from the renewable source, and would be given to certified green energy facilities in response to the displaced emissions their energy represents. Although many green emission programs presently are being established, it is predicted that the major credit trading arenas will be in:

- Air Pollution Regulations (SO₂, NOₓ, Air Toxins, Clean Air Act Standards)
- Carbon (driven mainly by the Kyoto Protocol)
- Renewable energy credits, green tags, and certificates
- Renewable Portfolio Standard REC’s (Rickstraw, 2000).

As these arenas are being defined, there is a large opportunity for the wind energy industry to shape its future by supporting the creation of green emission credits. Gaining a thorough understanding of how these credits represent a potential source of revenue will aid any wind energy investor.
**Wind Energy Economics Conclusion**

Wind energy has the potential to stimulate stagnant rural economies. The influx of money will come to these rural areas in the form of lease payments to landowners, tax payments to municipalities, and salaries to employees. In order for this to take place, however, a developer needs to be aware of the factors that separate a profitable wind energy development from one that loses money or fails. Only then will rural economies, as well as the wind energy industry alike, be able to benefit from the clean, renewable source of electricity that can be harnessed from the wind.
Chapter 6

Cost Analysis of Wind Energy

Analysis of the economics of a small wind system is fraught with assumptions about the future. The assumptions you use may or may not reflect conditions over the 20-year life of a wind system. No one knows with certainty what the future will bring. There’s a degree of risk associated with every investment. Consequently, there’s no simple answer to the question, “Is it a good deal?” (Gipe, 1993).

After the thorough investigation of a site’s wind resource, proximity to available transmission lines, local and state tax incentives and other factors that enter the siting equation, the next step in the wind energy development process is to calculate the annual energy output (AEO) a specific turbine will have at the selected site. This is done by examining the “economics of various sizes and brands of wind machines to find the highest producing turbine for the site” (Gipe, 1993). Only after the AEO is estimated can the potential profitability of a wind energy development be understood.

The three measures most commonly used to describe any wind energy development’s cost are described in this section. An understanding of these different approaches will help a potential developer describe and interpret the costs incurred by a proposed installation, and estimate magnitude of each cost. The three cost measures are presented in increasing complexity. The simplest of the three, the Installed Capital Cost is measured in dollars per kilowatt (kW). Next is the Specific Capital Cost (introduced in the wind energy economic section of this paper) which combines the Installed Capital Cost with the predicted output of a specific
wind turbine. Finally, the most inclusive of the three measures is the Life-Cycle Cost of Energy which is calculated in units of cents/kWh. This calculation is reached through combining the Specific Capital Cost with the operation and maintenance expenses throughout the 20 to 30 year life of the wind farm.

Financial analyses, such as the three presented above, can be helpful in determining the economic feasibility of a particular site. They provide a first look at the economics of a given site as well as a way to compare one site to another or one turbine to another at the same site. It should be understood that the most useful of these is the Life-Cycle Cost of Energy (COE) measure. The COE is a standard measure used by the energy industry that takes into account the long-term performance of the turbine. Once completed, however, a more detailed analysis of the financial equation is necessary. This section presents a breakdown of how to calculate the Installed Capital Cost, the Specific Capital Cost and the Life-Cycle Cost of Energy of a wind energy development.

I. Simple Economic Calculations

Installed Capital Cost

The Installed Capital Cost (ICC) of a wind energy facility is defined as the total price for a turnkey installation, including the cost of the wind turbine, tower, foundation, installation, and any associated costs for interconnection (Gipe and Canter, 1997). The National Wind Coordinating Committee outlines the ICC of a wind farm as including the:

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17 An introduction to a computer model used by the renewable energy community that helps investors analyze a wind energy project can be found in Appendix IV.
• Wind resource assessment and analysis

• Permitting surveying and financing

• Construction of service roads

• Construction of foundations for wind turbines, pad mount transformers and substation

• Wind turbine and tower delivered to the site and installed

• Construction and installation of wind speed and direction sensors together with communication capability to the associated wind turbines

• Construction of the power collection system including the power wiring from each wind turbine to the pad mount transformer and from the pad mount transformers to the substation

• Construction of operations and maintenance facilities

• Construction and installation of a wind farm communication system, supporting control commands and data flow from each wind turbine to a central operations facility

• Provision of power measurement and wind turbine computer control display and data archiving facilities

• Integration and checkout of all systems for correction operation

• Commissioning and shakedown period (NWCC, No. 11, 1997).

It should be noted that the Installed Capital Cost of a wind energy facility does not say anything about the performance of a specific development. Rather, it solely outlines the expense on a per kilowatt basis that is required to make a facility operational. The average ICC, which was $2,500/kW in the 1980s, has decreased in the past two decades to its present range of $900/kW to $1,200/kW. The ICC is dependent upon factors such as the size of the installation, location of the site (due to
shipping and construction costs) as well as the transmission system upgrades that are necessary to get the project online. Traditional utility engineers are accustomed to using the ICC when discussing the cost of electricity, thus it was applied to wind energy. The installed capital cost works well for power plants that run at a constant output, but for wind machines, the cost per kilowatt can confuse the issue:

The cost per-kilowatt-hour isn’t the same as the cost per kilowatt-hour you pay for electricity from the utility. They’re two different animals. The cost per kilowatt-hour measure should be used only for comparing one wind machine to another. It’s not appropriate for comparing a wind machine to other forms of energy because it doesn’t account for all the costs and benefits from the wind turbine over its entire life cycle. It’s merely a measure for comparison shopping, nothing more (Gipe, 1993).

A measure that is occasionally used for wind energy systems in place of the installed capital cost is the cost per swept area ($/m²) of the rotor surface. This measure assumes that all turbines are similarly designed and equally efficient at converting wind into electricity, which is not the case as the efficiencies of turbines differ. The cost per swept area, like the ICC, is a quick approach to calculating the cost per kilowatt hour generated at your specific site (Gipe, 1993).

**Specific Capital Cost**

As outlined in the Wind Energy Economics section of this paper, the Specific Capital Cost of a wind energy development is simply the cost required to generate one kilowatt-hour of electricity per year. This is calculated by dividing the Installed Capital Cost by the performance of a specific wind turbine at a specific site.
CkWh/Yr. = \textbf{Installed Capital Cost} \\
\textbf{Energy Production per Year / Turbine Size}

Under a capacity factor\textsuperscript{18} of 28% a 500 kW wind turbine would produce 1.226 million kWh/year. \((8,760 \text{ hr} \times 28\% \times 500 \text{ kw} = 1.226 \text{ million kWh/year})\). With this value of the annual energy production and the Installed Capital Cost value of $1,000, the Specific Capital Cost can be calculated at $.41/kWh/Year \[\frac{($1,000/\text{kw})(500)}{1.226 \text{ million kWh/year}}\] (NWCC, No. 11, 1997). While the specific capital cost does include the performance of a turbine at a site, and therefore is somewhat more revealing than the Installed Capital Cost, it does not reflect the operation and maintenance, the cost of financing nor the life of the facility, all of which are included in the Life-cycle Cost of Energy calculation.

\textbf{Life-Cycle Cost of Energy}

The life-cycle cost of energy (COE) is an easily calculated inclusive measurement of a wind energy development's feasibility. This measure includes all the elements of a facility's cost:

- Installed capital cost
- Cost of capital
- Costs of operations and maintenance (O&M) over the life of the installation
- Cost of major overhauls and substation replacement (NWCC, No. 11, 1997).

\textsuperscript{18} A measure of productivity. The quotient of the actual energy generated to that possible if the generator had operated at its rated capacity (power) over the time interval of interest, most often that of one year (8,760 hours) (Gipe and Canter, 1997).
The COE does not measure the economic feasibility of a project but is used rather, as Vaughn Nelson of the Alternative Energy Institute phrases it, as an “indication of feasibility.” When the COE of wind energy is compared to the COE of energy generated by traditional means, a sense of a project’s feasibility can be gathered. A COE for wind projects that is 30% greater than that of traditional sources justifies continued analysis (Nelson, 1996).

The cost elements may be combined into four categories. These are the installed capital costs, economic and cost of money assumptions, annually-recurring costs, and the costs of major overhauls and replacements that occur every five to fifteen years. By taking into account the time value of money through net present value calculations, the cost elements are summed and then divided by the annual energy production to form the levelized COE, with units of cents/kWh (NWCC, No.11, 1997).

\[
\text{COE} = \frac{\text{ICC} \cdot \text{FCR} + \text{O&M} + \text{LRC}}{\text{Energy Production per Year}}
\]

Where:
- **ICC** = Installed Capital Cost (Cents)
- **FCR** = Annual Fixed Charge Rate (Percent)
- **O & M** = Annual Operating & Maintenance Cost (Cents)
- **LRC** = Levelized Replacement Cost (Cents)

\((\text{ICC} \cdot \text{FCR})\) \text{ or Capital Cost}

The capital cost part of the COE equation is calculated by spreading the Installed Capital Cost over the entire lifetime of the wind farm. This is achieved through applying the Fixed Charge Rate\(^{19}\) (FCR) to the ICC. The capital cost aspect of the equation is equivalent in form to a typical home mortgage payment in that it is a fixed sum payable throughout the

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\(^{19}\) A multiplier that includes the effects of inflation, the lifetime of the investment, and the cost of financing equity and debt (Gipe and Canter, 1997).
lifetime of the debt and includes interest and principal. For wind energy
developments, the debt's lifetime often relates to the predicted life span of
the turbines which is on average 20 to 30 years. With a FCR of 7.5
percent/year and a Specific Capital Cost of 41 cents/year, the capital cost
part of the COE is 3.08 cents/kWh (NWCC, No.11, 1997).

**Operation and Maintenance (O& M)**

This category of O&M cost represent the typical or predicted costs
incurred with the everyday upkeep of a facility. The unpredicted expense
of an overhaul of a particular turbine or turbines, which is represented by
the Levelized Replacement Cost (LRC), is not included in this aspect of the
O&M cost and is described later. Typically, O&M costs include:

- The cost of unscheduled but statistically-predictable, routine
  maintenance visits to cure wind turbine malfunction.

- The costs of scheduled preventative maintenance for the wind
turbine and the power collection system.

- The cost of scheduled major overhauls and subsystem replacements
  of the wind turbine (NWCC, No.11, 1997).

The first two of these types of maintenance come on a yearly basis
while the third, which is the LCR, arrives at scheduled intervals (5,10,15
years) depending upon the turbine manufacturers recommendations. It is
estimated that the these three types of maintenance cost together should
total under 1 cent/kWh. A maintenance cost of .9 cent/kWh would
typically be broken down in the following manner:
TABLE 6.1  Breakdown of Maintenance Cost

<table>
<thead>
<tr>
<th>Maintenance Type</th>
<th>Percentage</th>
<th>Cost/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unscheduled maintenance visits</td>
<td>75%</td>
<td>0.68 cents/kWh</td>
</tr>
<tr>
<td>Preventive maintenance visits</td>
<td>20%</td>
<td>0.18 cents/kWh</td>
</tr>
<tr>
<td>Major overhaul (LCR)²⁰³</td>
<td>5%</td>
<td>0.04 cents/kWh</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>0.90 cents/kWh</td>
</tr>
</tbody>
</table>

(NWCC, No.11, 1997)

Other operating costs, such as property taxes, land-use payments, insurance, transmission, substation maintenance and management costs, also enter into the equation. The value of these depend on the location of the wind facility which again focuses on the significance of proper siting. Through using the above assumptions of wind plant installed capital cost ($1000/kW), power rating (500 kW), capacity factor (28%) and annual energy production of 1.226 million kWh/yr.; estimates for the other operating costs are as follows:

TABLE 6.2  Estimated Values for Other Operating Costs

<table>
<thead>
<tr>
<th>Operating Cost element</th>
<th>Value (cents/kWh)</th>
<th>Basis for Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property taxes</td>
<td>0.1</td>
<td>Assumed tax rate of 1% of depreciated facility value with a 20% floor, averaged over facility life</td>
</tr>
<tr>
<td>Land use</td>
<td>0.1</td>
<td>Assumed 2% of gross revenue @ 5 cents/kWh selling price</td>
</tr>
<tr>
<td>Insurance</td>
<td>0.003</td>
<td>Assumed insurance premium of 6.57 cents/$1,000 of valuation</td>
</tr>
<tr>
<td>Transmission</td>
<td>0.02</td>
<td>Single, quoted figure</td>
</tr>
<tr>
<td>Substation maintenance</td>
<td>0.02</td>
<td>Assumed annual maintenance cost of 1.5% of substation cost @ $30/kW</td>
</tr>
<tr>
<td>Management Fee</td>
<td>0.05</td>
<td>Assumed value</td>
</tr>
<tr>
<td>Total</td>
<td>0.393</td>
<td>Total operating cost</td>
</tr>
</tbody>
</table>

(NWCC, No.11, 1997)

Levelized Replacement Costs (LRC)

²⁰³ Although this major overhaul cost is part of the operation an maintenance cost it is described further as the Levelized Replacement Cost.
The LRC is the cost of major overhauls that take place every 5, 10 or 15 years to the specification of the turbine manufacturer. An example of this could be the upkeep or replacement of the turbine’s gears and bearings. This cost also represents the non-routine maintenance that is necessary to keep the facility online, such as the cost incurred while replacing the turbine blades that may have been damaged. These are major expenses and need to be properly accounted for in advance. Although it may be many years before such replacements are required, it is necessary to account for this expense on a yearly basis. Again, using the above assumptions, the LRC would be estimated at 0.04 cents/kWh (NWCC, No.11, 1997).

**Total Cost of Energy**

Through calculating the cost of energy (COE), or the levelized cost of generating electricity during the life of a wind facility (Gipe and Canter, 1997), a potential developer will gain an insight to the cost effectiveness of a specific installation. What should be acknowledged here is the relative weight each of the above costs have in the overall COE. As shown in the table below, the capital cost and the unscheduled maintenance make up 86% of the total COE.
TABLE 6.3

<table>
<thead>
<tr>
<th>COE</th>
<th>Value</th>
<th>Basis for Estimate</th>
<th>% of CoE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost (ICC*FCR)</td>
<td>3.08</td>
<td>Used FCR = 7.5%/year and specific capital cost = 41 cents/(kWh/yr.)</td>
<td>70</td>
</tr>
<tr>
<td>Unscheduled maintenance</td>
<td>0.68</td>
<td>75% of 0.9 cents/kWh total maintenance cost</td>
<td>16</td>
</tr>
<tr>
<td>Preventative maintenance</td>
<td>0.18</td>
<td>20% of 0.9 cents/kWh total maintenance cost</td>
<td>4.1</td>
</tr>
<tr>
<td>Major overhaul (LRC)</td>
<td>0.04</td>
<td>5% of 0.9 cents/kWh total maintenance cost</td>
<td>1</td>
</tr>
<tr>
<td>Other operating cost elements</td>
<td>0.39</td>
<td>Estimates from previous table</td>
<td>8.9</td>
</tr>
<tr>
<td><strong>Total COE</strong></td>
<td><strong>4.37</strong></td>
<td><strong>Total COE</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

(NWCC, No.11, 1997).

**Costs Analysis Conclusion**

The three most common measures of a wind farms cost have been outlined in this chapter. Clearly the available wind resource, proximity to transmission lines, facility of construction as well as other factors enter into the cost of a wind energy development. An understanding of what makes up the total cost of a wind farm prior to undertaking a feasibility study proves the significance of the siting process. Placing the turbines in the ideal location can not only lower expenses during construction, but will increase the overall production, thus decreasing the pay-back period. As the technology continues to improve the overall cost of wind energy is predicted to decline.
Conclusion

There are several elements essential for using wind energy successfully. Often a key ingredient is missing and success remains merely a wistful vision. Even where all elements are present, they reside in delicate balance, any disruption upsets the equilibrium (Gipe, 1995).

It is the aim of this paper to present the issues essential to successful wind energy developments. Wind energy is a complex topic that is affected by many outside forces, natural, financial, political and technical, and only through proper preparation, what Gipe calls reaching an “equilibrium” will a site be successful. The remote and intermittent nature of wind energy makes this balance difficult to achieve. For example, a strong wind resource is simply not useful if the electricity cannot reach a population base.

The best example of a region attempting to reach an equilibrium and tap into its enormous wind energy potential is the Midwest. In February 2002, a conference called “Wind Energy and Rural Development III” was held in Grand Forks, North Dakota. The location was an obvious choice for a venue, as North Dakota holds the largest wind energy resource of any state in the United States. The primary objective of this regional conference was to develop a plan for achieving this equilibrium. Such a plan would have to consider the various siting, economic, political, and technical hurdles, particularly as applied to rural areas benefiting from wind development.

Previously quoted in this paper, wind energy guru Paul Gipe has noted:
For wind energy to work, a potential user needs ample wind, a place to put a wind turbine, a market for the energy it will produce, and some assurance that the product, electricity, will reach the market and fetch the price necessary (Gipe, 1995).

A wind project’s success is most dependent upon its location: this combines the inherent wind resource with its transmission capacity. The site is key. What is required is that land, which is available for lease, be located near a transmission system that has adequate room to hold additional capacity, which also accesses a population base willing to pay for “green electricity.” Additionally, this site needs to have a suitable wind resource as well as a surrounding environment that will not be threatened by either the construction process or the presence of wind turbines. If all these factors are in balance there can be a successful development. If one or more of these factors are out of balance the wind energy development is out of equilibrium.

These criteria also have to be such that when added together they create a project that can meet the financial requirements placed on any sustainable enterprise.

When writing a paper of this sort, there is a temptation to become evangelical in an attempt to get the reader to believe in wind energy. Contributing to the energy independence of our country is, after all, a noble endeavor and any support renewable energy receives is justified. There is a line, however, between zealot and advocate and again between advocate and objective presenter. It was the intent of this project to remain as objective as an advocate can possibly be. Therefore, this paper set out to assist individuals in both the public and private sector to gain
an introductory knowledge of the issues that the wind energy industry must meet the equilibrium for future success.
Appendix I.

Source: Pacific Northwest Laboratory, 1987
Appendix II.

The Major Drivers of Renewable Energy Development

Government policies play a dominant role in encouraging the advancement of renewable energy development. As The Energy Project of the Land and Water Fund of the Rockies views it, there are two approaches to policy that could be employed. The first option is to use legislation and regulation to stimulate an increasingly competitive renewable energy industry while encouraging existing monopoly utilities to utilize more clean energy. The second option uses deregulation of the electric utility industry that may accelerate the transition to a new industry structure that encourages the use of clean energy technologies (The Energy Project, 1996).

Whichever approach or combination of approaches eventually prevails, we presently can witness four specific market drivers of the wind energy industry. Outlined by the American Wind Energy Association (AWEA) they are as follows: Federal Government Policy; State Government Policy; Declining Costs of the Technology; and the Green Power Market (AWEA, 2001). In recent years, the United States has lagged behind Europe in the promotion of grid-connected wind technology, particularly with respect to policy and marketing incentives at the federal level (B. Parsons, 1998). This appendix outlines the role declining equipment costs, specific federal and state policies and green

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marketing programs have in driving renewable energy development in the United States.

**The State of the Technology/Cost of Wind Energy**

Utilizing the wind as a source of power is nothing new. Wind energy has a long history in the United States and construction of small scale windmills, primarily to pump water on farms and other rural locations, dates back at least 150 years (BBC, 2000). As many as six million windmills and wind turbines have been installed in the United States over this long time period (Nix, 1995). In nearly doubling over the last 10 years, wind energy electricity generation in the United States has grown more rapidly than generation by any other renewable source. However, it represents only one tenth of one percent of the U.S. electric generation (BBC, 2000). More than 1,200 gigabits (more than 1 million megawatts [MW]) of wind power potential are available at sites across the country. In 2000, our nation’s generating capacity from all sources was only 775 gigawatts (Wind Power Today, 2001), showing that if developed, wind energy has the ability to produce 1.5 times the amount of electricity presently consumed by the United States.

To provide 20% of the nation’s electricity needs, only about .6% of the land of the lower 48 states would have to be developed with wind turbines. Furthermore, less than 5% of this land would be occupied by wind turbines, electrical equipment and access roads. Most existing land use, such as farming and ranching, could remain as it is now (NREL, 1992). While a 25 MW wind farm may occupy between 475 and 1,150
hectares, depending on the arrangement of the turbines, the machines themselves only require 5-10% of that area, leaving the remainder for customary agricultural or range use (Serchuk, 2000).

Much of the new development in wind energy is the result of the reducing costs of the technology. Since 1980, the cost of wind power has fallen by 80-90 percent, as a result of technological improvements and economies of scale in manufacturing and installation. In comparison to other fuels that are subject to international commodity markets, such as natural gas and oil, once installed, the wind is free (Clemmer, 2001), and thus a secure supply of energy. Outside the United States, wind is the world’s fastest growing energy resource, with annual growth rates of about 40% per year in Europe since 1991. Worldwide, the amount of installed wind capacity increased 24% in both 1996 and 1997 (B. Parsons, 1998).

**Federal and State Policy**

In light of growing public support for the benefits of renewable resources in electricity production, many now advocate that policies to promote renewable energy should be integral to electric industry restructuring (Rader and Norgaard, 1996). As society redesignates what it values, public policy follows suit. To many people, if two power plants produce the same amount of electricity at the exact cost to consumers, the plant that is more environmentally benign is of a higher value. In a study conducted by the Vermont Public Service Board in 1996, its members laid
out what they intend to gain from policies that encourage renewable energy development. The board’s four pillars are as follows:

- **Resource diversity.** A generation portfolio made up of plants of varying sizes and technologies, dispersed throughout the state or region, bears lower risks associated with unplanned outages and high required reserve margins. This reduced risk equates to lower costs of power in the long run.

- **Reduced fuel-price risk.** Perhaps the primary risk offset by the development of renewable resources is fossil fuel cost volatility. At a time when this nation is dependent upon foreign markets for more than half of its demand for oil, renewables offer a great measure of energy security and price stability.

- **Environmental protection.** For the most part, renewables provide significant environmental benefits, largely in the form of reduced emissions of airborne pollutants.

- **Sustainability.** Renewable technologies do not rely upon depletable resources. As such, they do not decrease the stock of “natural capital” passed on from one generation to the next; nor are they as susceptible as fossil fuels to price increases resulting from eventual scarcity (Vermont PSB, 1996).

The ideal policy structure would create a secure energy supply while protecting both the economy and the environment. This is beginning to be implemented in a number of states, primarily on the West Coast and in the Great Plains. Apart from good wind resources, wind power development in the largest wind states has been fostered by proactive states policies and incentives (BBC, 2000).

To promote renewable energy, federal and state legislators presently have a variety of policies to choose from. As with other areas of public policy, there is not one clear choice; each approach has its own set of advantages and disadvantages. In general, renewable energy
development may be supported by employing a variety of incentives with the hope that a market will develop, or by providing a specific market to guarantee that wind development will occur (Rader and Wiser, 1999).

Outlined by the National Wind Coordinating Committee, there are six main policy options now available from which decision makers may choose: Renewable Portfolio Standard; Production Tax Incentives; Direct Cash Payments to Investors; Low-Cost Capital Programs; Distributed Resource Policies; Customer Choice Opportunities; and General Environmental Regulations (NWCC, 1999).

Before a discussion of the Renewable Portfolio Standard and the Production Tax Credit, it is important to introduce the Public Utility Regulatory Policy Act (PURPA), which is a predecessor to the policies of today.

The Public Utility Regulatory Policy Act of 1978

A proper discussion of policy as an instigator of renewable energy development begins with the Public Utility Regulatory Policy Act of 1978 (PURPA). Responsible for the boom of wind energy development in the early 1980’s in California, PURPA is a leading federal policy for renewable energy. In essence, PURPA requires electric utilities to connect with and purchase the power from “qualified facilities” (QF), with wind energy being defined as a QF. Before PURPA, utilities had the option to deny any independent power producer an interconnection as well as the ability to sell their excess power. Presently, under PURPA, this is no longer at the utilities’ discretion; small power producers are given the
right of interconnection and a guarantee that a utility will purchase their electricity. PURPA can be credited with sparking the United States into developing its wind resource. PURPA was responsible for creating the market for utility sized renewable energy projects in the 1980's; it is the legislation that makes selling power back to the utilities an option (PURPA Handbook, 1992).

From about 1983 to 1990, state implementation of PURPA was a primary factor in the substantial development of renewable energy in many states, including California, Connecticut, Florida, Idaho, Maine, Massachusetts, Michigan, Nevada, New Hampshire, New York, North Carolina and Vermont (Hamrin and Rader, 1993).

Although PURPA can be viewed as a success, there are still hurdles to overcome.

Institutional barriers still exist. Interpretation of the law varies, creating implementation obstacles for the small power producer. Yet, when linked with progressive state legislation and regulation, PURPA makes renewable energy systems more viable in the past and an attractive option in many markets for those who wish to supplement or sell power from a clean energy source (PURPA Handbook, 1992).

The Renewable Portfolio Standard

The Renewable Portfolio Standard (RPS) is a flexible, market-driven policy that can ensure that the public benefits of wind, solar, biomass, and geothermal energy continue to be recognized as electricity markets become more competitive (AWEA, 1997). A policy currently implemented on the state level (Texas and Massachusetts leading the way), with debates on how it should be executed on the national scale, the renewable portfolio standard requires that electric utilities in a certain jurisdiction purchase a specified amount of renewable energy.
The RPS is designed to provide a minimum market for renewable resources, and thereby supply environmental, fuel diversity, energy security, and economic development benefits (AWEA, 1999). The percentages required are determined by the state legislature or utility commission after considering their policy objectives, market conditions, and the renewable resource supply curve (N. Rader and R. Norgaard, 1996).

Renewable Energy Credits (RECs), tradable certificates of proof that one kilowatt-hour (Kwh) of electricity has been generated by a renewably fueled source, are central to the RPS. If there is a RPS of 5% and a generator sells 200,000 kWh per year, at the end of each year they must have 10,000 RECs. If a generator does not meet the required level of RECs, it would be fined by an administrative agency for the RECs it is short (AWEA, 1997). The RPS can be seen as an opportunity by those utilities that hold on to more RECs than are required to meet their own RPS needs since RECs are transferable and can be sold to a utility that has not met its own quota (AWEA, 1999).

Properly implemented, a renewable portfolio standard can accomplish two important objectives. First, it will require that more renewables be integrated into the electricity grid. Today, just 2% of US electric supply comes from non-hydro renewable resources (AWEA, 1999). This factor takes into account the Vermont Public Service Board’s first pillar of resource diversity. Second, if the RPS is successful in driving down the cost of renewable energy, it may ultimately lead to reductions in the cost of electric supply (AWEA, 1999).
As a policy, the RPS is fairly progressive; however it receives criticism from environmentalists in that it sets a ceiling of development rather than a floor. Nonetheless, it appears to be doing its job in promoting an initial wave of development that is breaking the ice for what we hope will be an effective second wave.

The Production Tax Credit

The Production Tax Credit (PTC) is part of the Energy Policy Act of 1992 (EPAct). It contains a 1.5 cent per kilowatt-hour tax credit for wind generated electricity from qualifying facilities (AWEA, 2000). That credit is applied to the owner of the facility’s year-end taxes. By focusing on energy produced, not capital invested, this type of tax incentive rewards projects on their performance. For this reason, the PTC is widely considered to be a more effective support mechanism than the investment tax credit (ITC), especially for large installations of relatively mature technologies (Rader and Wiser, 1999). The 1.5 cent per kilowatt-hour credit enables the wind industry to compete with other generating sources, such as natural gas turbines, being sold at 3 cents per kilowatt-hour. Experts maintain that stimulating the development in wind energy will lower the cost of wind equipment, which they believe can be reduced by 40% from current levels. This could result only from an appropriate commitment of resources to research and development and from manufacturing economies of scale (Steve, 1999).

On the federal level, a production tax credit has been used for years to stimulate the development of renewables and has enjoyed moderate
success. The present federal PTC's sunset date recently has been extended to June 31, 2002. A state production tax credit, however, may result in a reduction in the size of the federal PTC. By design, the federal PTC is reduced for any grants, tax-exempt bonds, subsidized financing or other credits received by qualifying facilities (Rader and Wiser, 1999). Rader and Wiser have compiled a list of what they deem to be the five deterrents of the Production Tax Credit, which must be addressed to allow for the marketability of wind power generation to advance:

- The issue that must be considered for the PTC is the ability of investors to use the full value of the incentive; that is potential investors must have an adequate tax appetite.

- Stability in the size and permanency of the credit is essential for project developers to obtain financing.

- The PTC's apply only to those entities with taxable income, and therefore can be viewed as not competitively neutral. To ameliorate this problem, an equivalent direct cash production payment could be provided to nontaxable entities.

- The PTC may not effectively stimulate investment in small scale residential or agricultural wind systems.

- A PTC can be applied only if electricity production levels can be readily determined, so its effectiveness for supporting off-grid renewable applications is limited (Rader and Wiser, 1999).

The PTC is one of a group of tax credits used to encourage the development of renewable energy systems. Investment Tax Credits, Sales Tax Reductions, and Property Tax Reductions are also used by on the state level. Investment Tax credits, the reduction of taxable state income, are similar to production tax credits. As of 1998, ten states offered ITCs, which are applied mostly to small wind systems. One disadvantage of ITCs
is that it rewards the creation of the facilities, regardless of potential energy output. A Sales Tax Reduction in a state has the ability to make residential systems more feasible. Currently, renewable energy investors are at a disadvantage because fossil fuel generation equipment is generally exempt from sales taxes. However, such a sales tax reduction is not likely to influence the decision of whether to invest in large scale systems. Property Tax Reduction by 1% on renewable energy facilities could lower the price of electricity by .2 cents per kilowatt. Currently, property taxes for renewable energy facilities are on average 1-3% higher than traditional fuel facilities. Property taxes are an important local tax source, thus, any proposed reduction is met by local opposition (Hughes et al., 2000).

**Green Marketing: A Business Plan**

In the National Wind Coordinating Committee’s publication, New Markets for Wind: Creating Competitive Advantage, the Committee quotes a business owner who has recently become a member of a green pricing program saying, “Wind is sexy; consumers like windmills.” (NWCC, 1998). Each consumer has his or her own reason for placing a higher value on clean energy. Some individuals feel a social responsibility to do what they can to create a healthier environment; some like the way it makes them and their business come across to others with a “green image;” others still are willing simply to pay more because they think that it is neat. For whatever reason, it is clear through green pricing programs that there is a market for clean energy and people are willing to sacrifice paying more
to purchase it, which is no small thing for American consumers.

Before venturing into the world of “green marketing,” utilities researched whether people were truly willing to pay more for a clean supply of energy such as wind power. What was uncovered was no surprise to renewable energy advocates and students of human nature. People want clean power, even at a higher cost.

The genesis of this support is revealed in a new type of opinion poll called “deliberative polling” being conducted by Texas utilities. The companies invite a small, representative sample of their customers to spend a weekend at company expense learning about and discussing electricity, sources of energy and the environmental impacts of power generation. What company and state officials have learned from these structured discussions in Houston, Corpus Christi, and Beaumont is that Texans want more renewable energy, from sources like wind, and they are willing to pay a premium for it (B. Parsons, 1998).

Some wind development has resulted from voluntary customer purchases of green power. More than 190 electric utilities in the United States are now offering a wind power product to their customers (Clemmer, 2001). The most successful green pricing programs is the result of a partnership between the Land and Water Fund of the Rockies and Public Service Company of Colorado, in which the environmental group helped market the electric utility’s green power product. This approach to renewable energy development presents both risks and potential benefits, but may offer a model for other organizations in other states (R. Mayer, E. Blank, and B. Swezey, 1999).

Disclosure is key to green marketing. Like nutritional labels on food packages, an energy supplier, under new regulations, will be required to report the sources of its electricity. A program sponsored by the Center
for Resource Solutions, the Green-e program, certifies environmentally sound green power products and helps create customer confidence in renewable energy through a code of conduct, disclosure provisions and consumer education (B. Parsons, 1998).

Green marketing programs administered by utilities could help overcome market barriers, particularly the transactions costs associated with marketing and perhaps facilitating financing. Ideally, these programs could create a market that is large enough to sustain at least some aspect of the renewable energy world. (Rader and Norgaard, 1996).
Appendix III.

Topics Covered in an Environmental Impact Statement.

- Policy Framework. The application is placed in the context of national and regional policy.

- Site Selection. The choice of the particular site that has been selected is justified.

- Designated areas. The potential impact of the wind farm on any designated areas (e.g., National Parks) is evaluated.

- Visual and landscape assessment. This is generally the most important consideration and is certainly the most open to subjective judgment. It is usual to employ a professional consult to prepare the assessment. The main techniques which will be used include: zones of visual influence (ZVI) to indicate where the wind farm will be visible from, wireframe analysis which show the location of the turbines from particular views, and photomontage production which are computer generated images overlaid on a photograph of the site.

- Noise assessment. After visual impact, noise is likely to be the next most important topic. Hence predictions of the sound produced by the proposed development are required with special attention being paid to the nearest dwellings in each direction. It may be necessary to establish the background noise at the dwellings by a series of measurements so that realistic assessments can be made after the wind farm is in operation.

- Ecological assessment. The impact of the wind farm, including its construction, on the local flora and fauna needs to be considered. This may well require site surveys at a particular season of the year.

- Archaeological and historical assessment. This is an extension of the investigation undertaken during the site selection.

- Hydrological assessment. Depending on the site, it may be necessary to evaluate the impact of the project on water courses and supplies.

- Interference with telecommunication systems. Although wind turbines do cause some interference with television transmission
this is normally only a local effect and can usually be remedied at modest cost. Any interference with major point-to-point communication facilities (e.g., microwave systems) or airfield radar is likely to be a much more significant issue.

• Aircraft safety. The proximity to airfields or military training areas needs to be considered carefully.

• Safety. An assessment is required of the safety of the site including the structural integrity of the turbines. Particular local issues may include highway safety and shadow flicker.

• Traffic management and construction. The Environmental Impact Statement addresses all phases of the project and so both the access tracks and the increase in vehicle movements on the public roads need to be considered.

• Electrical connection. There may be significant environmental impact associated with the electrical connection (e.g., the construction of a substation and new circuit) Although this may be dealt with formally as a separate planning application it still needs to be considered, particularly as any requirement to place underground any long, high-voltage circuits will be very expensive.

• Economic effects on the local economy, global environmental benefits. It is common to emphasize the benefit that the wind farm will bring both to the local economy and the reduction in gaseous emissions.

• Decommissioning. The assessment should also include proposals for the decommissioning of the wind farm and the removal of the turbines at the end of the project. Decommissioning measures are likely to involve the removal of all equipment which is above ground and restoration of the surface of all areas.

• Mitigating measures. It is obvious that the wind farm will have an impact on the local environment and so this section details the steps that are proposed to mitigate any adverse effects. This is likely to emphasize the attempts that have been made to minimize visual intrusion and control noise.

• Nontechnical summary. Finally, a nontechnical summary is required and this may be used to distribute to local residents (Burton et al., 2001).
Appendix IV.

Financial Analysis Spreadsheet

Also available to those interested in wind energy development are computer models specifically designed for the financial analysis of wind energy projects. What follows as Appendix IV is a copy of a spreadsheet of a financial analysis of a fictional wind energy development in Amarillo, Texas. The spreadsheet was developed by the Government of Canada’s Energy Diversification Research Laboratory and has been downloaded from www.retscreen.gc.ca.
RETScreen® International is a standardised and integrated renewable energy project analysis software. This tool provides a common platform for both decision-support and capacity-building purposes. RETScreen can be used worldwide to evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for various renewable energy technologies (RETS). RETScreen is made available free-of-charge by the Government of Canada through Natural Resources Canada's CANMET Energy Diversification Research Laboratory (CEDRL). The user is encouraged to properly register at the RETScreen website so that CEDRL can report on the global use of RETScreen.

**Wind Energy Project Model**

TO START (click here)
- Brief Description & Model Flow Chart
- Cell Colour Coding

**RETScreen Features** (click to access info)
- Online Manual
- Product Data
- Weather Data
- Cost Data
- Currency Options

**Model Worksheets** (click to access sheets)
- Energy Model
- Equipment Data
- Cost Analysis
- Greenhouse Gas Analysis
- Financial Summary
- Blank Worksheets (3)

RETScreen is available free-of-charge at [http://retscreen.gc.ca](http://retscreen.gc.ca)

**Internet Options**
- RETScreen Website
- Training Information
- Registration
- Contact CEDRL

**Contributors**
- 85+ Technology Experts
- Collaborating Organisations

[UNEP] [NASA]
### Site Conditions

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### System Characteristics

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### Wind Turbine Production Data

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### Power and Energy Curves

[Graph showing power and energy curves]

[Return to Energy Model sheet]
## RETScreen® Cost Analysis - Wind Energy Project

### Initial Costs (Credits)

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<td>$28,704,200</td>
<td>$961,126</td>
<td></td>
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<tr>
<td>Contingencies</td>
<td>%</td>
<td>5%</td>
<td>$28,704,200</td>
<td>$1,435,210</td>
<td></td>
<td></td>
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<tr>
<td><strong>Sub-total</strong></td>
<td></td>
<td></td>
<td>$2,360,336</td>
<td>7.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Initial Costs - Total</strong></td>
<td></td>
<td></td>
<td>$31,072,536</td>
<td>100.0%</td>
<td></td>
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</tr>
</tbody>
</table>

### Annual Costs (Credits)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Amount</th>
<th>Relative Costs</th>
<th>Quantity Range</th>
<th>Unit Cost Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&amp;M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land lease</td>
<td>%</td>
<td>2.0%</td>
<td>$3,127,880</td>
<td>$62,558</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property taxes</td>
<td>%</td>
<td>0.9%</td>
<td>$3,127,880</td>
<td></td>
<td></td>
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<tr>
<td>Insurance premium</td>
<td>%</td>
<td>3.0%</td>
<td>$3,127,880</td>
<td>$93,836</td>
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<td></td>
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<tr>
<td>Transmission line maintenance</td>
<td>%</td>
<td>1.0%</td>
<td>$2,650,000</td>
<td>$79,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parts and labour</td>
<td>kWh</td>
<td>62,577,603</td>
<td>$0.50</td>
<td>$500,461</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community benefits</td>
<td>%</td>
<td>1%</td>
<td>$15,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel and accommodation</td>
<td>p-trip</td>
<td>12</td>
<td>$3,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General and administrative</td>
<td>%</td>
<td>6%</td>
<td>$787,355</td>
<td>$47,241</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>Sub-total</strong></td>
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<td></td>
<td>$313,372</td>
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### Periodic Costs (Credits)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Period</th>
<th>Unit Cost</th>
<th>Amount</th>
<th>Interval Range</th>
<th>Unit Cost Range</th>
</tr>
</thead>
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<tr>
<td>Dredging</td>
<td>Cost</td>
<td>10 yr</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td></td>
</tr>
<tr>
<td>Blasting</td>
<td>Cost</td>
<td>15 yr</td>
<td>$1,000,000</td>
<td>$1,000,000</td>
<td></td>
</tr>
<tr>
<td>End of project life</td>
<td>Credit</td>
<td>-</td>
<td>$</td>
<td>$</td>
<td>Go to GHG Analysis sheet</td>
</tr>
</tbody>
</table>
**RETScreen® Financial Summary - Wind Energy Project**

### Annual Energy Balance

<table>
<thead>
<tr>
<th>Project name</th>
<th>Example</th>
<th>Project location</th>
<th>Texas, USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable energy delivered MWh</td>
<td>62,558</td>
<td>GHG analysis sheet used?</td>
<td>Yes/no, Yes</td>
</tr>
<tr>
<td>Excess RE available MWh</td>
<td>28,283</td>
<td>Net GHG emission reduction - 25 yrs</td>
<td>706,563</td>
</tr>
<tr>
<td>Firm RE capacity kW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grid type</td>
<td>Central-grid</td>
<td></td>
<td></td>
</tr>
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### Financial Parameters

<table>
<thead>
<tr>
<th></th>
<th>$/kWh</th>
<th>Debt ratio</th>
<th>%</th>
<th>Debt term</th>
<th>yr</th>
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</thead>
<tbody>
<tr>
<td>Avoided cost of energy</td>
<td>0.050</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RE production credit</td>
<td>0.027</td>
<td>Debt interest rate</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RE production credit duration yr</td>
<td></td>
<td>Debt term</td>
<td>yr</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>RE credit escalation rate</td>
<td>%</td>
<td>2.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHG emission reduction credit</td>
<td></td>
<td>Income tax analysis?</td>
<td>yes/no</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Energy cost escalation rate</td>
<td>%</td>
<td>3.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td>%</td>
<td>2.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discount rate</td>
<td>%</td>
<td>12.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project life yr</td>
<td></td>
<td>25</td>
<td></td>
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</table>

### Project Costs and Savings

#### Initial Costs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility study</td>
<td>0.6%</td>
<td>195,200</td>
</tr>
<tr>
<td>Development</td>
<td>2.5%</td>
<td>770,500</td>
</tr>
<tr>
<td>Engineering</td>
<td>2.0%</td>
<td>610,500</td>
</tr>
<tr>
<td>RE equipment</td>
<td>68.4%</td>
<td>21,260,000</td>
</tr>
<tr>
<td>Balance of plant</td>
<td>18.9%</td>
<td>5,688,000</td>
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<tr>
<td>Miscellaneous</td>
<td>7.6%</td>
<td>3,268,336</td>
</tr>
</tbody>
</table>

| Initial Costs - Total | 100.0% | 31,072,938 |

<table>
<thead>
<tr>
<th></th>
<th>Incentives/Grants</th>
<th>$</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Periodic Costs (Credits)</th>
<th></th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive train</td>
<td>1,000,000</td>
<td></td>
</tr>
<tr>
<td>Blades</td>
<td>1,000,000</td>
<td></td>
</tr>
<tr>
<td>End of project life - Credit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Annual Costs and Debt

<table>
<thead>
<tr>
<th></th>
<th>O&amp;M</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Costs and Debt</td>
<td></td>
<td>913,332</td>
</tr>
<tr>
<td>Debt payments - 20 yrs</td>
<td></td>
<td>2,286,426</td>
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<tr>
<td>Annual Costs - Total</td>
<td></td>
<td>3,211,787</td>
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<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Costs - Total</td>
<td>31,072,938</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Annual Savings or Income</th>
<th>$</th>
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</thead>
<tbody>
<tr>
<td>Energy savings/income</td>
<td></td>
<td>3,127,800</td>
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<tr>
<td>Capacity savings/income</td>
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<td></td>
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<tr>
<td>RE production credit income - 10 yrs</td>
<td></td>
<td>1,689,055</td>
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<tr>
<td>Annual Savings - Total</td>
<td></td>
<td>4,816,935</td>
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#### Yearly Cash Flows

<table>
<thead>
<tr>
<th>Year</th>
<th>Pre-tax</th>
<th>After-tax</th>
<th>Cumulative</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>(9,321,761)</td>
<td>(9,321,761)</td>
<td>(9,321,761)</td>
</tr>
<tr>
<td>1</td>
<td>1,718,408</td>
<td>1,718,406</td>
<td>(7,603,353)</td>
</tr>
<tr>
<td>2</td>
<td>1,834,937</td>
<td>1,834,937</td>
<td>(5,768,416)</td>
</tr>
<tr>
<td>3</td>
<td>1,954,863</td>
<td>1,954,863</td>
<td>(3,813,553)</td>
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<tr>
<td>4</td>
<td>2,078,285</td>
<td>2,078,286</td>
<td>(1,735,268)</td>
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<tr>
<td>5</td>
<td>2,205,035</td>
<td>2,205,035</td>
<td>470,037</td>
</tr>
<tr>
<td>6</td>
<td>2,336,029</td>
<td>2,336,029</td>
<td>2,906,065</td>
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<tr>
<td>7</td>
<td>2,470,564</td>
<td>2,470,564</td>
<td>5,276,630</td>
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<tr>
<td>8</td>
<td>2,609,023</td>
<td>2,609,023</td>
<td>7,885,653</td>
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<tr>
<td>9</td>
<td>2,751,521</td>
<td>2,751,521</td>
<td>10,637,174</td>
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<tr>
<td>10</td>
<td>1,618,091</td>
<td>1,618,091</td>
<td>12,255,265</td>
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<tr>
<td>11</td>
<td>832,922</td>
<td>832,922</td>
<td>13,088,187</td>
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<td>12</td>
<td>932,854</td>
<td>932,854</td>
<td>14,021,041</td>
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<tr>
<td>13</td>
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<td>1,035,934</td>
<td>15,056,975</td>
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<td>1,142,260</td>
<td>1,142,260</td>
<td>16,199,235</td>
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<tr>
<td>15</td>
<td>(196,365)</td>
<td>(196,365)</td>
<td>16,002,870</td>
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<tr>
<td>16</td>
<td>1,365,058</td>
<td>1,365,058</td>
<td>17,367,928</td>
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<td>17</td>
<td>1,481,742</td>
<td>1,481,742</td>
<td>18,849,670</td>
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<tr>
<td>18</td>
<td>1,602,095</td>
<td>1,602,095</td>
<td>20,451,765</td>
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<tr>
<td>19</td>
<td>1,726,233</td>
<td>1,726,233</td>
<td>22,177,999</td>
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<tr>
<td>20</td>
<td>2,157,657</td>
<td>2,157,657</td>
<td>24,333,656</td>
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<tr>
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<td>2,484,763</td>
<td>2,484,763</td>
<td>26,678,419</td>
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<tr>
<td>22</td>
<td>4,420,976</td>
<td>4,420,976</td>
<td>31,099,396</td>
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<tr>
<td>23</td>
<td>4,561,467</td>
<td>4,561,467</td>
<td>35,660,863</td>
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<tr>
<td>24</td>
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<td>4,706,370</td>
<td>40,367,233</td>
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<tr>
<td>25</td>
<td>4,855,821</td>
<td>4,855,821</td>
<td>45,223,054</td>
</tr>
</tbody>
</table>

| Periodic Costs (Credits) | | |
| Drive train | 1,000,000 | Schedule yr # 10.20 |
| Blades | 1,000,000 | Schedule yr # 15 |
| End of project life - Credit | | |

<table>
<thead>
<tr>
<th>Calculate RE production cost?</th>
<th>yes/no</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculate GHG reduction cost?</td>
<td>yes/no</td>
<td></td>
</tr>
</tbody>
</table>

### Financial Feasibility

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-tax IRR and ROI %</td>
<td>20.6%</td>
<td></td>
</tr>
<tr>
<td>After-tax IRR and ROI %</td>
<td>20.8%</td>
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</tr>
<tr>
<td>Simple Payback yr</td>
<td>8.0</td>
<td>Project equity</td>
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<tr>
<td>Year-to-positive cash flow yr</td>
<td>4.8</td>
<td>Project debt</td>
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<tr>
<td>Net Present Value - NPV</td>
<td>5,984,899</td>
<td>Debt payments</td>
</tr>
<tr>
<td>Annual Life Cycle Savings $</td>
<td>763,074</td>
<td>Debt service coverage</td>
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<tr>
<td>Profitability Index - PI</td>
<td>0.64</td>
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</tbody>
</table>

**Version 2000 - Release 2 © Minister of Natural Resources Canada 1997 - 2000.**
Wind Energy Project Cumulative Cash Flows
Example, Texas, USA

Year-to-positive cash flow: 4.8 yr
IRR and ROI: 20.6%
Net Present Value: $5,984,899

Cumulative Cash Flows ($)

Years

(20,000,000)
(10,000,000)
0
10,000,000
20,000,000
30,000,000
40,000,000
50,000,000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
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