Project Number: IQP JRK-WND1

Wind Power Suitability in Worcester, Massachusetts

An Interactive Qualifying Project Report: submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

Christopher Kalisz
chkalisz@wpi.edu

Calixte Monast
cmonast@wpi.edu

Michael Santoro
santron@wpi.edu

Benjamin Trow
btrow@wpi.edu

Date: March 14, 2005

Faculty Advisors:

Professor Scott Jiusto

Professor Robert Krueger

ABSTRACT

The goal of this project was to identify criteria needed to determine the suitability of potential wind turbine sites in Worcester, Massachusetts. The report first discusses physical, environmental, economic, and social factors that affect the suitability of potential wind power sites. We then completed a case study for a site in downtown Worcester, directly applying the criteria. Our hope is the project will raise local awareness of renewable energy and illustrate the practicality of a clean energy project.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

CHAPTER 1: INTRODUCTION

The degree to which we have integrated electricity into our daily lives is astounding, making it as necessary to many as food and water. Living without our televisions, refrigerators or appliances is so terrifying a thought that we chose to live in ignorance of the source of that energy. While vast, almost incomprehensible, amounts of coal are burned daily to produce the exorbitant amount of electricity the US consumes, the by-products of those plants are being spewed into the environment.[1] To remedy this problem, clean energy sources have been explored recently to alleviate our dependence on the finite fossil fuels. While renewable energy is certainly a viable option for power generation, it will take time and effort to pull it out of its initial phases of development.

The responsibility of developing renewable sources of energy, like wind energy, is delegated to local governments across the country. While state and federal organizations can aid greatly, a wind project must occur in a town or a city, supported and driven by local interest. Many cities around the country, like Worcester, are in a position to provide leadership in this area. Some cities have already begun the process of supporting national renewable energy by developing wind farms of their own. The economic viability of inocorporating wind power into our electrical infrastructure is possible now, but the economics of developing a large scale energy replacement of coal with wind power provide a large barrier. However, any advancement made is one more step from energy production using coal: the dirtiest energy source available.

Currently, wind power is being developed very sporadically across the country, with only a handful of projects in Massachusetts. In most cases the wind farms provide large amounts of clean, renewable energy to the towns and cities that construct them. The difficulty lies in generating the interest, with both the citizens and the local government, required to propel such a project to completion. The Mayor of Worcester has pledged his support to supporting environmentally friendly programs, but there have been very few projects undertaken to underscore this stance.[2]

The lack of initiative is not a reflection upon the lack of unwillingness to act, but to the lack of information available for developing projects. There is very little information available in Worcester that could facilitate the development of wind power. Developers, public and private, interested in building a wind farm would be faced with the initial task of learning not only the basics of wind

[1] The Newsletter of the North American Commission for Environmental Cooperation, http://www.cec.org/trio/stories/index.cfm?ed=14&ID=159&varlan=english
[2] Cities for Climate Protection, http://www.iclei.org/co2/

power, but also about Worcester; its geography, political process and economics. Developing laws and a permitting process for wind turbines would be another way to facilitate development locally. This requires that lawmakers and city planners have a resource that allows them to understand key aspects of wind power development.

For potential developers, the lack of local due process can be daunting. The time and money associated with being the first project in an area can be as unappealing as a locality hostile to the whole idea. By providing a system of analysis to assess sites in the Worcester area, we hope this report will reduce the lack of knowledge of wind power. It is the goal of this report to provide a resource for local lawmakers and developers that will facilitate the development of wind power in the Worcester area. Additionally, we hope to provide the City of Worcester with the tools to take a step beyond many cities in the country and make an irrefutable statement about renewable energy by constructing their own municipal wind farm.

Chapter 2: The concept of "Suitability" is the basis for the system of analysis we have developed. In this chapter various siting criteria are presented and explained for use in determining how appropriate or suitable a site is for wind power. These criteria include the physical characteristics of the land, technological considerations, regulations, economics and aesthetics. Understanding the attributes of a good wind power site is the first step to understanding the entire process. With this knowledge, lawmakers and developers can better assess Worcester's wind resources and start an effective process for developing them.

The next chapter, "A Case Study in Worcester, MA", contains our application of the suitability criteria to an actual site in Worcester. By going through the process rigorously and carefully, this section will provide a model for those wishing to assess a site's wind potential. Additionally, it is our hope that this will provide enough local information on the process to assist in the development of a permitting process for future wind projects. We also present a process for determining the model of turbine appropriate for a given site. This analysis is divided into two parts: turbine analysis and final analysis, each of which takes into consideration the characteristics, economics and purpose of the sites.

While this case study was straightforward, many sites around the world exhibit more complicated problems commonly associated with larger sites. To address this discrepancy we have prepared a number of site comparisons in Appendix A: Site Comparisons. Here we highlight useful information from wind projects around the world. Some sites teach the reader specifically about the problems that can arise during development and construction. Other cases focus on the actions taken that allowed the sites to be successful. At the very least, these cases will familiarize the reader with the wind development process and emphasize how much a specific setting can change the planning and construction process.

The rest of the appendices contain useful information that is either referenced in the report or provide additional information on their own. The technological primer is a basic explanation of how a turbine works and some of the terms and concepts one must know fully understand our hold a discussion of wind energy. Most of the other appendices are referenced in the text, while the final two appendices contain references and useful information that we found researching this topic.

Wind Power in Perspective

While not a panacea, wind energy provides an alternative to fossil fuels. Each cent directed at integrating wind technology into our society prevents one pound of carbon dioxide from being created.[3] Global climate change is a result of increased carbon dioxide levels in the earth's atmosphere. The effects of pollution on the earth are shown through smog, acid rain, asthma, early death, and global climate change. If the pollution issue is ignored in favor of cheaper and easier forms of energy, the earth's resources may be tasked and problems of long-term pollution realized.

The Problem

Coal is the largest resource used for the production of electricity, capturing over one half of the energy market. It is the dirtiest source of energy in use, but remains as the primary fuel because it is domestically plentiful. Necessity dictates the development of alternate energy production methods to alleviate the pollution caused by coal. However, coal has not always controlled the energy market. Oil was the first fossil fuel to bring environmental concerns to the attention of the public. While oil is not now used widely in the power sector, it influenced the development of energy reform during the energy crisis (dicussed below), and is one important "extermal factor" that has impacted wind power over time.

The Path to Wind Power

The idea of harnessing wind energy has been around for years, dating back to powering grist mills. Since then, wind power has developed in spurts throughout history. During the 1930s, many American farmers had land that was not fertile enough to grow crops so windmills were built on the

---

[3] World Energy Assessment: Energy and the challenge of sustainability, http://www.undp.kz/library_of_publications/center_view.html?id=111

land to harness the wind and sell energy, compensating for the poor crops. This electricity could also be provided to homes that were not within range of a centralized electric grid. After the 1930s, the centralized grid extended to include all households and the windmills fell to disuse. It was not until the 1970s when wind energy technologies again advanced during the OPEC-triggered energy crisis.

The dependence on foreign oil production and declining domestic production led to a shortage of petroleum. The inability to import the necessary resources caused a panic that resulted in rising energy costs as well as a national and global economic recession.[4] During this time, oil was a larger portion of the fossil fuels used to produce electricity. It was during this same period of time that environmentalists brought the subject of energy management to the attention of the United States. The lack of oil necessitated alternative methods to produce energy; interest was expressed in all power options, and energy concerns directed efforts towards renewable energy sources.

Knowledge of wind energy prior to the energy crisis was limited to the windmills that had spotted the countryside some 40 years before; most had long since been taken down and forgotten. The technology was reborn during this period, providing insight that could not be forgotten as the country turned back to its traditional forms of energy.[5] Wind energy has continued to develop, making use of machines that are more powerful and efficient than their ancestors.

Wind energy has developed to such an extent that it can now be used as a viable source of energy for society. The technological advances have made wind farms capable of harnessing great amounts of wind, producing electricity to meet large power demands. This technology can be extended to increasing the number of wind farms as well as establishing wind turbines for individuals. While wind energy represents only one option for making use of renewable energy, the cost competitiveness for this source makes it attractive and possible now. It is a way to offset some of the pollution effects due to power production from coal.

The Opportunity

Due to pollution concerns, renewable energy has received a platform to expand upon. Technological advances are making renewable energy projects more economical and feasible. In addition, the nationally restructured electrical grid creates opportunities for all generating facilities, reducing barriers previously established for small electricity-producing endeavors. Overall, the opportunities for renewable energy have made wind energy hospitable in the setting of Worcester, Massachusetts.

---

[4] WTRG Economics, http://www.wtrg.com/EnergyCrisis/

[5] Wikipedia, http://en.wikipedia.org/wiki/1973_energy_crisis

The City's Commitment

The City of Worcester has the potential to be at the nucleus of an environmentally friendly energy development. The mayor of Worcester, Timothy Murray, stated in a Boston Globe Editorial that, "Massachusetts is poised to be a leader in New England and in the nation by issuing and fully implementing a climate action plan."[6] This plan can, in part, be realized through supporting renewable energy resources and reducing energy consumption. Worcester has recently signed on to the Cities for Climate Protection (CCP), an organization that is committed to decreasing greenhouse emissions released from fossil fuels.[7] To this end, the City of Worcester has purchased hybrid gas-electric cars for the municipal fleets as well as cut electricity usage in traffic lights by converting them to LEDs.[8] Additionally, Worcester has adopted a municipal garbage program that charges residents for trash in an effort to reduce waste incinerated or placed in a landfill. This action is a clear attempt by the city to foster environmentally friendly programs. We offer this report as a resource for the City of Worcester to support renewable energy through the development of wind turbines. The city has expressed a desire to develop such programs, and we hope that this report will inspire the city to embrace wind energy as a possible alternative to conventional energy production.

Making it Possible

To develop renewable energy, the technology must be profitable. With federal, state and local support, described in the economics and financing section of this report, wind power is becoming comparably priced to traditional fuels. As wind turbines become more efficient and affordable, their economic feasibility increases. In 2002, there was a 28% increase in global wind power production, reflecting more efficient technology and widespread support, heralding what may be the next generation of electrical generation.[9] With these improvements in technology, efforts required to integrate green technology are becoming less difficult, making a society largely based on renewable energy a viable future.

Restructuring

The traditional problems with interconnection to the electrical grid have been solved in part by recent restructuring of the energy system. What previously was a system based on complete, monopolistic control of electrical supply lines has now been reorganized to streamline the process of

---

[6] Boston Globe Editorial, http://www.boston.com/news/globe/editorial_opinion/oped/articles/2003/09/01/state_must_protect_our_climate_now/

[7] Cities for Climate Protection. http://www.iclei.org/us/ccp/

[8] Ibid

[9] American Wind Energy Association, http://www.ewea.org/doc/03-03-03%20World%20figures.pdf

buying, selling, and regulating energy. The system is now comprised of three categories: the generation of energy, the transmission of electricity along high voltage transmission lines, and the distribution of electricity to consumers through low voltage lines.[10] This separation of powers has guaranteed access to the grid for all power generators, including wind turbines. Currently, Massachusetts is part of the Independent System Operator - New England's (ISO-NE's) electrical grid which serves the New England area. Power can be imported from areas outside the grid, such as from Canada, to augment baseline supply and temporary power shortages. ISO-NE monitors the overall demand and adjusts the supply of electricity to smooth out any fluctuations.

Customer Choice

The large power generators sell the electricity into the electric grid through a bidding process. This ensures the electric load is met for the consumers and that an electricity surplus is avoided on the grid. ISO controls the large transmission lines that connect all of New England, and is responsible for maintaining the proper amount of power within the grid by monitoring the electrical production facilities.[11] Massachusetts Electric and Nantucket Electric are in charge of distributing the lower voltage electricity to local customers. Customers have the right to buy from any producer, meaning that energy produced from a wind turbine can be purchased by any consumer within the distributor's region. This enables consumers to buy renewable energy, directly supporting wind power.

State and Local Support

In addition to the restructured electrical grid, Massachusetts places additional regulations on electricity production. Now Generation Portfolio Standards (GPSs) have mandated that a certain percentage of electricity sold by distributors must be renewable. Additionally, incentives for renewable energy are offered by the state and are addressed in the economics and financing section of this report. With resources at its disposal, the City has the opportunity to support renewable technologies. A decisive stance on promoting renewable energy will allow advances to be made. A private project can be made to benefit from land the City owns, ordinances the City can pass, leadership officials can take, and information the City can provide to interested persons.

Conclusion

As pollution from fossil fuels continues to increase and key energy resources dwindle, alternative energy will be a necessity. Viability is the problem we currently have to deal with. To this end, many organizations including the state government and the ISO are trying to make renewable energy a

[10] Status of the Electric Grid in Massachusetts, http://www.mass.gov/dte/226govreport.pdf
[11] Proposed Uniform Standards for Interconnecting Distributed Generation in Massachusetts

reality before it is a necessity. These changes are not enough; the local government is the key. The City of Worcester is in a position to provide leadership not only to its citizens but also to other cities throughout the state by developing a renewable energy program that fosters the development of clean energy.

The Vision

The City of Worcester can provide support in three distinct areas for renewable energy: land, political leadership, and information. The first resource Worcester provides is a large amount of land in and around the City. A study could be completed to determine what land the City owns that would be preferred for wind energy. This land could be leased or sold to organizations interested in developing wind power. The second resource is political leadership on behalf of the local government. This includes actions such as buying green power for city residents, which guarantees that energy from a wind farm will be able to be sold; altering current regulations and zoning procedures to better support renewable energy sources; and passing local initiatives conducive to renewable energy. For example, local business owners might be encouraged to purchase a certain percentage of their monthly electricity from renewable energy sources. The third resource Worcester offers is information to aid efforts in developing wind energy. This information could include the local geography, regulations, possible tax incentives, and possible social problems. These possibilities are set forth in the suitability criteria that will be presented later in this report.

In many cities, current regulations do not address the wind power issue. Worcester is now presented with an opportunity to change that. Passing regulations and ordinances that clearly outline all political steps necessary during construction and operation would support this growing industry. The City can also help to facilitate development by making the planning process clear and concise. Presently, the closest permitting process to a wind turbine is that of a personal wireless tower. Updating regulations to encompass the construction of a wind turbine would be a first step in supporting the industry.

The suitability criteria that follow can be used as a basis for creating Worcester's wind energy policies. The City can set aside land that is particularly conducive to wind energy as decided using the criteria set forth in the following pages. Revising ordinances to address wind energy concerns and officially supporting wind energy is another possibility. Lastly, by maintaining an easily accessible record of wind energy opportunities and procedures, the City can foster wind projects in its backyard, making renewable energy a strong point of politics.

CHAPTER 2: SUITABILITY CRITERIA

This part of the report is intended to analyze the suitability criteria for the development of a wind turbine. The purpose of the criteria is support the evaluation of sites in the Worcester area where a wind turbine could be constructed. These criteria include physical characteristics, technological considerations, regulatory requirements, economics and financing, and societal concerns. These guidelines would then be employed by parties interested in wind energy development.

Physical Characteristics

The most influential criteria for suitability of a wind turbine in Worcester concern the physical characteristics of the land. Wind is the first dimension to be considered, as it is the impetus for turbines to produce power. The wind in a proposed location must have considerable strength to be efficient and generate electricity. If the wind speed is too low, then the turbine will not operate. To put these wind speeds in perspective: the wind speed must be between 7.6 – 8.9 mph[12] to achieve the "cut in" velocity, or the necessary velocity for the turbine to begin producing power. For maximum output, the wind should be stronger, ideally around 26.8 mph.[13]

The next variable to be considered is the consistency of the wind. Referred to as the annual average velocity, ideally this would be 26.8 mph, but could range up to around 56 mph when most turbines cease working, reaching the "cut off" speed.[14] Wind is more efficient at producing power when it is constant throughout the year. Periods of less wind strength, regardless of the yearly average velocity, can cause low power output. Fluctuations in wind velocity can cause unnecessary strain or even damage to a turbine.

Princeton, MA

Here, basic criteria of siting a turbine are reinforced. The turbines were located on state land on the face of Mt. Wachusett. This is an excellent source of clean, strong wind. Bird migration and community support were other factors that played a large role in this project.

Site Attributes:

- Clean Wind
- State Land
- High Velocity

[12] GE 1.5MW series service manual, http://www.gepower.com/prod_serv/products/wind_turbines/en/15mw/index.htm
[13] GE 1.5MW series service manual, http://www.gepower.com/prod_serv/products/wind_turbines/en/15mw/index.htm
[14] GE 1.5MW series service manual, http://www.gepower.com/prod_serv/products/wind_turbines/en/15mw/index.htm

An additional variable of wind is turbulence. Non-turbulent or "clean" air is necessary to develop an effective wind turbine. Lower areas induce a "puddling" effect at night, or during the winter, caused by the sinking of cool air.[15] Because this cool air is heavier than the ambient environment, there is a low tendency of this air to move. Stagnant air results in no power generated by a wind turbine. To ensure clean wind, the turbines should be located far from or above buildings which can reduce wind speed and create possibly damaging turbulence.

This problem is most easily solved by placing the turbine in a remote environment with generous elevation. Elevation, a dimension of the land, often provides a location with a high wind velocity. Generally, wind velocity increases as elevation increases. The general rule is to have a wind turbine 30ft higher than any obstruction within 300ft; the higher the better.[16] Location such as mountains and hills are popular places for wind turbines as they exploit this trait. A potential site may be aided by examining topographical data of Worcester.

Assessing the wind in an area can be a rather daunting process. For a completely accurate evaluation, close to one year or more of wind data should be collected at the exact location in question. It is extremely important to be rigorous when dealing with large scale projects (multiple, large turbines). For smaller, residential turbines an area's "wind class" and observable local features can be used for a rough wind speed estimate (see Figure 1 below).

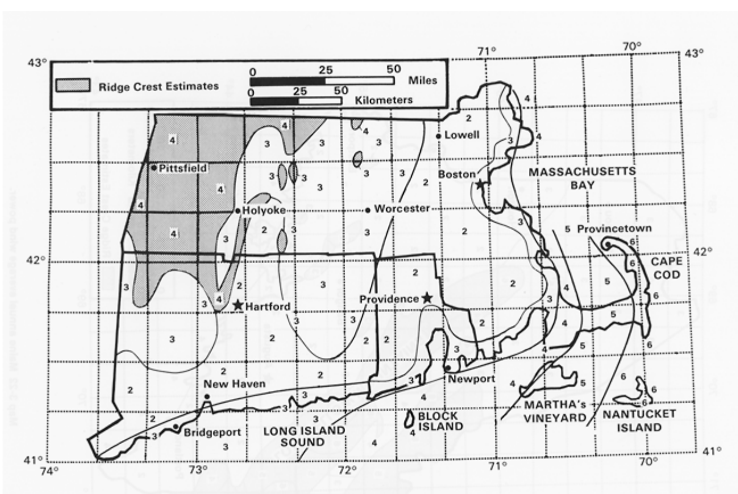


Figure 1: Local wind class regions.

[15] Siting Your Tower, http://www.renewableenergyworks.com/wind/TowerSiting.html
[16] Wind System Sitting, http://www.renewableenergyworks.com/wind/WindSiting.html

The number or class associated with each region is associated to a range of wind conditions using the table below:[17]

Classes of wind power density at 10 m and 50 m [(a)].				
Wind Power Class*	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density (W/m^2)	Speed [(b)] m/s (mph)	Wind Power Density (W/m^2)	Speed [(b)] m/s (mph)
	0	0	0	0
1				
	100	4.4 (9.8)	200	5.6 (12.5)
2				
	150	5.1 (11.5)	300	6.4 (14.3)
3				
	200	5.6 (12.5)	400	7.0 (15.7)
4				
	250	6.0 (13.4)	500	7.5 (16.8)
5				
	300	6.4 (14.3)	600	8.0 (17.9)
6				
	400	7.0 (15.7)	800	8.8 (19.7)
7				
	1000	9.4 (21.1)	2000	11.9 (26.6)

(a) Vertical extrapolation of wind speed based on the 1/7 power law.

(b) Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. Wind speed is for standard sea-level conditions.

Table 1: Wind Class Data

With this data, coupled with a realistic analysis of the site's surroundings, a group can evaluate a smaller project without the need to gather wind data. While this type of analysis can in no way replace site specific wind data gathered over a long period of time, it can provide the basis for a preliminary assessment. Using this data along with information on the power output of proposed turbines, a group can estimate the power production of the specific turbine at the site. In the case of Worcester, Massachusetts the wind class is 2-3, making it a marginal, but possible wind turbine site for energy production.

[17] Wind Classes for US-DOE Wind Maps, http://www.bergey.com/

Technical Considerations

Grid Integration

Once the turbines are built and ready to use they must be integrated into the electrical grid. Access to transmission lines is another dimension to consider as installing new lines for a wind farm increases the cost by 50% or more.[18] This is an enormous cost and is often not practical. A site is best when placed within 10 miles of existing transmission lines.[19] Additionally, construction to enable the interconnection of a wind turbine outside of this range will have a noticeable affect on traffic and noise pollution. In more rural areas, the community may not support the intrusive construction that would be required to extend the power grid. The destruction to the environment by large machinery in conjunction with increased traffic may have an adverse affect on public opinion.

Hull, MA

This site provided ease of integration as the project was developed through the Princeton Municipal Light District (PMLD). The electrical integration was established from the inception of the project.

Site Attributes:

- Existing Turbine
- Municipal Owned
- Easy Integration

There are, however, formalities to complete. Any electricity that is output by a generating source (our wind turbine, in the case) must be monitored and arranged by the Independent System Operator (ISO-New England). For small projects, the local distributor will handle the service for onsite generating facilities (OSGFs). It is the responsibility of the OSGF to contact the local electricity distributor and establish the necessary procedures to interconnect with the grid.[20]

The OSGF needs to ensure that the electricity produced is appropriate to introduce into the local grid. If direct-current (DC) power is generated, it needs to be converted to alternating-current (AC) power. Grid-tied inverters and turbines fitted with synchronous invertors or induced generators perform this function. It may also be required that the OSGF to establish a manual disconnect switch in case of grid failure. Additional issues to be addressed include: “harmonics, power factor, DC injection, and voltage flicker.”[21]

[18] Overview of Wind Technologies, http://www.eere.energy.gov/consumerinfo/pdfs/wind_overview.pdf
[19] Ibid.
[20] Renewable Energy & Distributed Generation Guidebook, Pg. 74
[21] Renewable Energy & Distributed Generation Guidebook, Pg. 75

This process may seem complicated, but all it really entails is contacting the local distribution company and inquiring what needs to be done. Under DTE's regulations, they have 45 days to perform an initial site inspection (free), which allows the distributor to evaluate what needs to be done and form an estimate for the installation. To continue with the interconnection, the OSGF must contact the distributor in writing. For more information concerning the content of this written request, please see page 77 of the "Renewable Energy & Distributed Generation Guidebook". The interconnection will be performed within 90 days, according to DTE's regulations.[22]

It is the responsibility of the OSGF to pay for the costs of interconnection. There exists an option to amortize the costs over three years with the distributor, although interest will be charged. The options of interconnection are left to the OSGF, but include net metering for facilities less than 60 kW, metering for facilities under 1 MW, and interconnection with ISO-New England for facilities producing more than 1 MW. If a large facility is chosen, a System Impact Study (SIS) will need to be performed.[23] For more information, please refer to pages 79-83 of "Renewable Energy & Distributed Generation Guidebook" and contact ISO-New England (http://www.iso-ne.com/).

Interconnection requires that an Interconnection Service Agreement be completed with the local electricity provider. This can proceed by one of three options, all interconnection applications. There is the Simplified Interconnection Application and Service Agreement for Facilities with Inverter Capacity of 10kW and under, which would be applicable to our situation of mounting a small turbine (>10kW) on the roof of our case study's house. Also available is the Expedited/Standard Process Interconnection Application. This addresses generating sources that are large enough to impose substantial impact on the local electrical grid and require a Supplemental Review Agreement. Finally, there are the study agreements, which are completed by the owner of the generating facility and can include an Impact Study Agreement or a Detailed Study Agreement, depending on the size of the project. All information described here can be examined further by referring to the Tariff to Accompany Proposed Uniform Standards for Interconnecting Distributed Generation in Massachusetts.[24]

Turbine Choice

There are two general turbine categories: horizontal and vertical axis turbines. The horizontal axis wind turbines (HAWTs) are most commonly associated with the term wind turbine. The two classes,

---

[22] Renewable Energy & Distributed Generation Guidebook, Pg. 75-76
[23] Renewable Energy & Distributed Generation Guidebook, Pg. 77-78
[24] http://www.mass.gov/dte/electric/02-38/515tariffr.pdf

upwind and downwind, specify the direction from which the turbine makes use of the wind. The turbine rotates to face the wind, adjusting to changing wind directions. Theses turbines can be seen below in Figure 2.

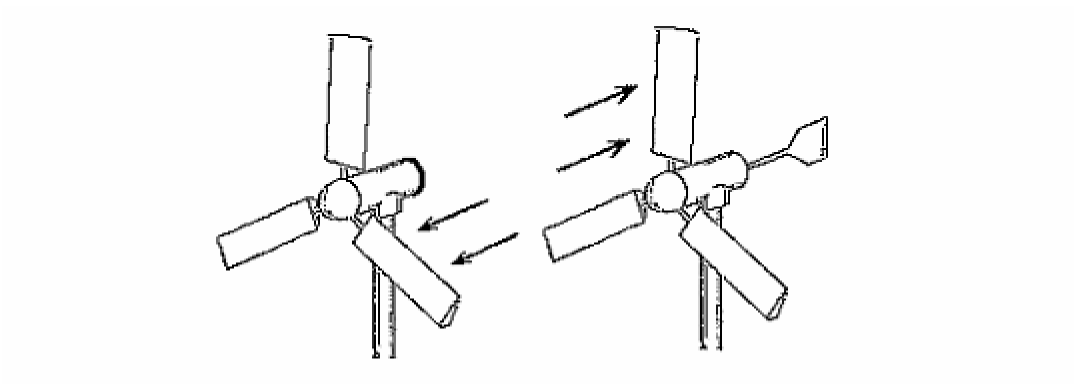


Figure 2: Horizontal Axis Wind Turbines: Upwind and Downwind, respectively[25]

The vertical axis wind turbines (VAWTs) are another possibility. These are omni-directional, meaning they can take advantage of the wind from any direction. These turbines can be seen below in Figure 3. These turbines are much less efficient than HAWTs and are, therefore, not as common. Because of this, any VAWT is more expensive than its HAWT counterpart. The different types include Giromill, Savonius, and Darrieus models. The Darrieus model is the most common, but does not work well in low winds as it has trouble starting automatically.[26] The two other models, Giromill and Savonius, are less common and could not be found in any search that we conducted.

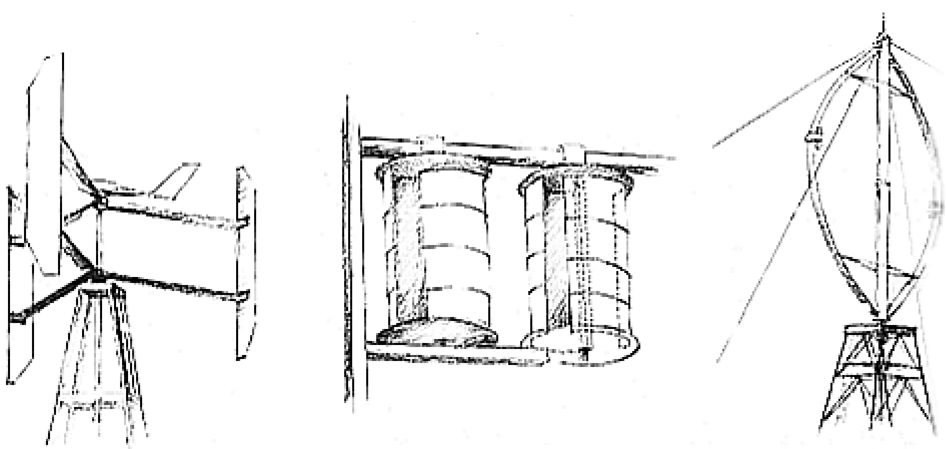


Figure 3: Vertical Axis Wind Turbines: Giromill, Savonius, and Darrieus, respectively[27]

[25] Alternative Energy Institute, http://www.wtamu.edu/research/aei/p2brochers.htm
[26] Wind Power for Home & Business
[27] Alternative Energy Institute, http://www.wtamu.edu/research/aei/p2brochers.htm

Regulations

Regulatory procedures provide an additional criterion to be considered when determining a suitable site for a wind turbine. Consideration must be given to laws and regulations at the federal, state, and local levels. The planning process for the city of Worcester does not currently include regulations for the construction of wind turbines, but can be surmised from the current planning process for personal wireless tower facilities, the closest reference available. This report contains some recommendations to develop regulations that would facilitate the development of wind turbines in the city of Worcester.

Federal Regulations

Environmental acts such as the Migratory Bird Treaty become important at the federal level. In the past, turbines in the migration path of birds have caused serious ecological problems (Appendix B, Altamont Pass). It is also illegal to construct a building that will infringe on species' natural migration paths. The issue can be addressed by consulting local bird experts, for example the local Audubon Societies[28] or a Natural History Museum. It would be prudent to document all information obtained, in case legal problems arise later.

Another relevant regulation is the Habitat Conservation Plan & Incidental Take Permit. This permit is necessary if the construction encroaches on any endangered species habitat. It must be accompanied by a Habitat Conservation Plan (HCP), which is a plan designed to offset any harmful effects the proposed activity might have on the species.[29] To find out whether any type of construction might require this permit and the subsequent plan, one should contact the local Fish and Wildlife Service office.[30]

Federal law also regulates waste water discharge. While this would most likely be applicable only during the construction process and rarely at that, it may be applicable during site selection and, more importantly, construction planning. The National Pollution Discharge Elimination System: Storm Water Notice of Intent[31] would become applicable if waste water will be generated during construction or groundwater will be affected in some way. If the necessary money and time to overcome any of these regulations is too great then a new site might be a better solution.

---

[28] National Audubon Society, http://www.audubon.org/
[29] Habitat Conservation Plan & Incidental Take Permit, http://endangered.fws.gov/hcp/
[30] List of Offices by States, http://offices.fws.gov/directory/listofficestate.cfm
[31] Electronic Storm water Notice of Intent, http://cfpub.epa.gov/npdes/stormwater/enoi.cfm

One key attribute of a successful wind turbine is its height in comparison to the surrounding area. The farther up the turbine can be built, and the farther away it is from structures that may cause turbulence, the more power it will generate. The downside to this is the effect it can have on anything that travels through the air; planes as well as birds. A Notice of Proposed Construction or Alteration must be completed for any structure over 200 feet to register it with the FAA.[32] An outline of the different regulations and which organizations to contact regarding them can be found in appendix B, table 4.

State Regulations

If any planned action during the construction or operation of the wind turbine will affect the environment adversely, one must be in contact with the Massachusetts Environmental Policy Act Office (MEPA). MEPA is part of the Executive Office of Environmental Affairs (EOEA) and is led by Secretary Ellen Roy Herzfelder. This agency conducts environmental impact studies on sites that require some type of state action. Agency actions also include granting state permits or licenses, providing state financial assistance, or transferring state land.[33] Luckily, this agency favors renewable energy projects, in particular wind energy, because of the pollution emissions that are offset by turbines.[34]

If state roads are altered or if transportation of materials requires an abnormally "wide load," Mass Highway should be contacted for the associated paperwork and approval.[35] A wide load would also require an equally wide access to the site, which may not be possible depending on the steepness and state of vegetation in proximity to the site. Mass Highway can also provide General Access Permits which would be necessary if construction or pre-construction activities would require the alteration of a state road. These aspects are extremely important since a site's suitability diminishes if cumbersome paperwork and committee presentations will drag the process out for months or years.

The state should be alerted if more than 25 acres of natural land is to be altered substantially. If construction of the turbine or wind farm is going to have an environmental impact on more than 25 acres then an Environmental Notification Form must be filled out.[36] The amount of alteration required to necessitate this form can be found through the EOEA.[37]

---

[32] Notice of Proposed Construction or Alteration, http://www.dot.state.oh.us/aviation/7460-1.pdf
[33] MEPA, http://www.mass.gov/envir/mepa/
[34] MEPA, http://www.mass.gov/envir/mepa/downloads/13229enf.doc
[35] Mass Highway, http://www.mhd.state.ma.us/mhd/home.htm
[36] Environmental Notification Form, http://www.mass.gov/envir/mepa/thirdlevelpages/downloads.htm
[37] Massachusetts Environmental Policy Act Office, http://www.mass.gov/envir/mepa/index.htm

Statewide regulations also affect the type of surroundings the turbine should be near. Regulations on sound output must be taken into consideration when reviewing a site. The relevant information on noise output by a power production facility is contained within the State Noise Control Policy.[38] This policy provides guidelines that a power production facility (like a wind turbine) must abide by. While in many cases the sound of the wind turbines is a common public concern before construction, it is rarely heard after construction. The social implications of the noise issue are addressed later in the Societal Concerns section.

Similarly, height restrictions and registration of elevated objects must be considered when building an unusually tall structure or when building near an airport. On the state level one should contact the Massachusetts Aeronautics Commissions through the Executive Office of Transportation.[39] Even if the proposed turbine is not near an airport it must be registered with the commission if it is over 200 feet.

In many instances a NEPOOL Interconnection System Impact Study & Facility Study will be a necessary part of plugging into the grid. This study exists to make sure that the grid can support the introduction of additional power at the specified point. While the technology of the electrical grid and how wind power interfaces with that is outside the scope of this report, it is worthwhile to note that the grid at any specific point must be analyzed. Due to the capital costs of expanding and upgrading, if the grid cannot handle the introduction of power then the site may be economically infeasible. An outline of the different state regulations and which organizations to contact regarding them can be found in appendix B, table 5.

Local Regulations

Locally one must obtain building permits, consult the planning board, abide by zoning laws, and contact the conservation commission.[40] A site may not be usable if zoning laws make the construction process overly expensive or legally exhaustive. Worcester has some specific zoning laws that may affect the suitability of a site. The Wetland Protection Ordinance was enacted to help protect the area's wetlands.[41] This is an example of a zoning ordinance that must be considered if construction near a wetland is going to take place. If the construction is forecasted to infringe on

---

[38] DEP Bureau of Waste Prevention Noise Policy, http://www.mass.gov/dep/energy/noispol.htm
[39] Executive Office of Transportation, http://www.eot.state.ma.us/eotc/index.html
[40] Administration and Procedure of Enforcement, http://www.ci.worcester.ma.us/cco/ordinances/ProposedArticleIVI/index23.html
[41] Wetland Protection Ordinance, http://www.ci.worcester.ma.us/cco/ordinances/wetlandordinance/index.html

any zoning laws, the Zoning Board of Appeals can be contacted. This board will hear special cases and decide whether the application of zoning laws in a specific instance is prudent.

The planning board must be consulted to ensure the installation do not have an unforeseen effect on the surroundings. They must review the site and approve the construction plan. The board may also have suggestions on how your site selection could better serve the city. Turbine placement at particular site may run against previously established municipal plans, especially if public land is to be used.

When any structure is built it must be approved by the building inspector. After the planning board has been contacted, and all zoning laws have been met, the building inspector (formally the Director of Code Enforcement) can issue a building permit that allows construction to proceed. It is not uncommon for there to be different guidelines for renewable energy related construction or construction that relates in any way to power generation. Since the city has not been faced with the task of assessing and approving a wind turbine, Worcester has no special considerations for renewable wind energy at this time.

Local regulations are very dependant on the local culture, politics and business. Due to this, one must research the local ordinances and laws that might pertain to renewable energy. Though the regulations may differ from town to town, the principle organizations that one should contact will be the same: building inspector, zoning board, planning board and the local electric and light commission, if one exists.

We have shown that the suitability of a proposed site for wind power generation is not simply dependant on the wind. Many regulatory, social, economic, and geographic variables must be considered during the selection process. It is through the analysis and implementation of these suitability criteria that a fitting site can be found. An outline of the different local regulations and which organizations to contact regarding them can be found in appendix B, table 6.

Worcester Planning Process

The planning process for a wind turbine in Worcester is limited; this is due to a lack of experience with projects of this kind. Because there have been no proposals to undertake the construction of a wind turbine, there are no zoning ordinances pertaining to this issue. The existing planning process for personal wireless service facilities is the closest comparison available and can serve as a model for developing ordinances in accordance with Worcester's goals.

The planning process for wind turbine would include the requirements outlined in Appendix C as well as include additional permits to address the needs of the turbine.[42] Increasing the public's knowledge of the wind turbines, as well as that of city officials, about the wind turbine and its benefits should be undertaken first. Many times, a public hearing is encouraged to foster a discussion on the issue. With public projects like Princeton, MA and projects that will affect a great many people like Cape Wind it is important to keep the public informed. Efforts should be made to interact with the community and determine the attitudes for a project in the area. Such activities may include sending surveys through the mail, or conducting interviews with local residents who will be affected by the wind turbine. A meeting with local landowners will also help to facilitate this process. A city board meeting comprised of the planning board and zoning board of appeals would prove helpful, achieving the same goal but with a different audience.

A site plan review is required by the city of Worcester to inform the planning board of the intentions of a wind turbine project. This is necessary before any construction permits are issued. Additionally, zoning restrictions will need to be dealt with, largely regarding the height regulations. The zoning board of appeals must make a decision to allow a special grant. Currently, a structure can be up to 150 feet in height, in a B-4.0 district. While exceptions might be more feasible in residential areas, the restrictions may make industrial wind turbines impossible to construct in the area. This would limit construction to smaller, more personal turbines providing enough power for an average household.

In addition to the local planning board and zoning board of appeals, other organizations need to be contacted. The Massachusetts Environmental Protection Agency (MEPA) determines if an Environmental Notification Form (ENF) will be required to assess the environmental impact of the project and any possible repercussions it can have. Construction of an access road also plays an important role in a site's suitability. Contacting the appropriate local agency to gain approval for a right-of-way will be necessary. The Federal Aviation Administration (FAA) also needs to determine that there is no aviation navigation hazard. The accordance with FAA Advisory Circular 70/7460-1 mandates towers that are marked and lighted properly. The National Heritage and Endangered Species Program (NHESP) needs to verify that there are no rare plants or animals in the proposed site. The Worcester Conservation Commission will also need to be contacted to determine the feasibility of the site. This organization works to protect wetlands most strongly and works in

[42] Worcester City Zoning Ordinances

collaboration with MEPA. The Massachusetts Historic Commission (MHC) must review the site if it is on the historic register.[43]

The code enforcement commissioner is an important person in this section. As of November 2004, Jill Dagilis held this position. She can be called at (508) 799-8534 or through email by code@ci.worcester.ma.us. The office is located at 25 Meade Street; Worcester, MA 01610. This office will need to be contacted if any questions arise as it is working in conjunction with the Planning Board, Zoning Board of Appeals, Conservation Commission, and Worcester Historical Commission.

[43] MRPC Comprehensive Planning, http://www.mrpc.org/comprehensive%20planning.htm

Economics and Financing

Justifying the large capital cost of a wind turbine can be a large problem. Economic factors have heavily influenced the development of wind turbines and performing a cost analysis is an important step for determining the suitability of a wind turbine. In this section we will cover the federal, state, and local financial incentives that were created to promote the development of a wind turbine site. This aid ranges from grants to tax credits and exemptions. Due to the increasing recognition of the benefits of renewable energy, many financial incentives in Massachusetts are directed towards increasing the percentage of green energy delivered to the grid. It should be noted, however, that these incentives change often and should be investigated at the time of the planned construction of the turbine.

Economics in Perspective

Before plans are brought to a municipal department, it is important to understand the economics of a wind turbine. The project must be profitable or the project will not succeed. It is important to make use of grants, tax incentives, and loans to determine the actual cost of a project. All facets must be considered: capital costs, civil works, electrical infrastructure, grid interconnection, project management, installation, insurance, legal/development costs, bank fees, and interest accrued. While some of these factors influence the project more heavily than others, none of them can be ignored. Operating and Management (O & M) costs must also be figured into the economics. There are different equations to use when formulating cost analyses, which are helpful only if the specifics of a wind turbine are known.

In this case, the type of turbine and power output would be an important consideration. Turbines can be very large and produce a large amount of energy (5 megawatts) or can be small and suitable for a small house or garage[44]. Price can vary as much as power output and depends on both installation and equipment costs, as seen in Table 2. To put these costs and sizes in perspective the following table has been prepared, comparing common models and manufacturers:

[44] Renewable Energy World, http://www.jxj.com/magsandj/rew/2001_03/great_expectations.html

Table 2: Comparison of Common Turbine Sizes and Models

Turbine Type	Capacity (kW)	Kilowatt Hours (monthly)	Average Tower Height (ft)	Approximate Cost (USD)
Jacobs 29-20/80 I	20.0	2300	60-120	31,000
BWC EXCEL-S	10.0	1500	60-120	24,000
Whisper 175	3.2	1000	30-80	5,000
BWC XL.1	1.0	400	30-100	2,000
Air-X Wind Turbine 400W	0.4	80	30-50	500

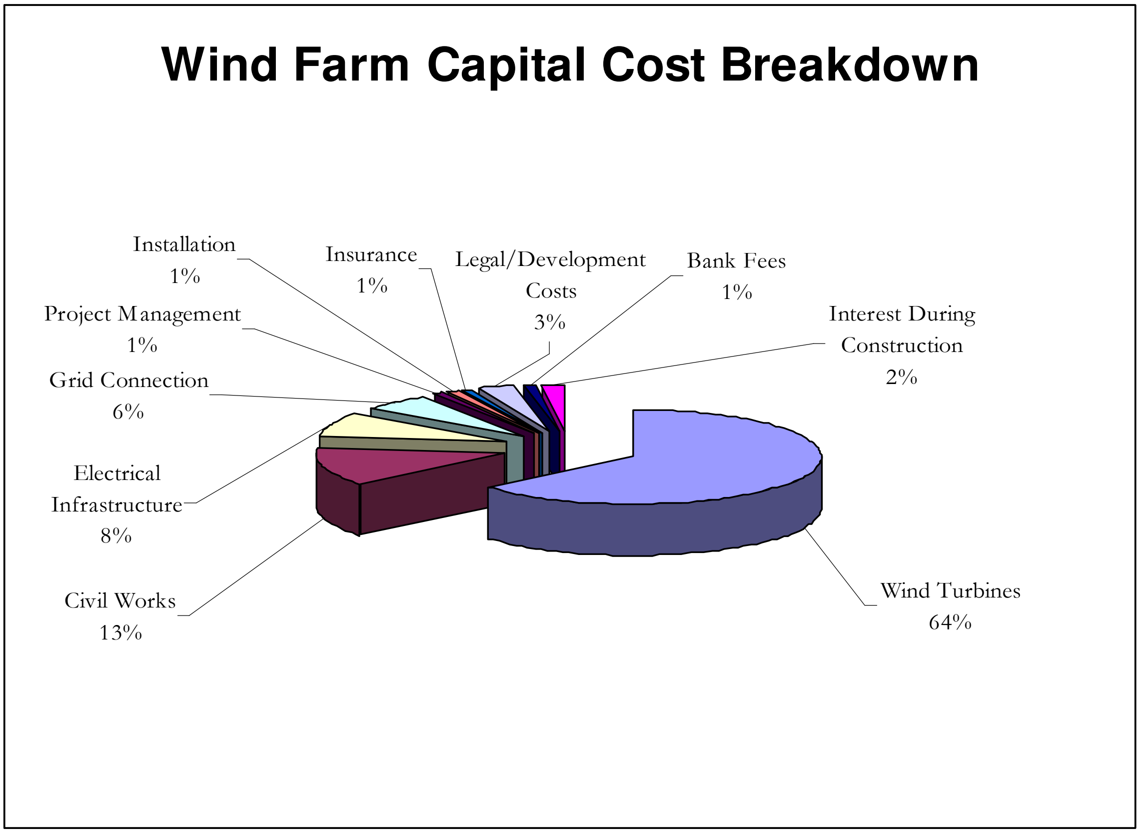


Figure 4: Wind Farm Capital Cost Breakdown

The chart above shows a rough estimate of the cost distribution in an average project. We use these estimates in our economic analysis later in this report to predict the total cost of a project based on the price of the turbine alone.

Federal

The federal government offsets some of the hefty costs associated with wind power through awards grants, tax credits and incentives. Tax credits are credited during the turbine's life, based on the amount of energy produced per year. The U.S. Department of Energy (DOE) and other federal agencies will issue Requests for Proposals (RFPs) biannually in the Commerce Business Daily and will award funds for specific projects as they become available.[45]

Grants

Federal money can be awarded in the form of grants. The National Industrial Competitiveness through Energy, Environment, and Economics (NICE3) grant provides funding to reduce the costs of renewable energy. This grant was established to reduce the pollution that comes from manufacturing by funding the "initial commercial demonstration of technologies used to improve energy efficiency."[46] To pursue the benefits of new technologies, the companies funded under this grant agree to share information about the project with other companies. These grants are given through state governments by the federal government and are used to fund projects at the state's discretion. The funding for Massachusetts is around $250,000 a year.[47] The grant can cover up to 50% of the project cost. Unfortunately, this program is in the process of being discontinued by the Department of Energy, but may prove to be a valuable resource of information from the mandated reports or by studying the companies that went through with the program.

The U.S. Environmental Protection Agency offers grants to promote the development of projects beneficial to the environment. The focus of these grants is to create outreach services in communities where projects are to be undertaken. This agency offers finances through the Environmental Finance Program (EFP). The EFP also aids projects by supplying information that is useful in financing and developing projects. These developed resources could prove invaluable to new developers.[48]

Tax Incentives

The federal government offers a Renewable Energy Production Tax Credit (PTC) which entitles private entities to receive a 1.5 cent tax credit, adjusted for inflation, for every kWh produced from a wind turbine for the first ten years of operation. This credit allows wind energy to compete with other established forms of energy production. Without it, the expenses of wind energy often become

[45] DOER Renewable Energy Programs, http://www.mass.gov/doer/programs/renew/renew.htm
[46] Ohio Department of Development, http://www.odod.state.oh.us/cdd/oee/c_i_nice3.htm
[47] U.S. Department of Energy, http://www.eere.energy.gov/wip/program/nice3.html
[48] Environmental Protection Agency, http://www.getf.org/file/toolmanager/O16F8897.htm

Top of Iowa

This project was manageable largely due to the abundance of financial incentives for wind power. The project made use of the PTC tax credit, MACRS program, as well as state incentives.

Site Attributes:

- Large Farm
- High Velocity
- Effective Economic Funding

too high and discourage development. This tax credit cannot be obtained by the government for wind energy projects.[49] The necessary forms for this credit can be found in the Internal Revenue Service Form 8835[50] Part I for private projects or Form 3800[51] for businesses who wish to utilize wind energy.

The Renewable Energy Production Incentive (REPI) provided a tax incentive of 1.5 cents per kWh of energy produced, adjusted for inflation. This incentive was not renewed and expired on September 30, 2003. New renewable generating technologies will not be able to participate in this program, but programs previously enrolled will continue to receive the incentive the remainder of the ten year allocation.[52] In combination with the PTC, these two credits were responsible for much of the development of renewable energy. This incentive was previously offered to "promote increases in the generation and utilization of electricity from renewable energy sources and to further the advances of renewable energy technologies."[53] It is possible that this incentive will be renewed so developers should investigate at the time of their project.

The Modified Accelerated Cost Recovery System (MACRS) allows businesses to recover investments through depreciation deductions from a period of 3 to 31.5 years. This allows the capital costs of constructing a turbine to be further offset by the low costs of operation. This strengthens one of the most attractive features of wind energy: the low cost of maintenance.[54] The forms can be found in Section 168 (e)(3)(b) of the Internal Revenue Code.[55]

Loans

The U.S. Small Business Association (SBA) offers aid in the form of loans for renewable energy projects. This organization also helps to ensure that the necessary loans are obtained by persuading

[49] Center for Energy Efficiency and Renewable Energy PowerPoint Presentation, http://www.ceere.org/rerl/events/ne_islands_2002/3_Forsyth_PTC_REPI_overview_Dec02.pdf
[50] Internal Revenue Service, http://www.irs.gov/pub/irs-dft/d8835.pdf
[51] Internal Revenue Service, http://www.irs.gov/pub/irs-dft/d3800.pdf
[52] Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/wip/program/repi.html
[53] Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/wip/program/repi.html
[54] Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/consumerinfo/factsheets/la7.html
[55] DOER Renewable Energy Programs, http://www.mass.gov/doer/programs/renew/renew.htm

lenders to invest in developing technologies. This association aids in the signing of loans that total not more than $750,000 or 75% of the project - loans up to $100,000 cannot exceed 80% of the project[56]. These loans can be used for the purchase of machinery, equipment, furniture, fixtures, facilities, buildings, supply materials, and land.

State

The State of Massachusetts offers financial aid in addition to that offered by the federal government. Because of the rising interest in the developing renewable energies, the state awards grants and offers tax incentives to encourage growth. In addition to the strict monetary advantages, the state also encourages alternative energy development through a number of state regulations that increase the demand for wind power.

Grants

The Massachusetts Renewable Energy Trust Fund provides money to support renewable energy development. The allocation is intended to be used to further the use and technology of renewable energy. The fund is created by electricity customers paying a system benefits charge of 3%, which totals to approximately $20 million each year. The money is administered by the Massachusetts Technology Collaborative (MTC) in an effort to provide the opportunity for renewable energy to be introduced onto the regional electrical grid.[57] The MTC is a "quasi-public research and development entity," that works in conjunction with planning assistance from the Massachusetts Department of Energy Resources (DOER) and an advisory board.[58]

Over the course of the next three years, the MTC's Commercial, Industrial, & Institutional Initiative (CI3) will be offering $6 million in grant funding. The grants are being offered to relieve grid congestion and offset power purchases. The organization that hosts the project must be grid-connected and consume at least half of the power generated by the renewable energy source. Grants can be obtained for feasibility studies (maximum of $40,000, organization paying at least 20% or $5,000, whichever is less) as well as design and construction (based on an incentive-per-watt basis). For a wind power project to be eligible, the capacity must be at least 100kW. "The Design phase award will not exceed $150,000 or 50% of the actual incremental design costs. The Construction phase award will not exceed $500,000 or 50% of the actual incremental construction costs." Grant opportunities will be offered twice a year for three years. "Applicants will submit proposals for either a Feasibility Study Grant or a Design & Construction Grant depending on the stage of

[56] Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/industry/financial/fedsba1.html
[57] Interview with Dr. Golding of the Worcester Ecotarium
[58] Northeast Sustainable Energy Association, http://www.nesea.org/energy/ma_incentives.html

development of their project. Feasibility study applicants may apply for a Design & Construction Grant during a future round."[59,60]

Tax Credits

In addition to grants, Massachusetts offers tax credits and exemptions. By reducing some of the costs associated with developing technologies, the state hopes to provide satisfactory incentive for supporters to invest in new programs. It is the hope of the state that the continuing development of renewable energy will make the system self-supportive, but for now aid is provided.

The State Individual Income Tax Credit is available to those who install renewable energy in their homes. The credit is 15% of the net expenditure or $1000, whichever is less. The credit can be carried over to the next tax year if it is not all used. The form can be found in the Massachusetts Tax Form Schedule EC.[61]

A State Sales Tax Exemption is available that allows the sales tax to be withheld when buying equipment directly related to the installation of wind energy into one's personal residence. This deduction can be found under Massachusetts Tax Form ST-12[62]. For businesses, the Massachusetts' Corporate Income Tax Deduction allows companies to deduct installation expenses from its net income. This deduction can be found under Massachusetts Tax Law, M.G.L. c.63, sec. 38H.[63]

Regulations

Another state-based advantage to renewable energy comes not in the form of financial aid, but in restrictions on current energy production. The state has passed numerous laws that are directed at developing renewable energies. The programs are meant for use by any alternative energy, and act to boost the potential of wind energy as much as any other technology.

The Generation Performance Standards (GPS) provide a specific limit for the amount of pollution allowed to be produced by a designated unit of electricity.[64] The purpose of the GPS is to shut down

---

[59] Massachusetts Incentives for Renewable Energy, http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=MA19F&state=MA&CurrentPageID=1

[60] To find out more about forms for applying visit: http://www.masstech.org/Grants_and_Awards/GBP/GreenBuildingsandInfrastructureProgram.htm

[61] State Income Tax E xemption, http://www.dor.state.ma.us/forms/inctax03/addlpdfs/sch_ec.pdf

[62] State Sales Tax Exemption, http://www.dor.state.ma.us/forms/wage_rpt/pdfs/st_12.pdf

[63] DOER Renewable Energy Programs, http://www.mass.gov/doer/programs/renew/renew.htm

[64] Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/state_energy/policy_casestudies_massachusetts.cfm

power plants that are excessively "dirty" and, as the standards become stricter, increase the demand for clean, renewable energy.[65] This is different than the Clean Air Act because the GPS indirectly strictly limits the air pollution created by energy production. While wind energy would also benefit from Clean Air Act guidelines, the GPS provides additional regulations that aid the advancement of renewable energy. These standards were put in place on May 1, 2003.

The Renewable Energy Portfolio Standard (RPS) requires that energy distributors include a minimum percentage of renewable energy sources (1.5% of sales in 2004, 2.0% of sales in 2005) to their customers. The percentages increase every year until at least 9% of each utility's entire distribution is renewable energy. To make sure that this policy is adhered to, Massachusetts requires that Renewable Energy Credits (REC) be accounted for. "A Credit is a tradable certificate of proof that one kWh of electricity has been generated by a renewable-fueled source." This means that if the RPS mandates that 2% of electricity come from renewable energy and 100,000 kWh were distributed, then there needs to be proof that 2,000 Credits were bought, or created by the generator at the end of the year.[66] The credits are not the same as the amount of power produced and are purchased independently of the green power.

A disclosure policy has also been passed by the state, requiring that electricity suppliers must inform customers as to the generation sources of their electricity. This is an attempt to educate the public about the source of their electricity. This gives individuals an opportunity to pay a little more to support renewable energy sources.

The Renewable Energy Research Laboratory (RERL) at the University of Massachusetts at Amherst is available for consultation of renewable energy projects. The Hull wind project was sited by this laboratory which is one of the sites we analyze later in this report (Appendix B). This organization provides aid during the preconstruction planning process. For more information about obtaining help from the RERL regarding wind technology, contact Sally Wright, P.E.[67]

City of Worcester

Locations such as the city of Worcester may also offer some financial incentives for renewable energy. The demand for renewable energy is increasing and is supported on many levels. The support ranges from tax exemptions to finding local organizations that are willing to support a green

[65] Massachusetts Department of Environmental Protection, http://www.mass.gov/dep/utilrest/files/gps.pdf
[66] American Wind Energy Association, http://www.awea.org/policy/rpsbrief.html
[67] Sally Wright, P.E., 413-545-3914, rerl@ecs.umass.edu, http://www.ceere.org/rerl/

energy project. Many of the local benefits are site specific and will need to be researched when actually conducting the project. The local government can be contacted for further information.

The Local Property Tax Exemption allows a residence or business to claim exemption for up to 20 years on the increased assessment that the wind turbine creates for the property. The form can be found under Massachusetts tax law Chapter 59, Section 5, Clause 45[68]. More sources may be available through the city of Worcester, but more research needs to be completed in this area. Worcester may be particularly beneficial as the mayor has expressed an interest in the growth and development of renewable energy resources.

Recently the Clean Energy Coalition (CEC) has proposed a resolution to the city of Worcester to promote renewable energy. This resolution would require 20% of the city's power for city operations to be produced by renewable sources by the year 2010. This was modeled after a similar resolution in New Haven, CT. This is an example of the local support that must exist to establish the demand needed to get the wind power industry "off the ground." The potential for developing support for clean energy is large as only 178 of 62,000 residences in Worcester were signed up for renewable energy as of 2004.[69]

[68] DOER Renewable Energy Programs, http://www.mass.gov/doer/programs/renew/renew.htm
[69] Carissa Williams, Clean Energy Coordinator

Societal Concerns

Community support is important and can decide the fate of a wind project in its early stages thus steps should be taken to address concerns including noise, aesthetics, ownership, and effects on local wildlife. By providing information on these topics, developers can help insure that the community will debate or agree from an informed position, making future dialogues and meetings much more productive. Including the community in the planning process also helps to avoid future problems and conflicts.

Noise

The sound produced by wind turbines is a common concern among people who live nearby. After construction some of the fears and concerns of the public will be allayed. It is a common misconception that wind turbines produce large amounts of noise. A good way to address this concern would be to show the public, through sound recordings of existing wind turbines, what different models sound like at various distances. The hypothetical comparison shown below in Figure 5 illustrates that wind turbines are quiet with respect to common activities that we are accustomed to hearing.

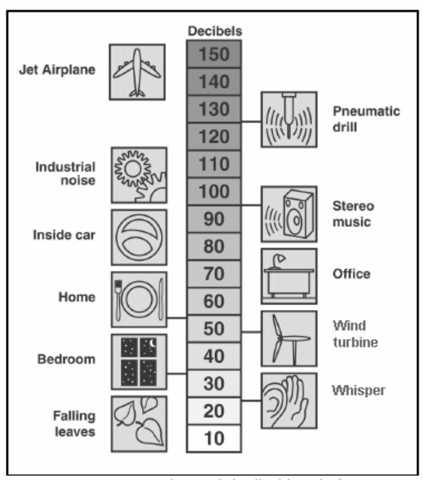


Figure 5: Comparison of decibel levels from a hypothetical wind turbine.

Noise from turbines comes from two sources: aerodynamics and mechanics. The aerodynamic noise is produced by the wind and the turbine's blades. This is the "whooshing" sound that many people hear and associate with wind turbines. Usually, this is due to the passing of the blades, but can be also attributed to the turbulence of the wind. Blades are being developed that are more efficient, thereby capturing more wind and producing less noise. As more is understood about these sources, technology will adapt to solve the problem.[70] A chart is attached as Appendix D explaining the numerous sources of aerodynamic noise.

Another problem is that of the mechanical noises of a wind turbine. Parts such as the gearbox, generator, yaw drives, cooling fans, and hydraulic equipment can produce sound. These tones are usually more harsh and tonal, causing more opposition than aerodynamic sounds. While some of these sounds can be reduced by insulating the tower or by regularly maintaining the gearbox, many of these sounds cannot be eliminated entirely.[71] Many of the noise issues need to be dealt with as zoning ordinances restrict the increase in ambient noise. Worcester has regulations that mandate the maximum noise increase, heard at the border of property, of 50 dB.[72]

Aesthetics

A further dimension that creates opposition is the aesthetics of the turbines. To gather wind a turbine must be elevated causing it to be visible over long distances. There are many people who may argue that nature was not intended to be home to large, invasive machines. Others see them as the solution to keeping our environment beautiful, and that the machines themselves are quite attractive. Actually visiting a wind turbine or farm would be the best way to develop an informed opinion on the aesthetic issue.

Searsburg, Vermont

This site exemplifies the importance of securing support from the local government and population. Support for the project remained extremely high throughout. In Searsburg, the aesthetics of the wind turbines didn't hinder, but helped, the project by attracting tourists to the small town.

Site Attributes:

- Aesthetically Attractive
- Public support
- Government owned

Another variable that must be taken into consideration is "flicker." When the sun is rising or setting behind the turbine, an unwanted flicking shadow effect can be created by the spinning blades. As seen in other sites (Appendix A), these concerns can become negligible when a site is properly chosen.

Ownership

Many of these dimensions will differ whether the site is owned by a public or private organization. The drawback to buying a parcel of land is money. Availability of land that fits the criteria for a good wind farm site may be limited. Public land is common, especially in wide open

[70] Wind Energy Explained, Pg. 487
[71] Wind Energy Explained, Pg. 488
[72] Worcester City Zoning Ordinances

areas where a turbine would be most effective. Worcester may be willing to provide or lease public land to be used for a wind farm. Organizations that exist to educate or support the environment would be excellent recipients of this symbiotic relationship. In this case public land may be the only viable option. It must be noted that once public land is used, the government has some jurisdiction over the project as per an agreement or lease.

Environmental Concerns

A location may be suitable for producing electricity, but the construction process may cause more environmental harm than good. Environmentally sensitive areas such as wetlands and endangered species' habitats are possible sites, but should be approached with caution. The Massachusetts Endangered Species Act regulates all actions that could affect an endangered or rare species.[73] If construction were forecasted to infringe on a species habitat, considerable time and paperwork would be required to legally build on the site. Special permits and notes of intent must be filled if an area is to be affected in any way by proposed construction. Additionally, the Massachusetts Wetlands Protection Act may cause substantial setbacks when obtaining the proper documentation for construction.[74] If any wetlands are to be altered, actions must be taken to develop wetlands somewhere else. The specifics of these regulations are addressed in the "Regulations" section.

Altamont Pass, CA

The Altamont Pass project showed how neglecting careful research into the surrounding area, specifically bird migration, can hinder the progress of a renewable energy project. Not only does this look unfavorable in the public's eyes but it also makes any other future sites impossible without directly addressing the public and convincing them of the safety of the site.

Site Attributes:

- Large open space
- Far from population
- Bird deaths

The variable of most concern to residents is that of avian impact.[75] The migration of birds presents problems that are best to avoid. If it is unavoidable to build on a migration route, developers must plan accordingly. Fewer, larger turbines instead of numerous, smaller turbines will decrease the effect on the bird population passing through the area. Perching and nesting on turbines has been a problem in some areas. A solution to this problem has been to remove any lattice that a bird might perch on. This can be best accomplished by utilizing a

---

[73] Mass. Endangered Species Act, http://www.mass.gov/legis/laws/mgl/gl-131a-toc.htm
[74] Mass. Wetland Protection At, http://www.mass.gov/legis/laws/mgl/131-40.htm
[75] Wind Energy Explained

monopole as a stand for the turbine. To avoid the nesting problem altogether, maintenance personnel should remove nests whenever possible to discourage it on or near the turbines. Additionally, removing potential food sources is a method of keeping away birds, especially birds of prey. This can be accomplished by fencing off the area. Lastly, electrical lines should be buried instead of being elevated. This eliminates a potential perching spot and another hazard to flying through the area.

Transportation Considerations

Site access can hinder construction, especially considering the nature of sites that would be conducive to wind power. While the wind conditions may be perfect, the road conditions may not. Sites that are elevated and contain open land tend to exist on top of mountains or hills. Construction will put the greatest strain on the ability to access the site. Large equipment and machinery wear on back roads that may not have been designed for heavy loads. While routine maintenance may seem inconsequential after construction, but it is still a factor. The site should be accessible during all seasons in case a problem occurs.

In an urban setting, the access problem will take on a different approach. The construction will need to be performed without considerably disrupting local traffic and commerce. In some areas, a narrow rural road can allow better maneuverability than a cramped city street. However, a skilled driver, early mornings, and smart engineering can alleviate this urban concern if the site is worth the trouble.

Conclusion

With the above report anyone interested in developing wind power, plus city planners and others interested in the process, should have the information needed to perform a suitability analysis. While different locations and situations will change the specifics of site analysis, we believe this report sets forth a basic framework that will apply to any site. A checklist has also been developed for this report to aid the site analysis process (following 2 pages). The purpose of this tool is to simplify the procedure, using this report as a reference when more information is necessary. This checklist can be used for any site, as it is derived from the suitability report above.

To make this report a more complete guide to wind power development we have developed two other sections to supplement the main focus on suitability criteria: Chapter 3: Case Study in Worcester, MA and Appendix A: Alternate Wind Power Site Descriptions. The Case Study in Worcester, MA is a suitability study performed on an actual site in Worcester. This provides an example of how one might apply the above suitability criteria in a real world setting. While the site itself is residential, the general process should be the same regardless of project size.

To further supplement our suitability criteria and reinforce the diversity that can exist in many wind projects, Appendix A contains a number of alternate site descriptions. These comparisons are taken from all around the world from wind projects of varying success. The hope is that these will provide a feel for the attributes of a successful site; both physical and political.

Y/N Write in

1. Physical Characteristics

Average wind velocity

Clean air flow

Geography: is the turbine placed 30ft higher than any obstruction within a 300ft radius?

Height: is this location the highest around?

2. Technical Considerations

Power production of turbine: how much electricity is being produced?

a) Interconnection: If Power<60kW: Is net metering viable?

a-1) If Power<1MW and net metering not viable, direct connection to distributor necessary

b) Access to transmission lines: If Power>1MW, are the turbines adjacent to transmission lines?

Construction location: does the turbine interfere with the town/city that they are placed in?

Noise: What is the distance to the closest houses/buildings?

3. Regulations

Federal

Migratory Bird Treaty: are the turbines in the migration path of any avian species?

Habitat Conservation Plan & Incidental Take Permit: does the location encroach on any endangered species?

Waste water discharge: will the construction process affect the ground water?

Height: does the structure meet FAA standards [under 200ft]?

State

Massachusetts Environmental Policy Act: will this affect the environment adversely?

General Access Permits: Will the construction necessitate the use of "wide load" vehicles?

Environmental Notification Form: will more than 25 acres of land be altered?

Noise Control Policy: will the noise of the turbines violate the local noise zoning laws?

Height Restrictions: are the turbines near an airport?

ISO New England Interconnection System Impact & Facility Study: will the turbines be connected to the grid?

Local

Wetland Protection Ordinance: will the installation affect any local wetlands?

Structure Inspected: has the building inspector been contacted?

Special Permit Granting Authority: Have you applied for a special permit?

Zoning laws: have you addressed all the zoning laws?

	Y/N	Write in
4. Economics and Financing		
Is this for a business? If yes go to section a.		
Is this for a personal use? If yes go to section b.		
If this is to be built by a branch of Government, skip this section.		
a		
Have you applied for the National Industrial Competitiveness through Energy, Environment, and Economics (NICE3) grant?		
Have you applied for the U.S. Environmental Protection Agency (EPA) grant?		
Have you filed for the Modified Accelerated Cost Recovery System?		
Have you consulted the U.S. Small Business Association for a loan?		
Have you applied for the Massachusetts Technology Collaborative (MTC) Trust Fund?		
Have you applied for MTC's Commercial, Industrial, & Institutional Initiative?		
b		
Have you filled for the Renewable Energy Production Tax Credit?		
Have you applied for the Massachusetts Technology Trust Fund?		
Have you filed for the Massachusetts State Individual Income Tax Credit?		
Have you filed for the Massachusetts State Sales Tax Exemption?		
Have you filed for the Local Property Tax Exemption?		
5. Societal Impact		
Complete review of societal impact, and present to city/town board for review		

CHAPTER 3: CASE STUDY IN WORCESTER, MA

This case study closely mirrors our suitability factors used for siting a wind turbine in Worcester, MA. This report implements the methodology developed in the previous report to illustrate how one would apply the suitability criteria in a real world setting. The purpose of this is twofold: to provide a rubric that a group might follow that is interested in installing a wind turbine and to provide information to the City of Worcester to aid in stimulating and effectively regulating wind power development.

This report is not simply a hypothetical application. We have been asked by a potential investor to analyze a real site in downtown Worcester. This case study will establish a method of completing a site suitability analysis that could be applied to a wide variety of situations. By applying our criteria thoroughly and rigorously we will cover all potential paths wind turbine development might require.

The Opportunity

The development of a wind turbine in downtown Worcester has implications beyond that of a single source of renewable energy. This project will help to pioneer renewable energy in the urban setting of Worcester. We hope that this implementation of clean energy will foster more energy development of this kind. If successful, this project will bring with it a myriad of benefits, applicable to numerous members of society:

- Potential wind investors will have an established method of developing a wind turbine
- Worcester lawmakers will have a resource to use while establishing informed regulations to deal with wind energy
- Advocates of renewable energy will have an example to base future projects on
- Worcester will be able to further proclaim its support of environmentally friendly policies
- The public will gain some understanding of renewable energy that will allow them to form an educated and informed opinion

This case study will explore the siting process; compile information available for development of wind turbines and make suggestions as to how the process can be simplified in Worcester.

Introduction

The project site is located in downtown Worcester, south of the Worcester Common Outlets, north of I-290. Our initial visit to the site was on Monday, November 22, 2004 when we were given a tour of the property. During the tour and following talk with the owner, the following points were raised:

- The owner's preference was to place the turbine on the roof, but other possibilities should be considered.
- The site has an anecdotally high average wind speed.
- Interest was expressed in making use of local businesses to provide a wind turbine.
- A vertical axis wind turbine was mentioned as a possible design.
- The energy needs of the house are around 1000 kWh monthly.
- We were to perform an analysis on the site and recommend a specific wind turbine that would fulfill the above criteria.

The scope of this project was conducted with the knowledge that this wind turbine was primarily aimed at increasing awareness of renewable energy in the area. The project was designed to pioneer residential wind energy in Worcester; a consideration that heavily influenced our analysis. We stressed ease of installation and minimizing the degree of intrusion over power production and economic feasibility.

Suitability Analysis

This site analysis follows the suitability criteria outlined in the preceding chapter, Chapter 2: Suitability Criteria. We discuss each issue addressed in our report and provide explanations for any decisions made. The process can be followed by any potential developer, though the process should be tailored to specific restrictions, concerns and attributes.

Physical Characteristics

The most important factor concerning a site's suitability is the average wind speed. It is important to thoroughly gather data for a specific site as the entire economic analysis is based upon how much energy the turbine can produce. Knowing the average wind speed allows a realistic economic analysis to be performed using power output data provided by a turbine's manufacturer.

Optimally, data would be collected over a period of 14 months. To aid in this effort, the Renewable Energy Resource Lab (RERL) has an anemometer loan program available to individuals and organizations interested in developing wind power. The loan program helps to defray the cost of wind data collection.[76]

The time frame for our analysis did not allow us to gather the recommended amount of data. Therefore, to determine a wind speed to base all of our estimates on we searched four different sources: NOAA, state wind resource maps, MTC community wind resource maps, and NREL wind maps.

The first source is the National Oceanic and Atmospheric Administration (NOAA). This organization provides data for various National Climate Data Centers (NCDCs).[77] Unfortunately, the data was difficult to work with as it was a text file of strings of numbers with no breaks or descriptions. Another source available is a state wind resource map. These maps are available online through the US Department of Energy (Figure 6).[78] The corresponding wind data tables are also available for specific areas.[79]

---

[76] Renewable Energy Resource Lab, http://www.ceere.org/rerl/projects/support/weps.html
[77] National Oceanic and Atmospheric Administration, http://www.ncdc.noaa.gov/oa/mppsearch.html.
[78] US Dept. of Energy State Wind Maps, http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp
[79] Worcester wind data, http://truewind.teamcamelot.com/bin/TrueWind.dll?DetailSheet?Area=NE&X=250&Y=4650&Z=30&Map=?258,239

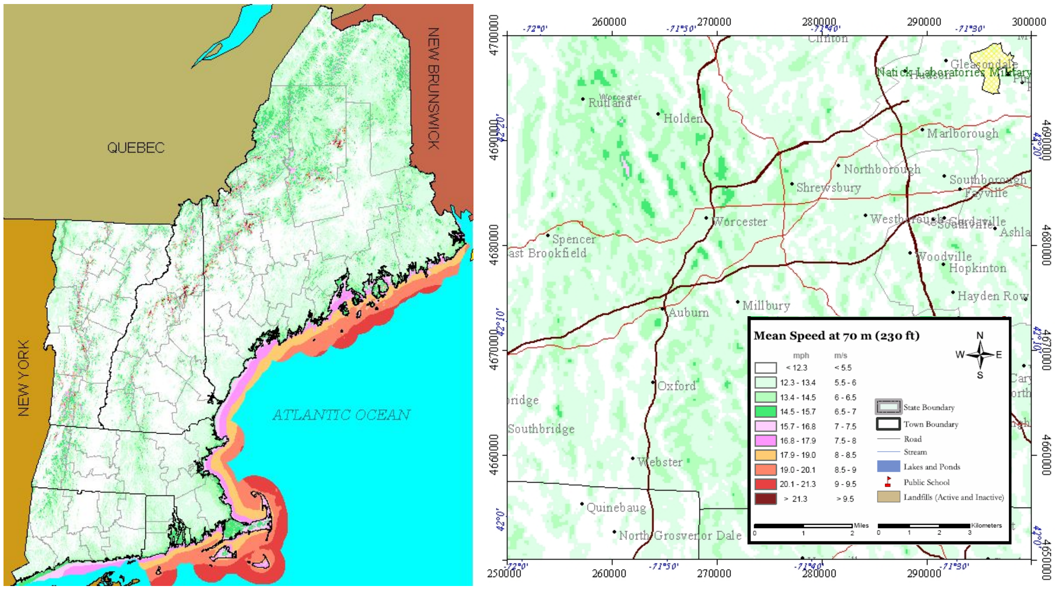


Figure 6: New England Wind Velocity and Worcester Area Wind Velocity

Another source of wind data maps is the Massachusetts Technology Collaborative (MTC). These maps are available for the state of Massachusetts and are specific to local communities.[80] The map for Worcester shows the average wind speed is between 12.3 and 15.7 mph, depending on the location in the county[81].

The last wind map resource we explored was the National Energy Resource Lab (NREL).[82] These maps are general and easy to use. This resource summarizes wind regimes, instead of focusing solely on Massachusetts or New England. According to the wind map shown below (Figure 7), Worcester is in a class 3 wind region.[83] An accompanying table translates this class into an average wind speed of 11.5 mph and 12.5 mph at a distance of 10 meters above the ground and 14.3 mph to 15.7 mph at a distance of 50 meters above the ground.[84]

[80] MTC Community Wind Maps, http://www.masstech.org/RenewableEnergy/Community_Wind/atlas.htm
[81] MTC Worcester Wind Map, http://www.masstech.org/RenewableEnergy/Community_Wind/maps/Wind%20Resources_WORCESTER.pdf
[82] NREL maps, http://rredc.nrel.gov/wind/pubs/atlas/maps.html#3-21
[83] Wind Energy Resource Atlas; http://rredc.nrel.gov/wind/pubs/atlas/maps/chap3/3-21m.html
[84] Wind Energy Resource Atlas; http://rredc.nrel.gov/wind/pubs/atlas/tables/1-1T.html

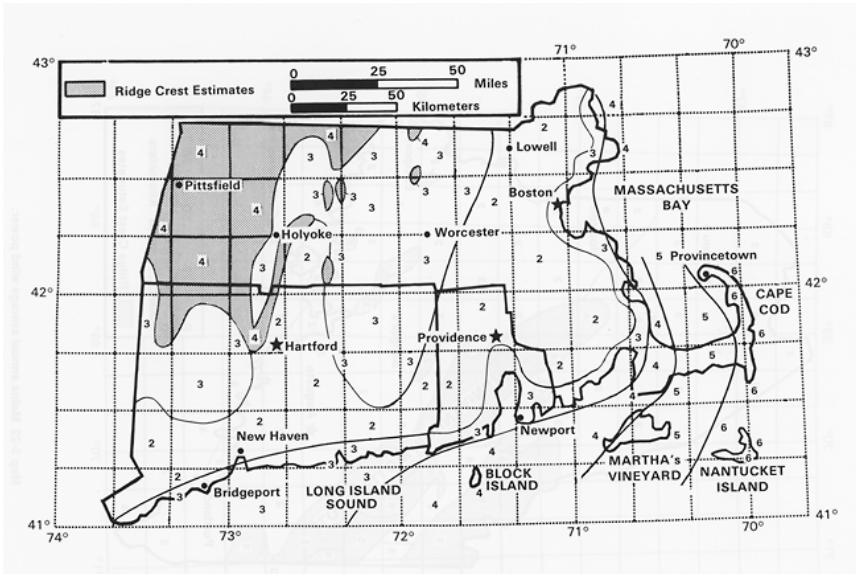


Figure 7: Wind regions of Massachusetts, Connecticut, and Rhode Island.

Considering the nature of this project, which is as educationally oriented as it is practical, we will use the range of wind speed taken from the NREL wind map. The turbine to be installed at the site in question will be approximately 10 meters above the ground, but the elevation of the property makes the wind speed there analogous to a point 30 meters above the ground. Upon our visits to the site, we noticed high relative wind velocities as compared to the surrounding area. Additionally, the owner reported that the wind speed was consistently high for the entire year. These factors, along with the lack of obstructions near the site led us to assume an average wind speed at the higher end of the wind map scales. We are confident that a wind speed estimate of 15 mph is a suitable extrapolation from the data available. We will continue our analysis with this estimate.

It is important to note that any wind project completed should include actual wind data. Without it, it is necessary to rely on generalizations of wind behavior, which are not terribly accurate. By relying on wind regimes, a rigorous site analysis is difficult to accomplish. This is especially important to consider when the project represents a large amount of money and time. Installing a wind turbine only to find out that there is inadequate wind is an avoidable mistake. We justify the above generalization within the scope of the project, because the focus of this case study is to establish a wind turbine for the sake of renewable energy.

The consistency and turbulence of the wind are two other important factors, especially in an urban setting. The consistency refers to the constancy of the wind speed. The degree of variance in its direction and speed can give insight into the wear that the turbine will experience. Unfortunately, the wind data that could give us a very good scientific insight into this would take an unrealistically long time to collect for this project. Considering the relatively small scope of the project we assessed these dimensions by analysis of the site's surroundings.

There are several facts that lead us to believe the consistency and turbulence of the wind will be favorable at this location:

- The site is located on top of a small hill, elevating it above abutters
- There are no large buildings in the vicinity that are likely to affect the wind direction or speed, a problem in many urban settings
- Anecdotally high wind speeds

Overall, considering the clear, open location of the site, the wind should be relatively consistent and non-turbulent; suitable for wind power production. If the developer of this site wishes to continue this project to the next level of development, it is the recommendation of this group that rigorous wind data collection be performed. To facilitate this effort, it is best to consult with the RERL and take part in the anemometer loan program discussed above.

Technical Considerations

Grid Integration

Developers involved in large projects should carefully consider grid integration, especially in a rural area. This site, being residential in both size and location, already has a tie into the grid. The amount of power being handled is small, requiring little special wiring and none that might affect the overall suitability. The existing wiring in the building is relatively new so it should be able to handle the load placed on it by a small turbine. The wiring should still be examined to ensure that it passes the National Electric Code (NEC).[85] As long as the installation is carried out carefully, the turbine should integrate into the house's electrical system seamlessly.

To perform this electrical installation the owner is required to contact Mass Electric to interconnect to the grid. Mass Electric will have 45 days to complete an onsite analysis and provide an estimate. The distributor then has 90 days to complete the interconnection. All interconnection costs are charged to the owner of the generating facility.

Turbine Type

The two general turbine types are: vertical axis turbines (Giromill, Savonius, and Darrieus) and horizontal axis turbines (upwind and downwind, with many suppliers). We were asked to specifically consider a vertical axis turbine by the owner. These turbines are much less efficient and not as common, and because of this, any vertical axis wind turbine (VAWT) is more expensive than its horizontal axis wind turbine (HAWT) counterpart. In addition, numerous searches for VAWTs ended with no results.[86] There are no suppliers that advertise this type of turbine for sale. For a HAWT, upwind models are common, with few downwind models available for retail.[87]

This project is best suited for an upwind, horizontal axis wind turbine. This is due to the availability and efficiency of this type of turbine. While the other types were considered, they were either unfit for our site or there was too little information to perform an accurate analysis.

Mounting Equipment

The last issue that needs to be addressed is that of mounting the turbine. In this case, it will be attached to the roof and will need a roof mounting kit and heavy-duty cables to secure the structure. If the turbine were to be based off of the ground, it would require a tower, most likely a monopole

[85] Renewable Energy & Distributed Generation Guidebook, Pg. 76
[86] Alternative Energy Institute, http://www.wtamu.edu/research/aei/p2brochers.htm
[87] Further explanation can be found in our accompanying report

that elevates the turbine above surrounding buildings or causes of turbulence. Larger, industrial, turbines often are placed on towers as high as 100 m (about 300 ft.). This is not necessary for this case study.

Equipment must be purchased so that the turbine may be interconnected to the local grid by the distributor. This equipment includes an inverter, allowing the common DC output of the turbine to be converted to AC current, and a breaker, which allows the flow of electricity from the turbine to be shut off in the case of an emergency. Additionally, an electrical meter must be purchased so that the distributor can monitor the amount of electricity being produced by the turbine and award appropriate compensations (i.e., Renewable Energy Credits, RECs).

Regulations

Many of the regulations presented in this section do not apply to a project as small as this, yet it is important to analyze all of the possibilities. Larger projects should be as rigorous as possible with the regulations that might apply to their project.

Federal

The federal regulations that could possibly apply to this project are discussed below (Appendix B). It is prudent to address each of these concerns, even if they appear to be obviously, for the benefit of future wind energy projects in the Worcester area.

The Migratory Bird Treaty protects the migration paths of birds. The best course of action to take in addressing this regulation is to consult a local source of wildlife knowledge concerning the migration of birds in the area of the site in question. Related to this is the Habitat Conservation Plan & Incidental Take Permit that applies to projects that could infringe on the habitat of an endangered species. Considering the urban setting of the site, this regulation is probably not necessary, but it would still be prudent to contact a local wildlife specialist.

In an attempt to gather information for our case study, we contacted individuals concerning local species. We began at the Ecotarium with a member of the local Audubon Society. He then directed us to contact the Mass Audubon Regional Ecologist, who did not reply to our inquiries. We were also directed to the Wachusett Meadow and the Broad Meadow Brook. Out of these inquiries, we received one recommendation to contact a local bird expert who worked at Broad Meadow Brook Wildlife Sanctuary and was a member of the Mass Audubon Worcester sanctuary. The response from that expert expressed concern for the wellbeing of some bird species, particularly those with flyways through the city of Worcester. He voiced particular concerns for migrating water foul, common nighthawks and peregrine falcons.

Concerns such as these are often encountered in wind turbine development. Local environmental issues are not to be taken lightly, as they are one of the more common forms of opposition encountered by wind power developers. A tactful approach to concerned citizens and professionals is necessary to encourage peaceful development to try to emphasize the fact that developers and environmentalists are not enemies, but allies in the renewable energy crusade. It is in the best interest of a potential wind energy project to collaborate with avian and other local experts to both better understand the subjects they specialize in and to respect the local populations' concerns. Many times, it is possible to compromise between the projected harm to local wildlife and the benefit of wind power over traditional coal power production.

In the specific case of our project, the turbine is to be mounted on the roof of the building so it will probably not rise high enough to affect migration paths. However, it is the recommendation of this group that if this project develops further, meetings should be held to allow for the expression of opinions from concerned citizens. Larger projects should perform an impact study on local species, taking into consideration the specific parameters of the project.

The two final federal regulations to be addressed concern waste water and the FAA. In large scale projects where considerable waste water will be discharged during some point in the construction process, a Storm Water Notice of Intent must be completed. In the case of this project the scope does not lead us to believe that such a notice will be necessary. For larger projects the company responsible for installation should be consulted as to whether or not this should be a concern. The final federal regulation is very important for tall turbines, especially in open areas. If the turbine is more than 200 feet above the ground the FAA must be notified and the structure registered. In the case of this project, the small residential sized turbine will be well under 200 feet tall.

State

State laws address local concerns like the environment and land restrictions (Appendix B). Because of the small scope of this project and its urban setting, neither the Massachusetts Environmental Policy Act (MEPA) nor the Environmental Notification Form will apply. Usually projects that could impact the environment in a noticeable way would fall under MEPA's jurisdiction. Projects that would alter more than 25 acres of land would need to fill out an Environmental Notification Form. Both of these apply to larger projects.

The Noise Control Policy regulates the amount of sound that can be produced by a power production facility. The DEP website associated with this policy specifically outlines the criteria for violation. The maximum increase in decibel level must be less than 10 dB above the ambient noise level. Considering the urban setting and small size of the proposed turbines, this policy will likely have no effect. To be sure of this, noise level estimates from the various proposed turbines can be found from the manufacturers. Once the turbine is installed further study can be performed if any uncertainty exists as to whether this regulation has been met. To decrease the noise created, a turbine can be modified via greasing or noise dampening if necessary.

Some miscellaneous state regulations include height restriction and general access. State height restrictions are exactly the same as federal height restrictions. The turbine will be no where near 200 feet high so this restriction does not apply. General Access Permits are required if construction were forecasted to alter a state road in any way. Since there is already ample access to the site, alteration will not be necessary, thus General Access Permits are not applicable.

While an interconnection impact study is necessary for large projects, the scope of this project suggests it will not be necessary. This project is in accordance with net metering parameters and will most likely follow with those requirements. Even if the turbine were to be connected directly to the electrical grid, the power generation is small enough that Mass Electric, the local electricity distributor, will install the necessary interconnection components.

Local

There is no local due process for the regulation of a wind turbine in Worcester. We can, however, look at ordinances that could possibly apply to the project (Appendix B). Wetland Protection can be applicable in certain turbine projects, but does not come into play here. Inspection is important regardless of the turbine size and setting. While there is no precedence for such an inspection, the Code Enforcement Officer will be consulted. Further investigation will need to be done before this project can be undertaken.

Worcester Planning Process

Currently there are no accommodations made in the Worcester permitting process for wind turbine construction. We have attempted to include the steps in our initial report that a potential developer would need to take to get the needed approval. The nonexistence of this due process may deter developers from wind projects in the Worcester area. They might assume that the first project will take the most effort and money to get through, to establish a permitting process.

Presently the personal wireless construction guidelines are the closest thing to a turbine permitting process that the City of Worcester has. A possible solution is to modify these guidelines to apply more directly to a wind turbine and propose it to the city administration as a possible solution to the problem. It is important to be as specific as possible when creating regulations, such as specifying the height limits of turbines. Additionally, it would be beneficial to establish zoning regulations for small, individual turbines independently from large, industrial turbines due to the large variance of suitability criteria. By establishing a very general model for small wind turbines, permitting larger wind turbines could follow a similar process and be incorporated into the Worcester planning process in the future.

Economics and Financing

To determine the practicality of building a turbine at a specific site, it is important to take into account the cost of the turbines themselves, as well as other expenses that will be incurred during development. Additionally, anything that might mitigate the cost will be evaluated.

This case study is concerned with the development of a single turbine on the roof of a small house. An economic analysis needs to be completed to determine the profitability of any turbine considered. Many federal, state, and local programs exist to lower the large initial capital costs of a wind turbine project. By taking advantage of renewable energy programs, the cost of establishing a wind turbine is almost competitive with other power options. To accurately complete a return on investment (ROI) analysis, all of the economic opportunities need to be taken into account. When wind energy is being produced and used onsite, then energy does not need to be distributed via transmission lines to the house meaning the resident does not have to pay the distribution costs for their electricity. The savings from this act as an additional incentive to implement wind energy. In this section, we study the costs associated with developing a wind turbine; the federal, state, and local benefits available for a renewable energy project; and the means for predicting the income production of a turbine.

Costs

The major cost associated with a wind turbine project is the initial capital cost of the turbine. Generally, the price of a turbine increases with its size and power capacity. Being mounted on the roof necessitates that the turbine be light weight and introduces the least interference for the residents as possible; this results in a smaller model being chosen, which also reduces cost. If the turbine were to be mounted upon a tower, the costs would increase substantially. Along with this scenario, guide wires and further mounting devices would require a larger initial capital expenditure. This option would need to be investigated further to determine its feasibility.

The other large cost to consider is that associated with connecting the wind turbine to the electric grid. This price depends on the scope of the project, and for specific details it is necessary to contact your local electricity distributor (Mass Electric in this case). For larger turbines, greater that 1MW, it may be necessary to interconnect to the transmission lines of the regional grid, for which you will need to contact ISO-New England for an estimate. The procedure for contacting these entities is explained in this report, in Chapter 1 under the heading: technical considerations.

Other costs to consider over the period of development are: installation, legal and development costs, insurance, bank fees, and interest. These costs are usually small compared to the capital cost of a turbine, but by implementing a small turbine, these factors are maximized in a cost analysis. Many times, it will be necessary to contact the manufacturer of the turbine to establish an estimate for these costs. Those that relate to financing the turbine will depend on the bank and repayment plan that is chosen. Insurance is not required for turbines rated less than 10 kW, but it is recommended to protect against unforeseen incidents.[88]

Federal Benefits

The federal government offers grants, tax incentives, and loans to make wind energy development possible. However, because our study is focusing on a residential turbine, many of the opportunities are not applicable (i.e. the National Industrial Competitiveness through Energy, Environment, and Economics (NICE3) grant is available only to industry wind development). Additionally, grants from the U.S. Environmental Protection Agency are unlikely (although not impossible) because financing is not the halting issue for this project. Additionally, there is already support for this project, such as from the Renewable Energy Council, so there is no reason for a grant to be awarded.

The same situation exists with tax incentives and loans. The Renewable Energy Production Incentive (REPI), which contributed 1.5 cents for every kWh generated, was not renewed and therefore cannot be taken advantage of. However, there is potential for this incentive to be renewed and it should be looked into if a renewable energy project is undertaken. The Modified Accelerated Cost Recovery System (MACRS) is also unavailable for this project as this site is not a business. As for loans, the U.S. Small Business Association (SBA) is unlikely to lend its service because of the scope of this project. This organization is involved in projects of bigger proportions.

The only applicable federal benefit is the Renewable Energy Production Tax Credit (PTC). This tax incentive allows a credit of 1.5 cents per kWh generated by the turbine to be credited for the first ten years of operation. This is similar to the REPI, but it is a separate incentive. The financial benefit of this incentive can be determined by multiplying $0.015 by the kWh produced annually.

State Benefits

The state also has renewable energy benefits in the form of grants, tax incentives, and regulations. The Massachusetts Technology Collaborative offers grants through the Massachusetts Renewable

---

[88] Tariff to Accompany Proposed Uniform Standards for Interconnecting Distributed Generation in Massachusetts, http://www.mass.gov/dte/electric/02-38/515tariffr.pdf

Energy Trust Fund. The largest grant opportunity, the MTC's Commercial, Industrial, & Institutional Initiative (CI3), is only available to industry-scale projects.

The state's tax incentives are more applicable to individual projects as compared to the federal tax incentives that are primarily directed towards businesses. Interested persons can take advantage of the State Individual Income Tax Credit equal to 15% of the net wind power expenditure or $1000, whichever is less. The credit can be carried over to the next tax year if it is not all used. Additionally, a State Sales Tax Exemption is available which allows the sales tax to be withheld when buying equipment directly related to the installation of wind energy into one's personal residence. The only state incentive that cannot be used is the Corporate Income Tax Deduction, because this site is, quite obviously, not a business, and this plays the same role as the Individual Income Tax Credit for the business sector.

In addition to financial benefits, Massachusetts promotes renewable energy by requiring local electricity distributors to include a certain percentage of their electricity from renewable energy sources. Making use of the Generation Performance Standards (GPS), Renewable Energy Portfolio Standard (RPS), and disclosure policies, wind energy can benefit from the available Renewable Energy Credits (RECs). The credits represent one MWh of electricity produced by a renewable energy source. If a renewable generating source produces less than 1 MWh of electricity, then smaller amounts of credits can be sold to the local distributor, who will auction off the certificates to larger prospective buyers. The credits are then sold, independently of the electricity, to distributors throughout the state. The credits should be valued at close to $0.06 per kWh generated.

City of Worcester Benefits

Worcester does not have many established financial benefits for renewable energy resources. However, the Local Property Tax Exemption allows a residence or business to claim exemption for up to 20 years for the value that the turbine adds to the property.[89] Further incentives may exist in the future as renewable sources become feasible in urban settings, but for now, this tax exemption is all that Worcester has to offer.

Income Prediction

The state provides financial opportunities to support a wind turbine. The income tax credit as well as the sales tax exemption allows the benefits of wind power to be recognized. The regulations established in Massachusetts allow wind energy to be competitive with other energy sources, largely

[89] Mass. General Laws Chapter 59, Section 5, Clause 45

by offering the Renewable Energy Credits that can be sold independently of the electricity to offset the larger costs of wind turbines. However, it may be necessary to sell higher volumes of these credits than anticipated for this project to be applicable for this reward.[90] In addition to all of this, the MTC can provide helpful information concerning the project, even while they may not be able to offer grants. The Renewable Energy Research Lab (RERL) can also be contacted with questions or concerns. Additionally, the contributions of the federal Production Tax Credit of 1.5 cents/kWh and the local property tax incentive

In order to estimate the profitability of the turbine, it is necessary to take into account all of the financial factors. To calculate the amount of electricity produced, it is necessary to know the average wind speed at the site. As stated earlier in this paper, we have based our assumptions on 15 mph wind due to reasons stated in the section: physical characteristics. The power production can be found using data from the manufacturer of the wind turbine model chosen. To find out how much one will save by investing in the turbine, one can use the following equations:

$$TurbineCost + InstallationEquip + ElectricalIntegrationEquip = CapitalCosts \quad (1)$$

$$CapitalCosts * 0.15 = IncomeTaxCredit \quad (2)$$

$$\frac{kWh}{year} * Electrical\,\mathrm{Pr}\,oductionAndTransmissionCosts = MoneySaved \quad (3)$$

$$\frac{kWh}{year} * 0.015 = TaxExemption \quad (4)$$

Equation (1) explains how to roughly estimate the project's cost. Equation (2) is the state's individual income tax credit. This amount can be deducted up to $1000. Equation (3) will give the amount saved by net metering the electricity produced as well as not utilizing the distribution networks of the electrical grid. Equation (4) is how much money the government will credit the investor for producing renewable energy; this is the compensation of the PTC. Renewable Energy Credits (RECs) may be applicable to reduce the cost of a project, but no public resale value has been established to the best of our knowledge.

---

[90] green-e.org, http://www.green-e.org/pdf/trc_standard.pdf

Societal Concerns

It is important to consider those that will have to live near the site being assessed. Especially in an urban setting, in some cases construction will disrupt daily life to such an extent that it may not be worth it. With respect to this small project, though it is indeed urban, it will not be as intrusive as the implementation of a larger turbine.

Noise

The noise from turbines rarely turns out to be an issue once construction is complete, though it is a common concern during the planning process. Unless the proposed project is a very large wind farm the noise is not usually noticeable. Considering the urban setting, high level of ambient noise, and relative silence of the smaller turbines we are considering, noise will probably not be a problem.

Aesthetics

The flicker effect occurs when the sun shines through the turbine making a flicking shadow appear on the ground. Though we have little control over the shadow (since the location and the suns path are both fixed variables) the size of this residential turbine should minimize flicker to an almost nonexistent level. A variable we do have control over is the height of the tower, by taking the aesthetics into consideration during the selection process we should be able to minimize negative reactions.

Ownership

When dealing with a private owner, one manages to skip the processes that would be required if one were to propose a municipal project. No town votes or committee discussions are necessary. As long as the private investor has sufficient capital to fund the project (generally the biggest problem with private projects) then ownership will not be an issue.

Environmental Concerns

The local Audubon Society will need to be contacted to make sure that there are no migratory paths across the area of the intended installation. When putting the turbine in a city, and then on a building, many of the possible concerns will no longer apply, such as wetlands, wildlife, and endangered species protection. Local experts vary, but we have established the appropriate persons to contact in the regulations section of this chapter.

Transportation Concerns

It will be necessary to ensure that necessary transportation will be possible to the site. Small one way streets may be bothersome, but it is unlikely that this would cause any great problem, especially considering the size of turbine being erected at the site. If is it necessary, however, the city should be contacted is streets must be blocked for an extended amount of time. This may occur if a crane is necessary for mounting the turbine on the roof. The extent of this will be more apparent in later stages of development.

Site Suitability Conclusions

Overall, the site seems to be very suitable for a small, residential sized turbine. The site itself appears to have a constant, unobstructed wind flow which is rare in an urban setting. However, the advantage to urban construction is that interconnection to the grid is not an issue. As far as regulations go, the size and location disqualify the project from many federal and state regulations. Locally, the lack of regulatory process could be a problem, though it is our hope that this report will help to remedy that situation. Economically, the interested investor is willing to invest in a turbine of this size, overcoming the biggest economic problem in the private sector. Though the size of this project causes many grants and incentives to not apply, it also makes the initial investment much smaller to begin with, alleviating the need for financial aid. Lastly, the aesthetic considerations, while very important with a large turbine, are not as much a cause for concern with this project.

The goal of this case study was first, to assess the site for the owner and, second, to provide an example as to how one might apply our suitability criteria. The steps presented in this section provide an example that should allow an organization to easily develop a suitability study anywhere in Worcester. While many attributes, especially turbine size and number, will make a project look very different than the one presented here, the same general process will still apply.

Turbine Analysis

Turbine Selection

To determine what turbines would be suitable, the first thing that needs to be done is to choose the desired power output. In our case the output had a maximum of 1000 kWh per month, because the building used no more than this amount on a monthly basis. It was not practical to install a larger turbine than necessary for this project, especially for a roof-mounted turbine. The next factor analyzed was the locality of the distributor. There are several distributors in Massachusetts and a couple in Worcester, Massachusetts. The largest of these is the Alternative Energy Store[91]. The Alternative Energy Store has many options for turbines ranging from 1 W to 5.1 kW. Using a wind speed of 15 mph as our design parameter, the turbines were selected to produce sufficient power. We also considered the efficiency of our wind turbine choices in low wind conditions.

Analysis

Six turbines were chosen for analysis; the Lakota, the Southwest Air-X, the Bergey XL.1, and the Whisper H40, H80, and H175.[92] The power output of each of these turbines was compared at 10-15 mph average wind speed. The other factors that were also compared include: cost, weight of the turbine, rotor diameter, aesthetics, and rooftop mount-ability. A suitability analysis was done for each turbine using these criteria and can be seen below in Table 3.

The categories are listed on the top line and the numerical value next to them represents the importance of that category. Each turbine then received a grade of 0-100 for each category by looking at the specification sheets. A 100 represents the best choice for that criterion while 0 would mean that specific turbine does not meet suitability standards for the criterion. The number next to each criterion is the weighted importance of the criterion. The total is found by adding up all the weighted sums. This analysis is weighted specifically for turbines that have the main factor of rooftop mount-ability and do not have cost or power production as key factors. Different projects would have the same categories but would have different weighting for each category, decided by the investors and developers. In our case if we did not care about the rooftop mount-ability the Whisper H175 and the Bergey would have become the top choices.

[91] The Alternative Energy Store - http://shop.altenergystore.com/
[92] The Alternative Energy Store - http://shop.altenergystore.com/

	Cost	10	Power Production	40	Aesthetics	60	Weight	20	Rooftop Mountability	80	Blade Size	40	TOTAL
Air-X-24v-Land 400w	100	1000	10	400	30	1800	100	2000	100	8000	100	4000	17200
Whisper H40	40	400	30	1200	50	3000	80	1600	80	6400	85	3400	16000
Lakota 900-48v	40	400	55	2200	80	4800	80	1600	35	2800	85	3400	15200
Bergey BWC XL.1	25	250	80	3200	80	4800	50	1000	20	1600	70	2800	13650
Whisper H80	25	250	60	2400	80	4800	50	1000	35	2800	50	2000	13250
Whisper 175	10	100	100	4000	10	600	10	200	10	800	25	1000	6700
The catergories listed above are the criteria important to a roof mounted turbine. The number next to each criterion is the scale used to weight the criteria on importance. Different projects will have different scale values.													

Table 3: Suitability Analysis

The Air-X 400W had the highest score while the Whisper H175 had the lowest. Then a rough cost of project was done by estimating the turbine cost to be 64% of the total project cost, a rough estimate that can be found from the graph on page 24 of this report. From this state grants and tax incentives were deducted to get an initial investment amount. Then calculating the amount saved by electricity generated by the turbine, a return on investment graph was produced as seen in Figure 8. Through the suitability analysis and the return on investment graph, we determined that the Whisper series of turbines would not be suitable for our case. The H175 and H80 had the lowest ratings in the suitability analysis, while the H40 had the poorest return on investment.

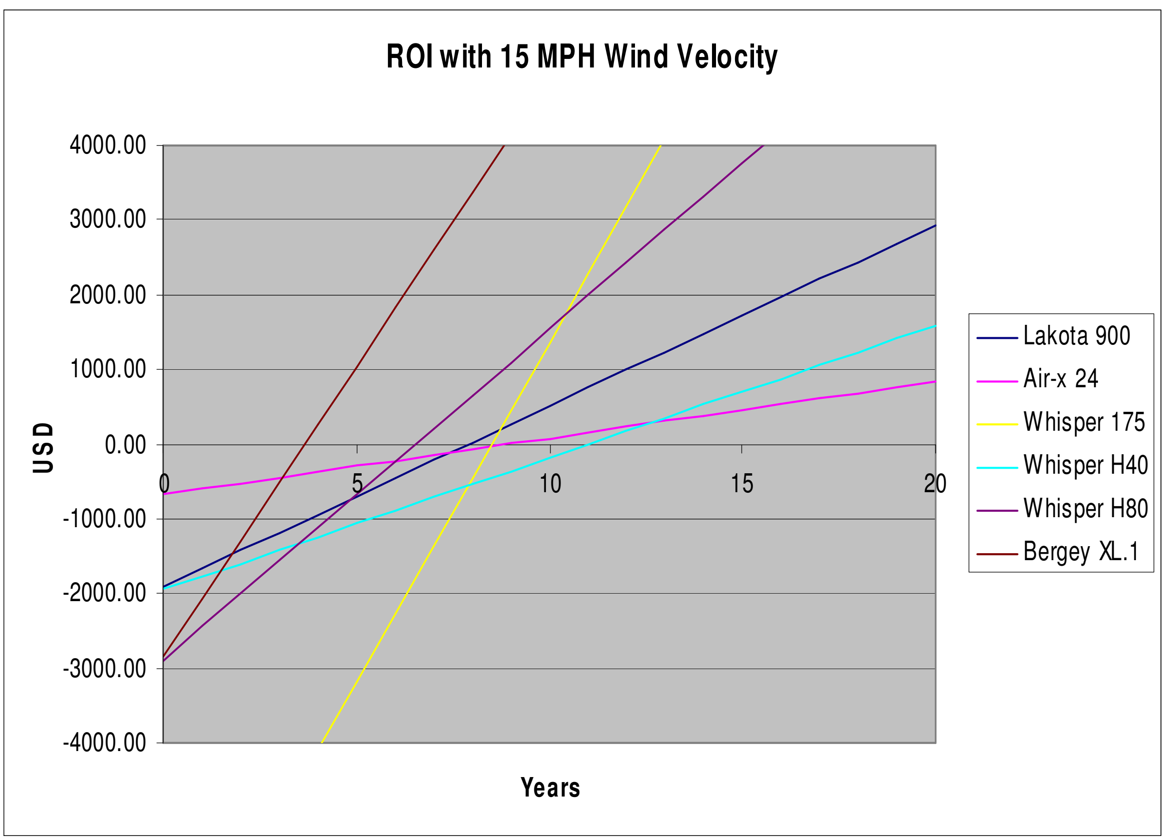


Figure 8: Initial Return on Investment

From the initial six turbines, three were chosen for further analysis: the Air-X, the Lakota 900, and the Bergey XL.1. These three had the best return on investment at 15 MPH of wind speed and cost benefit analysis. They also had the possibility to be mounted on a roof. The Air-X was chosen for further study as it is the smallest and is made for rooftop mounting. The Bergey XL.1 was selected as it had the best return on investment. The Lakota was chosen as it could possibly be rooftop mounted, produces enough power to generate part of the apartment, and creates a decent return. Figure 9 shows the power output for these three turbines at different wind speeds. One can see that the Bergey will produce the most power at any of the wind speeds that will occur at the proposed site. The Air-X produces the lowest amount of power, but as stated before that is not a big issue in our case. We then conferred with the alternative energy store, which is considering placing a wind turbine on their building and were informed that the Bergey XL.1 could not be installed on a rooftop without creating strong vibrations throughout the building. As per this information, we felt that the Bergey XL.1 was not a suitable wind turbine for our case study.

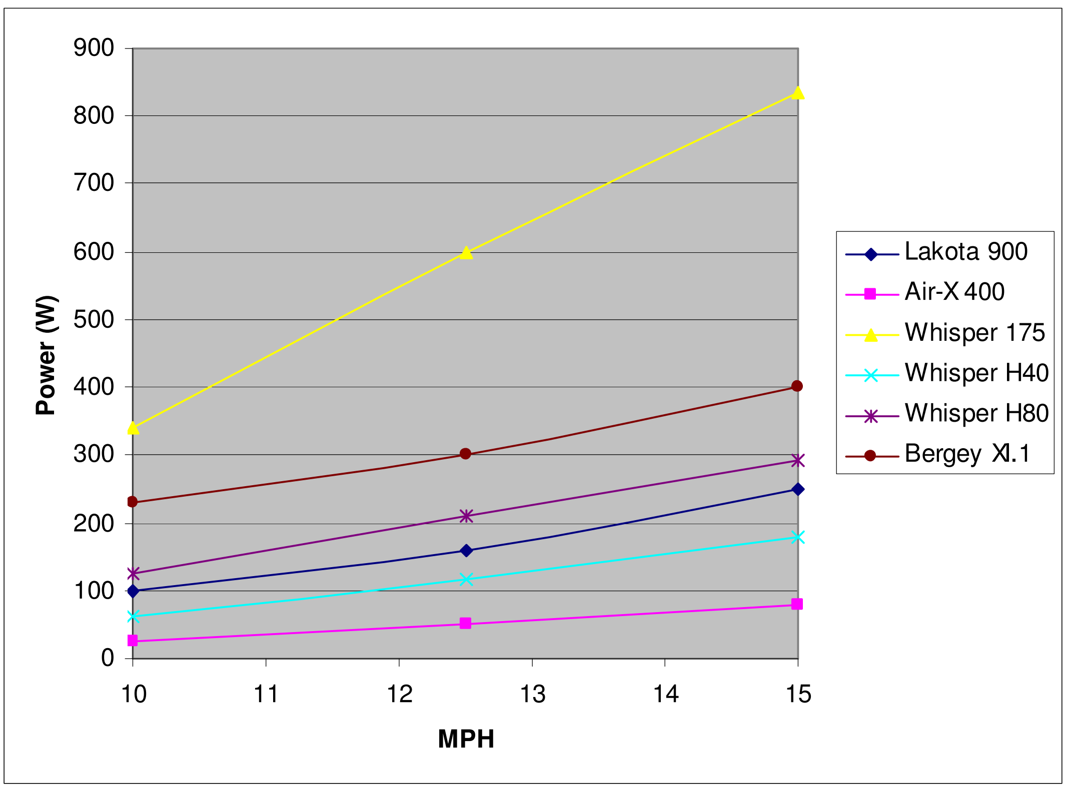


Figure 9: Power Output for Different Wind Speeds

Final Turbine Analysis

Introduction

The Air-X-24v was selected as the most viable option for mounting on the roof. Our analysis assumed an average wind speed of 15 mph at a height of 30 m and created an output of 80kWh/month. It had a relatively low total initial cost of $2000. The total cost estimates are based on economic data from various wind farms. Realistically the cost could vary but this estimate should be accurate enough for comparison purposes. This cost includes the purchase of the turbine and all necessary components as well as connection and installation costs. It was determined that the Air-X would take approximately 15 years to make a return on investment as shown below in Figure 10.

The Lakota 900 is considerably larger than the Air-X-24v and is designed to provide a substantial amount of residential power. Unfortunately, the turbine's size limits its ability to be roof mounted. The renewable energy store in Worcester, MA is planning on installing this model on top of their facility here in Worcester. The renewable energy store expressed interest in the project and spoke of the possibility of helping out with installation. It may also be possible to install this turbine on the roof, but most likely it will be necessary to install it on its own tower. Once again we assumed an average wind speed of 15 mph at a height of 30m. The Lakota's power output is up to 250 kWh/month. The total capital costs for this turbine is $4000. The Return on Investment for the Lakota 900 is about 8 years and can be seen below in Figure 11.

Air-X-24v

Wind Speed: 15mph
Height: 30m (from house, height of hill, and turbine mounting)
Power: 80kWh/month (estimated with 15mph of wind)

Costs[93]:

Description	Cost (USD)	Benefits (yearly)	Savings (USD)
Air-X-24v	$500	Produced power	$74.92
roof mount kit	$85	CRE (Credits)	$4.80
Cb50-403 50a Breaker For Air403 Or Air-X	$25		
Sw600-12 600w, 24v Pure Sine Wave	$300		
meter	$150		
heavy duty cables	$250		
Interconnection	$120		
Installation	$200		
Miscellaneous	$370		
Total Capital	$2,000		

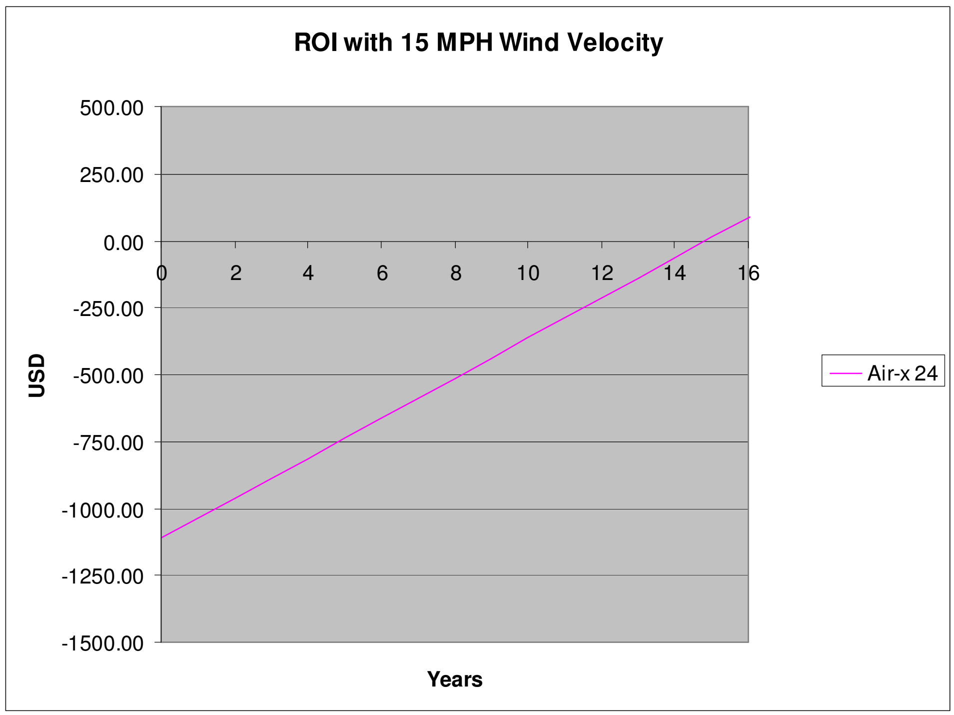


Figure 10: ROI for Air-X 24V

State and Local Financial Incentives
State Individual Income Tax Credit: 15% or $1000 (whichever is less)
State Sales Tax Exemption: Tax: free components
Local Property Tax Exemption

[93] The Alternative Energy Store - http://shop.altenergystore.com/

<u>Lakota 900</u>

Wind Speed: 15mph
Height: 30m (from house, height of hill, and turbine mounting)
Power: 250kWh/month (estimated with 15mph of wind)

Costs[94]:

Description	Cost (USD)	Benefits (yearly)	Savings (USD)
Lakota 900	$1,440	Produced power	$189.12
2, 1000W Dump Load Resistors	$92	CRE (Credits)	$15.00
Wind Machine Controller	$130		
Meter	$150		
heavy duty cables	$250		
Interconnection	$150		
Installation	$800		
Miscellaneous	$488		
Total Capital	$3,500		

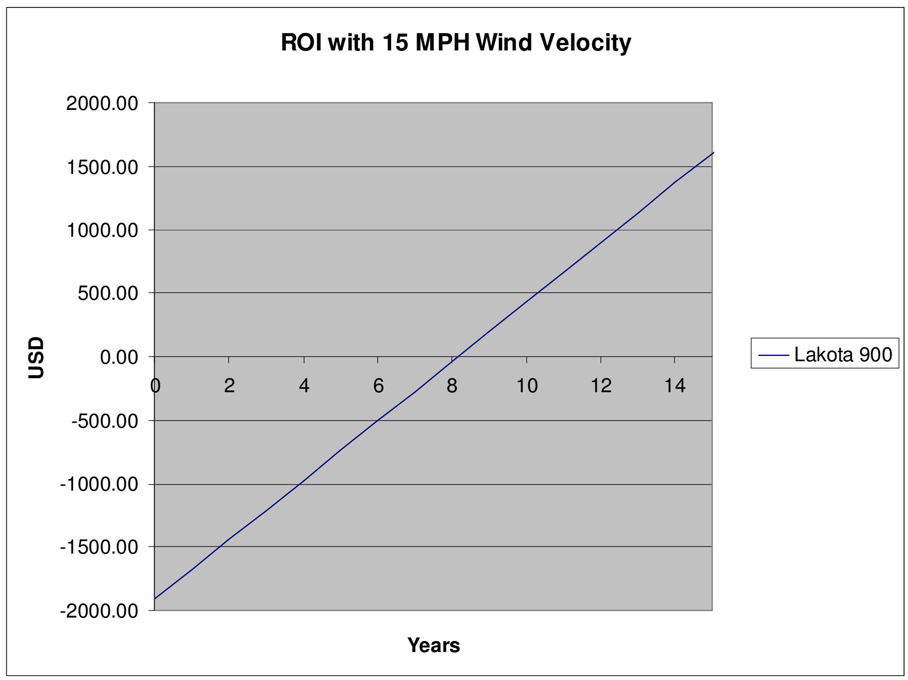


Figure 11: ROI for Lakota 900

<u>State and Local Financial Incentives</u>
State Individual Income Tax Credit: 15% or $1000 (whichever is less)
State Sales Tax Exemption: Tax: free components
Local Property Tax Exemption

[94] The Alternative Energy Store - http://shop.altenergystore.com/

Conclusion

We are recommending either the Air-x-24 or the Lakota 900 for use at this site. The Air-X is the only turbine found that will undoubtedly allow roof installation. It does not produce much power and therefore will not save much money. It will, however, make the desired statement of having a wind turbine in downtown Worcester. We would recommend a more complete structure analysis for the roof if the Lakota is determined to be the desired turbine. Rooftop mounting could be possible, but thorough tests would need to be done to make sure vibrations would not be a problem. Our findings conclude that it would be best to install it on an independent tower, which would require a revised suitability study. The Lakota will produce roughly three times the power of the Air-X. If there is more emphasis on producing power than we were led to believe, the Lakota would be the preferred choice.

APPENDIX A: ALTERNATE WIND POWER SITE DESCRIPTIONS

By comparing existing turbine sites one can gain a better understanding of the site selection process. Some site comparisons can apply directly to the Worcester area; turbines constructed in or near a small city can provide valuable insight into a process that many would find unfamiliar. Other sites have been designed to take advantage of geographic and political attributes unique to the region. Though these sites may not seem to serve as a useful comparison they still reinforce the analysis process and, by contrast, may provide a useful point of view.

Princeton, Massachusetts

Figure 12: Princeton Wind Farm

In Princeton, geography played a key role in constructing their wind farm. Since 1984, the town has had wind power. The proximity of Mt. Wachusett provided an ideal area to begin a search for a suitable site. Due to the elevation the average wind speed is considerably higher than the flatter areas of the state and the developers were hopeful about the capabilities of the updated wind farm. Unfortunately, by not anticipating the effect of large tree canopies, the site did not suit a wind farm as much as developers had anticipated.

To abide by regulations such as the Migratory Bird Treaty, the Audubon Society and other local organizations were contacted to check for possibly adverse, unforeseen effects on the environment. An important local concern was the large hawk population on Mt. Wachusett. The public feared that the turbines would cause damage to this ecologically vital species. By studying the hawks and local birds it was determined that turbines placed 170 feet above the ground would be too low to affect the hawk population and too high to harm smaller species. With the wildlife taken into consideration, economics were the next problem.

One of the programs that benefited the Princeton Municipal Light Department (PMLD) was the Renewable Energy Production Incentive (REPI), an annual cash rebate given to any municipality that generates renewable energy. The current rebate is fixed at $.017 per kWh.[95] The incentive helped projects that were installed from 1993 through 2003, and will help those projects until 2013.

[95] REPI, http://www.eere.energy.gov/wip/program/repi.html

Unfortunately the incentive was not renewed by congress. Unless there is new political action on the topic the incentive will not be able to provide assistance to any future Worcester projects.

The PMLD expanded on its current wind farm, erected in 1984. Using state land proved to be advantageous for several reasons including economics and aesthetics. The site can only be seen from close proximity, preventing complaints common elsewhere. The PMLD already owned transmission lines near the site from the previous wind farm that was being replaced. This eliminated the difficult and expensive process of tapping into or creating new transmission lines. Approximately 75% of people supported the wind farm expansion, proving that the consideration taken during planning was sufficient.[96] The Princeton wind farm example shows that when an old project exists, it is advantageous to use the existing infrastructure installed onsite. This saves two of the most important things: time and money.

Altamont Pass, California

Figure 13: Altamont Pass Wind Farm

Site suitability factors such as plentiful, non-turbulent wind; no obstructions; and reduced social impact of noise and aesthetics are found in the desert. Due to a long standing energy crisis restricting growth, the state offers incentives for the building of alternative energy sources. It is California's goal to provide 20% of its energy from renewable sources by 2010, which will decrease the pollution in its large cities.[97] To reach this goal, California offers a total of $231.2 million to finance the construction of windmills. The state also offers a 75% reimbursement for any small party who constructs a wind turbine of their own.[98] This is sanctioned under the Renewable Energy Program and California's Renewable Portfolio Standard. All these facts make California a great place for wind power.

Even with the best possible site care must still be taken in the site selection process. In the case of Altamont Pass California, a lack of research proved to be the site's downfall. Careful environmental analysis of the proposed location was not carried out. The perfect spot for wind power generation

---

[96] Public Support chart, http://www.endlessenergy.com/general_public_support.shtml
[97] Public Support chart, http://www.endlessenergy.com/general_public_support.shtml
[98] Ibid.

turned out to be a migratory path for eagles, raptors, and other endangered birds. The Altamont Pass wind farms are currently the most dangerous place to avian life in North America. This site now violates federal and state wildlife laws including the Bald Eagle and Golden Eagle Protection Act[99] and the Migratory Bird Treaty Act[100]. While this may not directly relate to siting criteria in Worcester it reinforces the importance of Federal Regulations and careful impact studies.

Cape Wind

Where California used a desert setting to find strong, constant wind patterns the ocean offered the same for the Cape Wind project. This wind farm is being erected several miles offshore. Due to the enormous engineering and orchestration required to construct in the open ocean, installation and maintenance costs will be more expensive than any onshore site. The Cape Wind project is a large scale facility that will bring many jobs and if completed, provide a huge amount of energy.

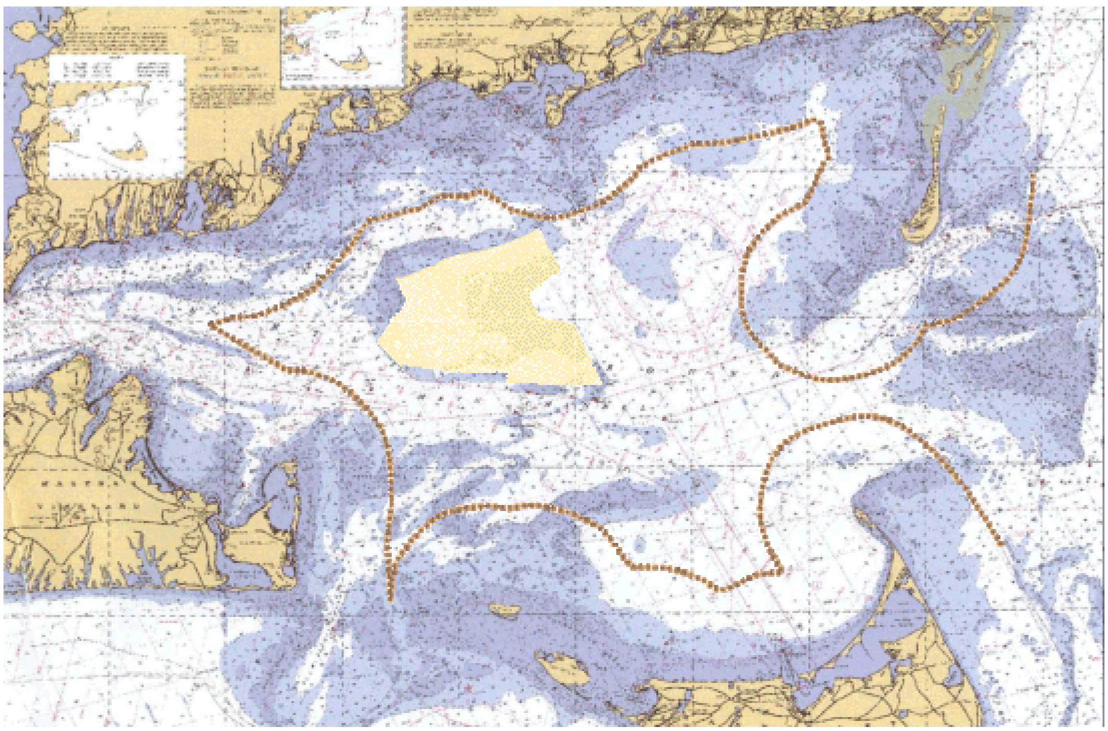


Figure 14: Cape Wind Project Siting and Visual Stimulus. The yellow area denotes proposed wind turbine sites while the brown dots represent points three miles from beaches.

One of the major problems with this project is the effects on the aesthetics of nearby waters and

[99] U.S. Code Collection, Title 16>Chapter 5A> Subchapter II> 668, http://assembler.law.cornell.edu/uscode/html/uscode16/usc_sec_16_00000668----000-.html
[100] U.S. Code Collection, Title 16> Chapter 7> Subchapter II, http://assembler.law.cornell.edu/uscode/html/uscode16/usc_sup_01_16_10_7_20_II.html

beaches. Due to the visible nature of the turbines they can be seen from local resort areas and vacation spots. This would decrease the tourism in the area and impact the local economy, which is supported largely by this industry. The site could also impact the local aquatic wildlife, possibly decreasing local fish populations, in turn damaging local fisheries, both commercial and recreational. To deal with the public outcry Cape Wind has funded research into the area in order to discover the effect of turbines on local wildlife.

In Worcester a site of this magnitude is not realistic. It would be difficult to find the land and funds necessary to undertake its development. Cape Wind serves as a good example of the effect the public can have on a wind power project. Environmentally sensitive areas should be considered as possible sites, but with caution and concern.

Top of Iowa Wind Farm

Figure 15: Top of Iowa Wind Farm

To find a suitable site for a wind turbine in Iowa, previous studies from Oklahoma were used. This is possible due to the geographic similarities that exist between the two states. They then used GIS to study the landscape and installed tall towers to collect data for 1-2 years. Once the data was collected, they sent their findings to potential investors and did a cost-benefit analysis to show landowners that they would get a full benefit for their investment. Finally they used state programs to gain prospective land owners permission to install turbines on their land.[101]

Legal issues, not financial issues, provide the most resistance to alternative energy. Most of Iowa's wind power production comes from large, multi-turbine wind farms. A program called the Alternate Energy Revolving Loan Program (AERLP) is responsible for the large number of turbines. This loan program provides 50% of a project's cost with a max loan of $250,000. There is no interest on this loan for 20 years.[102]

Like Massachusetts, some legal issues can hinder renewable energy resource development. Zoning permits, building codes, and permission for land use are all required by law. The Public Utility

[101] Top of Iowa Wind Farm Study, http://www.state.ia.us/dnr/energy/MAIN/PROGRAMS/WIND/documents/topofiaWindFarmCaseStudy.pdf

[102] AERLP, http://www.energy.iastate.edu/funding/aerlp-index.html

Regulatory Policies Act of 1978[103] allows owners of wind turbines to sell their surplus to power companies. A simple example of this act in use can be seen in Alliant Energy and their agreement to purchase the wind energy from Worth County under a 15 year agreement.[104] In Des Moines, many steps were undertaken to ensure that a wind turbine system will not damage the current power infrastructure. It's necessary to show that the proposed wind turbines will provide valuable, usable energy. Finding a company to agree to buy surplus wind energy will be harder in Massachusetts because there isn't already a longtime history of wind energy. While it may not be as familiar a practice this doesn't mean that education cannot get people used to the idea.

Also in Iowa, Des Moines is building a 310 MW wind farm. The public's support was gained by advertising that the world's largest wind farm was being constructed. When the public feels that they are making history, they are more agreeable to supporting a large turbine project. For any project undertaken in Worcester, it is necessary to instill the same type of pride in the community, convincing the public that they are making history when developing a turbine.

Cornwall, England

Figure 16: Wind turbines at Cornwall, England

The wind turbines in Cornwall England have large support from the local population and it is quickly becoming one of the largest wind energy producing areas of the world. Most of the turbines in Cornwall are large scale with the smallest rated at 400kW. The population feels that it is very important to turn to this new phase of energy. Due to England's large imports, cutting down the dependence on foreign energy saves the country millions of dollars over a period of several years. The only problem that has arisen is the location of some of these wind turbines. The area of Cornwall is a beautiful area which the residents feel obligated to protect. Instead of not allowing the wind turbines to be constructed, the residents asked that they be moved

---

103 Public Utility Regulatory Policies Act , http://www.ucsusa.org/clean_energy/renewable_energy/
104 Alliant Energy, http://www.alliantenergy.com/

to an off-shore location.[105] This would contrast the Worcester situation; there would be no option to move the turbines off-shore to gain the public's approval.

Another concern that needed to be addressed in Cornwall was interference in television signals and microwave communications.[106] For this reason, several proposed wind turbines were built with the consideration that relay stations would be needed, or the sites were discarded. An additional public concern is the possible decrease in the value of land in close proximity to a wind turbine. Broken blades during operation were another local concern; this has occurred twice, without harm.

Contrasted to many other sites, some of the population feels "cheated" when it comes to building wind turbines. They feel that the turbines do not produce the power that they claim, are not as environmentally helpful, and are not as reliable.[107] This could cause problems in the future for other possible constructions of wind turbines.

Hull, Massachusetts

Much like the turbines in Cornwall the wind turbines in Hull, Massachusetts have similar support in their community. The turbines in Hull dealt with the issue of the public by giving them direct control over the situation. This enabled the people to choose what they thought was the best possible course for the turbines. In doing so, the investors dealt with the turbine

Figure 17: Wind turbine at Hull, Massachusetts

[105] BBC NEWS, http://news.bbc.co.uk/1/hi/england/2678895.stm
[106] What's Wrong with Windfarms?, http://www.countryguardian.net/case.htm
[107] Wind Power: Future Energy Solutions

noise and visual impact at the same time by leaving it to the public to decide. This was also made easier by the fact that there had been a wind turbine in the area for the past 20 years which the new turbine was to replace. The site of Hull, Massachusetts has a history of having windmills as early as the 1820's.[108] This made it much easier for the project to be readily accepted by the public. These turbines are located at the tip of Boston harbor. This produces a unique situation in which the turbines are in a highly populated area. The turbines are eight miles away from the city hall, 100 feet from the local high school, and just five miles away from Logan Airport. All of these factors produce a confined area for the turbine's siting. The turbines in Hull are on the water giving them a site with high wind velocity.

The Hull wind project is part of the Hull Municipal Light Plant (HMLP); this enables it to avoid many complications. The HMLP is exempt from zoning requirements in Massachusetts and the land in which the turbine is situated is owned by the town. As the HMLP was the coordinator for the project, the need to secure a power purchase agreement was not necessary, and the turbine would be guaranteed a market for selling its energy.

Figure 18: Map of Hull

Like Hull, Worcester has a similarly dense population and city dynamic. However, Worcester is not located near the ocean and cannot benefit from its strong, steady winds. With no history of wind power in Worcester, developing a turbine project will meet more opposition than it did in Hull.

Searsburg, VT

In the small town of Searsburg, VT, eleven turbines create close to six megawatts of power, enough to power 2,000 homes. The site is on the side of a mountain overlooking a cemetery, half a mile from the nearest home. There was little opposition to this project. The general support for alternative energy, coupled with the graceful nature of the turbines led to a town proud of their support of renewable energy.

[108] What's Wrong with Windfarms?, http://www.countryguardian.net/case.htm

The site was constructed in 1997 costing $11 million, $4 million of which was covered by grants from the DOE and the Electric Power Research Institute. The site itself took 30 years to develop, chosen for the high, constant wind speeds. The "cut in" speed of these turbines is 10 mph, a wind speed that is present 95% of the time.[109]

Figure 19: Searsburg, Vermont Turbines

Because the wind farm is located in Vermont, the winter weather needed to be taken into account. These particular wind turbines have black fiberglass blades. In the winter the blades absorb the heat from the sun, melting any buildup of ice. This created the unusual hazard of falling, razor sharp sheets of ice. Another cold weather consideration was the turbine's hydraulic system which had to be fitted with heaters after they froze up in the cold. In addition to the cold, the turbines need to be able to withstand lightning strikes. As of May 12, 2002, two turbine blades had been struck. To address this issue, the site and the turbines needed to be made "lightning safe."

The turbines are owned by Green Mountain Power Corp., a public, for-profit regulated utility in Vermont. The electricity that is produced by these turbines if fed directly into the electrical grid that feeds all of New England. Because of this, the benefits of the wind energy are not felt directly by the inhabitants of the town.

In addition to providing profit, the turbines are a surprising source of tourism. This aspect was not expected, but grew to such an extent that a parking lot had to be made to support the crowds that came to visit the structures. Most people don't know what to expect of a wind turbine and are generally pleased with the result. One tourist, Jane Coogan, said, "I thought they were absolutely beautiful. I thought I was at the ballet, to some degree."[110] While this view does not reflect the views of every person, it does make the point that wind turbines can be engineered to fit with the landscape.

[109] Searsburg Wind Power, http://www.gmpvt.com/whoweare/searsburg.shtml
[110] Ibid

Tourism is an interesting siting criterion that we have not yet examined. While the local population may be against the visual impact a turbine might have on the surrounding area, it could attract tourists. Erecting the turbines in an accessible place and catering to the curious population would help to educate and spread the word on green power.

Comparison Analysis

Much can be gleaned from the analysis of other wind turbine sites. One must be aware of the shortcomings of these comparisons which stem from the transferability of each site. Some analyzed sites are sufficiently similar to the Worcester area that one can learn from them, their mistakes, and apply that knowledge to a Worcester project. This analysis produces accurate, on site data, which can be more valuable and useful than any speculation we might provide.

From the comparison of Princeton the basic criteria of siting a turbine are reinforced. The location of the turbines was on state land on the face of Mt. Wachusett. This solves both the acquisition of land and the clean, strong wind problems. The site also highlights the opposition that is almost always going to appear. Careful politics must be used to satisfy the publics concerns, avoiding many simple problems, such as the issue of migrating birds, and continue building the project on schedule.

The Altamont Pass project showed how neglecting careful research into the surrounding area can hinder the progress of a renewable energy project. Not only does this look unfavorable in the publics' eyes but it also makes any other future sites impossible without directly addressing the public and completely convincing them of the safety of the site. While the specific situation is unique to the Altamont Pass, the site comparison reinforces careful study of the site and how important the environment is, not only to the projects image but also to the public.

The Cape Wind project is an excellent example how the public can affect a projects outcome. The local population of Martha's Vineyard, Nantucket, and the Cape are reluctant to allow the construction of the turbines for fear of the destruction of the environment. This has given many people with any doubt in the project a forum, with substantial local support, to protest its construction. The lesson here is that the public plays a very large role in these projects. They must be addressed, respected, and negotiated with. If the project does not serve the people then it does not serve a large part of its purpose.

The sitting of the turbines of Iowa, Hull, Massachusetts, and Searsburg are examples of how important it is to secure the support of the local government, and residents. By providing the proper information and facts to the community the project proceeded smoothly. Going through the local government not only helps to gain the support of the public, but it also helps facilitate the resolution of the many legal issues that can arise during planning and construction. The city of Worcester will need to be very involved in a large scale wind turbine project. Such a project could serve as a great way to force the creation of or test legislation that would deal with renewable energy. Such a project would be an important learning experience for all involved and upon its successful completion could inspire and smooth the progress of future projects.

In Cornwall, England developers worked closely with the community tried to address everyone's concerns. The issue of aesthetics was solved by putting many of the turbines offshore. While this is not a reasonable solution in the Worcester area, it emphasizes the importance of public involvement in the process, where possible. Generally, the public has come to welcome the cleaner power provided by wind turbines but have issues with their sitting. The issues of aesthetics and wildlife are among the most important and should be addressed as publicly as possible regardless of where the site is being constructed.

Each of these comparisons highlights either a problem and solution or simply a fatal problem. These examples should help to eliminate future problems. Worcester's first renewable energy project will be an important step for the community as well as the city. Every possible precaution should be taken to make sure the process advances smoothly so that all involved learn and take away a positive attitude towards renewable energy and, specifically, wind turbines.

APPENDIX B: TABLES OF REGULATIONS

Table 4: Federal Regulations

Federal Regulation	Organization
Migratory Bird Treaty	Audubon Society, Natural History Museum
Habitat Conservation Plan & Incidental Take Permit	Local Fish and Wildlife Service
National Pollution Discharge Elimination System:	EPA
Storm Water Notice of Intent	
Notice of Proposed Construction or Alteration	Federal Aviation Association

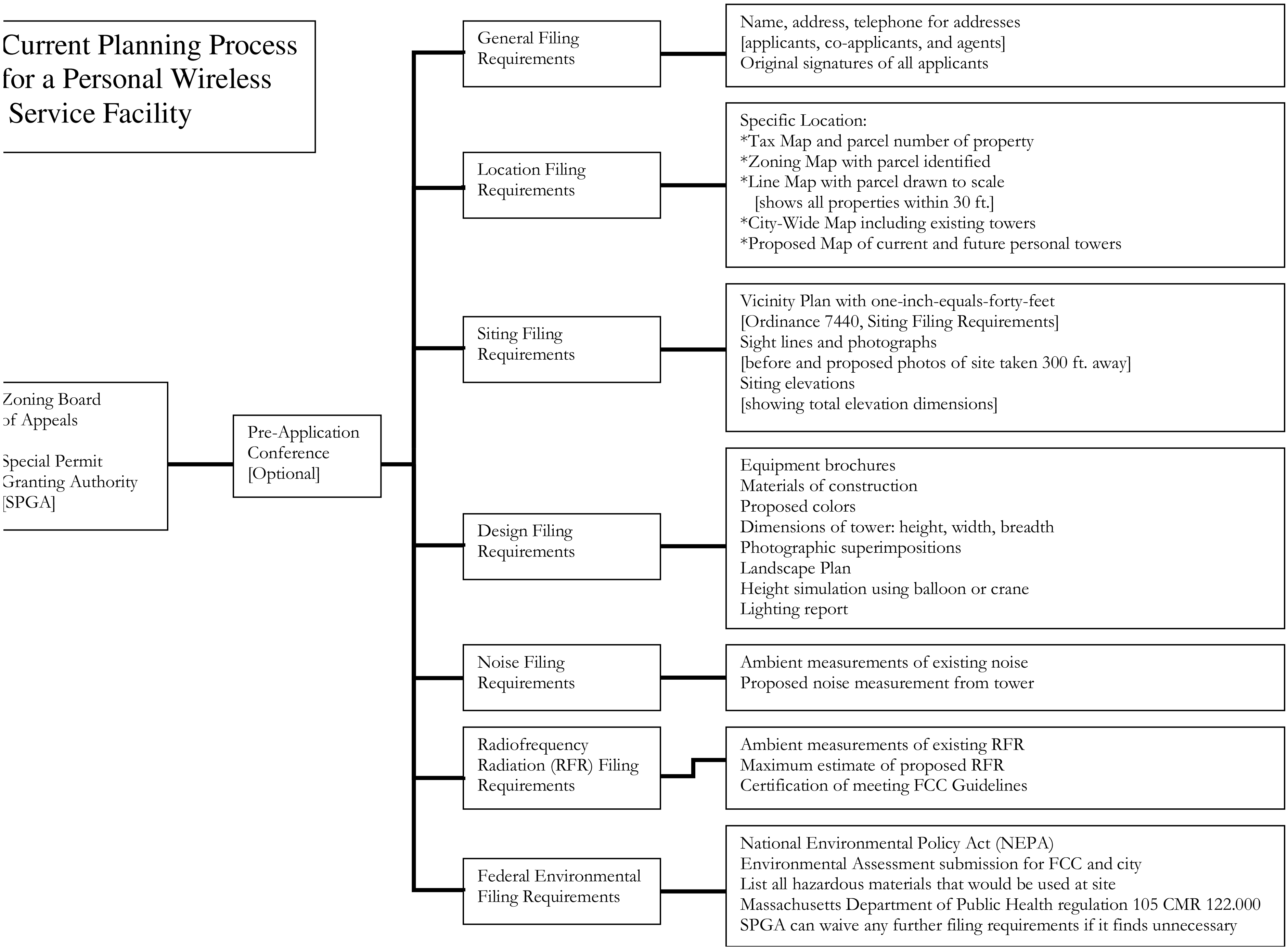
Table 5: State Regulations

State Regulation	Organization
Massachusetts Environmental Policy Act	Executive Office of Environmental Affairs
General Access Permits	Mass Highway
Environmental Notification Form	Executive Office of Environmental Affairs
Noise Control Policy	DEP Bureau of Waste Prevention Noise Policy
Height Restrictions	Massachusetts Aeronautics Commissions
ISO New England Interconnection System	NEPOOL
Impact Study & Facility Study	

Table 6: Local Regulations

Local Regulation	Organization
Wetland Protection Ordinance	Zoning Board of Appeals
Structure Inspected	Office of Code Enforcement

APPENDIX C: PERMITTING FLOWSHEET



APPENDIX D: AERODYNAMIC NOISE

Type or Indication	Mechanism	Main Characteristics and Importance
Low-Frequency Noise		
Steady thickness noise; steady loading noise	Rotation of blades or rotation of lifting surfaces	Frequency is related to blade passing frequency, not important at current rotational speeds
Unsteady loading noise	Passage of blades through tower velocity deficit or wakes	Frequency is related to blade passing frequency, small in cases of upwind turbines/possibly contributing in case of wind farms
Inflow Turbulence Noise	Interaction of blades with atmospheric turbulence	Contributing to broadband noise; not yet fully quantified
Airfoil self-noise		
Trailing-edge noise	Interaction of boundary layer turbulence with blade trailing edge	Broadband; main source of High-frequency noise
Tip Noise	Interaction of tip turbulence with blade tip surface	Broadband; not fully understood
Stall, separation noise	Interaction of turbulence with blade surface	Broadband
Laminar boundary layer noise	Non-linear boundary layer instabilities interacting with the blade surface	Tonal, can be avoided
Blunt trailing edge noise	Vortex shedding at blunt trailing edge	Tonal, can be avoided
Noise from flow over holes, slits, and intrusions	Unstable shear flows over holes and slits, vortex shedding from intrusions	Tonal, can be avoided

*Chart from "Wind Energy Explained" Pg. 487

APPENDIX E: TECHNOLOGICAL PRIMER

Wind turbines come in all shapes and sizes, but the basic design and components are very similar. The **blades** are the most visible part of the windmill. There are two types of blades that operate on two different principles; drag and lift. Drag blades actually make the wind push them out of the way. Drag turbines are generally used when slower blade speeds, but more torque is required. While this design does not lend itself to generating energy it was the main source of power for rural mills that might grind grain or drive some agricultural process. Blades that operate on lift operate like an airplane wing. A pressure difference on the two faces of the blade cause torque that in turn causes the blades to spin. These blades produce a much faster rotation but not as much torque. This makes them ideal for power generation.[111]

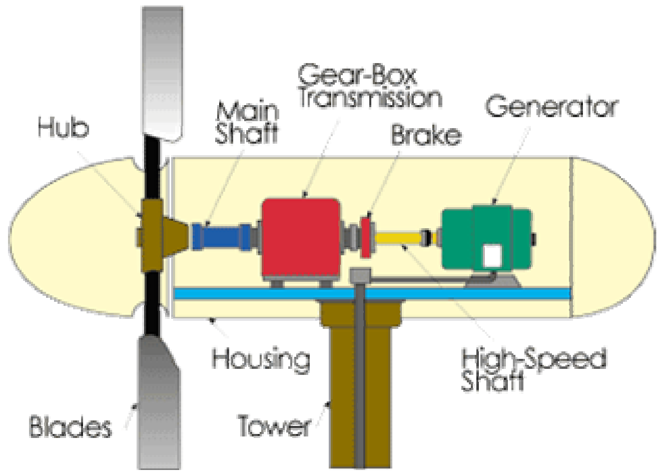


Figure 20: The main components of a wind turbine

The **generator** is the part of the windmill that makes electricity. All generators function on the principle of electromagnetic induction. A coil of wire is rotated through a magnetic field producing a flow of electrons, or electricity. The energy being converted into electricity is the rotational energy required to turn the coil, this is the function of the blades and the wind. Generators can produce different types of energy, one must be aware of the difference between AC and DC power when choosing a turbine. AC or alternating current is the power used in your house. It powers your refrigerator, television, lights, etc. Generators that produce AC power are generally designed to output a constant 120 volts at a constant frequency of 60 cycles, regardless of the varying wind speed and direction. Appliances and machinery can also use DC or direct current. This is the type of electricity your car or boat uses to start the engine. Turbines that produce DC power are usually used to charge batteries or run some type of machinery.

To generate either AC or DC power the coil needs to spin between 1,200 and 1,800 rpm (revolutions per minute), but the blades can only spin between 40 rpm and 400 rpm. To solve this problem most

[111] Wind Energy Manual, http://www.energy.iastate.edu/renewable/wind/wem/wem-07_systems.html

turbines are equipped with a **gear-box transmission**, like the transmission in your car. While this greatly increases the rotation of the coil and the electricity generation, it also increases the need for maintenance.[112]

The **tower** that a wind turbine is installed on must be high enough for the blades to clear the ground and high enough to catch the stronger, more constant wind. Generally the height of a tower is very dependant on the area in which it is installed, characteristics like the surrounding geography, wind speed, and wind quality can all affect the actual height.

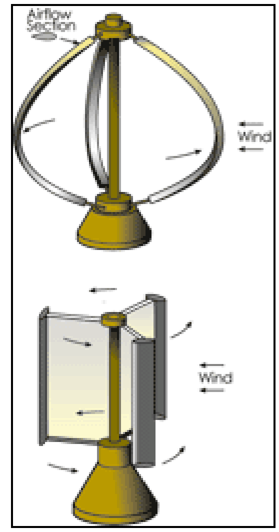


Figure 21: Vertical axis rotors

There are two basic types of turbines: horizontal axis and vertical axis. Horizontal axis is the design that many are familiar with. The blade rotation is parallel to the ground and wind flow. Some face into the wind while others face away from the wind, depending on the design.

Vertical turbines operate slightly differently. The vertical rotor, as seen in Figure 5, spins perpendicular to the wind instead of parallel to it. This design has been around far longer than the conventional one but because it cannot take advantage of the higher wind speeds it is not used as much anymore. The one advantage is that the turbine does not need to be oriented in relation to the wind direction. In areas that don't have a well defined prevailing wind this design may still be useful even though it isn't as efficient.

Turbines can be found in groups as well as single structures. For maximum power output an organization can put multiple turbines on a single piece of land; this is called a "wind farm." Limiting factors to the number of turbines a group could construct include: initial capital costs, land and market availability. Many industrial developers construct many turbines at once to produce the maximum amount of power for the minimum initial investment. This is especially popular in the Midwest where open land and strong, constant winds are common.

[112] Wind Energy Manual, http://www.energy.iastate.edu/renewable/wind/wem/wem-07_systems.html

APPENDIX F: INTEREST LETTER

wind@wpi.edu
Wind IQP Group
c/o Calixte Monast
100 Institute Rd.
WPI – Box 0129
Worcester, MA 01609

To Whom It May Concern:

We are a small group of juniors at Worcester Polytechnic Institute (WPI) doing a wind suitability study of the Worcester area. The goal of this project is to facilitate the development of wind farms and increase local understanding of renewable energy. During the first phase of this project we developed a comprehensive report on suitability criteria that can be used by potential wind developers.

Recently, we were approached with a unique opportunity to apply the criteria we have developed. A potential wind energy investor asked us to investigate a site and assess the possibility of installing wind power. While we have developed a very good informational resource, we are inexperienced in the actual process of construction and installation. We are also unfamiliar with the options that exist for a residential-sized wind turbine.

Technically, the site appears extremely suitable for this venture. Strong, consistent winds are well documented in the area. It is elevated above much of the surrounding geography on a hill in the middle of the City of Worcester. The power production required is moderate for a residential turbine and need not power the entire house. A rough estimate of power capacity required would be between 1 and 10 kW. Optimally the turbine would be roof mounted, which would limit the size considerably, though other options are possible.

Though the basic suitability criteria are met, the potential investor has more in mind than just energy production. He is interested in the educational value of this venture. His involvement in the local media will provide great exposure for wind energy. The site lends itself to this goal, being highly visible in an urban setting. We also hope to use this project as a tool to motivate the city to develop a permitting process supportive of wind turbines and farms. This, coupled with the report we are developing, will hopefully arouse local interest in wind energy.

Any information or insight into the possible options we should consider for this venture would be greatly appreciated. This would include, but is not limited to, popular residential wind turbine models, the construction process and the process of electrical integration. Thank you very much for your time.

Sincerely,
Calixte Monast
Wind IQP Group

APPENDIX G: USEFUL RESOURCES

This appendix is directed at providing interested individuals the information necessary to develop a wind energy project. Many of these reports contain information that is technical and is best made use of by visiting the publication, as opposed to this report having summarized it. A brief summary of the resources will be listed, along with information about how the source can be found for personal use. These resources, in conjunction with our report, should answer all questions concerning wind energy production.

"Wind Energy – The Facts." http://www.ewea.org/06projects_events/proj_WEfacts.htm
This document is a publication of the European Wind Energy Association (EWEA). It addresses the common questions, concerns, and opportunities of wind energy as they exist globally. Information is available on the current technology, costs, industry, environmental impacts, and market development. This is a resource to be consulted concerning the nature of wind energy.

Renewable Energy Resource Lab (RERL) Community Wind Fact-Sheet Series.
http://www.ceere.org/rerl/about_wind/
These set of documents address overall wind concerns inclusive to technology, economics, siting, assessments, permitting, and other useful areas of concern. They provide a helpful background to the wind energy domain.

"Small Wind Electric Systems: A Massachusetts Consumer's Guide."
http://www.mass.gov/doer/programs/renew/sm-wind.pdf
This document is a publication of the U.S. Department of Energy. It gives a general overview of the potential for wind energy in the state of Massachusetts as well as the topics that will need to be addressed when considering a project. It is useful during the initial phases of development for a project.

"Wind Power for Home & Business: Renewable Energy for the 1990s and Beyond." Gipe, Paul.
This resource provides the methodology for developing wind power on a small-scale. Explanations are given so that site analyses can be completed and questions can be answered. This book is easy to follow and provides up-to-date information on the growing field of wind energy.

"Wind Turbine Interactions with Birds and Bats: A Summary of Research Results and Remaining Questions." http://www.nationalwind.org/publications/avian/wildlife_factsheet.pdf

This document analyzes the impact of wind turbines on birds and bats: a major concern that needs to be addressed. This resource should be consulted if substantial complaints concerning avian impacts occur.

"Tariff to Accompany Proposed Uniform Standards for Interconnecting Distributed Generation in Massachusetts." http://www.mass.gov/dte/electric/02-38/515tariffr.pdf
This document is a publication of the Distributed Generation Interconnection Collaborative. It dictates the process a project must complete to interconnect to the local electrical grid. This resource should be consulted when questions arise concerning methods and procedures of interconnecting the turbine.

"Renewable Energy & Distributed Generation Guidebook: A Developer's Guide to Regulations, Policies and Programs that Affect Renewable Energy and Distributed Generation Facilities in Massachusetts." http://www.mass.gov/doer/pub_info/guidebook.pdf
This document is a publication of the Massachusetts Division of Energy Resources (DOER). It provides information specific to the state concerning electrical integration, laws and regulations, siting and permitting processes, financial incentives, and additional helpful information for all renewable energy projects. It is a comprehensive guidebook that should be referenced if any questions arise.

National Wind Coordinating Committee Publications.
http://www.nationalwind.org/publications/default.htm#Issue
These documents are a compilation of the NWCC that address concerns most encountered during wind energy development. It is a good overall resource that offers information for all facets of the industry.

APPENDIX H: BIBLIOGRAPHY

General

BBC News (2003, January 21). Wind Farm Plans Blown Out. Retrieved September 23, 2004, from the World Wide Web: http://news.bbc.co.uk/1/hi/england/2678895.stm

Cohen, J. & Wind, T. (2001). Distributed Wind Power Assessment. Washington: National Wind Coordinating Committee.

Devine, M., O'Connor, B., Ellis, T., Rogers, T., Wright, S. & Manwell, J. (2003). Massachusetts Wind Energy Predevelopment Support Program & Feasibility Study for Marblehead, Massachusetts. Amherst: Renewable Energy Research Lab. Retrieved September 2, 2004, from the World Wide Web: http://www.ceere.org/rerl/publications/reports/WEPS_and_Marblehead_Wind_Feasibility_AWEA03.pdf

EIBI. (2002). Wind Power: Future Energy Solutions, On-site Generation. Electronic: Author. Retrieved September 2, 2004, from the World Wide Web: www.future-energy-solutions.com/assets/WindPower.pdf

Endless Energy Corporation (2004). Existing Wind Farm: Public Support. Yarmouth: Author. Retrieved October 2, 2004, from the World Wide Web: http://www.endlessenergy.com/general_public_support.shtml

Energy Altermatives. Retrieved September 2, 2004, from the World Wide Web: http://www.energyalternatives.ca/SystemDesign/wind1.html

Energy Information Administration. Retrieved September 7, 2004, from the World Wide Web: http://www.eia.doe.gov/

European Commission Directorate-General for Energy. (1996). Wind Energy: The Facts. Retrieved September 2, 2004, from the World Wide Web: http://www.agores.org/Publications/Wind%20Energy%20-%20The%20Facts/WE%20-%20Intro%20&%20Contents.pdf

Gipe, P. (1995). Wind Energy Comes of Age. New York: John Wiley & Sons.

Idaho Wind Power Ad Hoc Steering Committee. (2002). Idaho Wind Power Development Strategic Plan for the Idaho Wind Power Working Group. Boise: Idaho Department of Water Resources, Energy Division. Retrieved September 8, 2004, from the World Wide Web: http://www.idwr.state.id.us/energy/wind/strategic_web.pdf

Manwell, J., McGowan, J., & Rogers, A. (2002). Wind Energy Explained: Theory, Design and Application. New York: John Wiley & Sons.

Meo, M., Shafer, M., Yuan, M., Salisbury, J., & Stadler, S. (2000). The Oklahoma Wind Power Assessment Initiative: A proposed plan for stimulating economic development through wind power production in Oklahoma. Oklahoma City: The Oklahoma Department of Commerce. Retrieved September 8, 2004, from the World Wide Web: http://www.seic.okstate.edu/owpi/About/Library/proposal.pdf

Reeves, A. (2003). Wind Energy for Electric Power: A REPP Issue Brief. Washington: Renewable Energy Policy Project (REPP). Retrieved September 2, 2004, from the World Wide Web: http://solstice.crest.org/articles/static/1/binaries/wind%20issue%20brief_FINAL.pdf

Renewable Energy Research Laboratory (2004). Retrieved September 20, 2004, from the World Wide Web: http://www.ceere.org/rerl/

Renewable Energy Research Laboratory, University of Massachusetts at Amherst. (2003). Wind Power on the Community Scale, Community Wind Case Study: Hull. Amherst: Author. Retrieved September 8, 2004, from the World Wide Web: http://www.ceere.org/rerl/about_wind/RERL_Case_Study_Hull_Wind_One.pdf

Tennis, M., Clemmer, S., Howland, J. (1999). Assessing Wind Resources: A Guide for Landowners, Project Developers, and Power Suppliers. Cambridge: Union of Concerned Students. Retrieved September 15, 2004, from the World Wide Web: http://www.ucsusa.org/documents/ACFxF7PQ2.pdf

U.S. Department of Energy (2004). State Energy Alternatives. Washington: Energy Efficiency and Renewable Energy. Retrieved October 5, 2004, from the World Wide Web: http://www.eere.energy.gov/state_energy/

U.S. Department of Energy. (2000). Massachusetts: Wind Powering America- Clean Energy for the 21st Century. Washington: Author. Retrieved September 8, 2004, from the World Wide Web: http://www.eere.energy.gov/windpoweringamerica/pdfs/factsheets/fs_ma.pdf

U.S. Department of Energy. (2003a). Small Wind Electric Systems: A Massachusetts Consumer's Guide. Boston: Author. Retrieved September 8, 2004, from the World Wide Web: http://www.nrel.gov/docs/fy03osti/34341.pdf

U.S. Department of Energy. (2003b). Wind and Hydropower Technologies Program: Wind Energy Program Multi Year Technical Plan For 2004-2010. Washington: Author. Retrieved September 6, 2004, from the World Wide Web: http://www.eere.energy.gov/windandhydro/

U.S. Department of Energy. (March 2004). Wind Power: Today and Tomorrow. Washington: National Renewable Energy Laboratory. Retrieved October 5, 2004, from the World Wide Web: http://www.nrel.gov/docs/fy04osti/34915.pdf

Union of Concerned Scientists (2002). Clean Energy. Retrieved September 7, 2004, from the World Wide Web: http://www.ucsusa.org/clean_energy/renewable_energy/

United Nations Development Programme. (2000). Word Energy Assessment: Energy and the challenge of sustainability. New York: Author. Retrieved August 31, 2004, from the World Wide Web: http://www.undp.kz/library_of_publications/center_view.html?id=111

US Wind Status (July/August 2004). reFocus. Oxford: Elsevier. Pg. 40

Environmental

American Wind Energy Association (1998). The Renewables Portfolio Standard:How It Works and Why It's Needed. Retrieved October 2, 2004, from the World Wide Web: http://www.awea.org/policy/rpsbrief.html

Carbon Dioxide Emissions From Energy Consumption by Sector, 1980-2002. (2003). Retrieved October 4, 2004, from the World Wide Web: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec12_5.pdf

Deming, D. (2003). Are We Running Out of Oil? Washington: National Center for Policy Analysis. Retrieved October 4, 2004, from the World Wide Web: http://www.ncpa.org/pub/bg/bg159/

Gore, D. & Danby, G. (1999). Wind Power. United Kingdom: House of Commons. Retrieved September 2, 2004, from the World Wide Web: http://www.parliament.uk/commons/lib/research/rp99/rp99-055.pdf

Khan, J. (2003, July). Wind Power Planning in Three Swedish Municipalities. Journal of Environmental Planning and Management. 46(4). pp. 563-581. Lund: Carfax Publishing.

Massachusetts Department of Environmental Protection (1997). Commonwealth of Massachusetts Executive Office of Environmental Affairs: Generation Performance Standard. Boston: Author. Retrieved September 30, 2004, from the World Wide Web: http://www.mass.gov/dep/utilrest/files/gps.pdf

Monahan, J. (2003, November 3). Worcester aims to reduce global warming emissions. Worcester Telegram & Gazette. pp. A1.

National Energy Foundation (2002). Fuel Consumption Stats. Retrieved October 2, 2004, from the World Wide Web: http://www.nef1.org/ea/eastats.html

Renewable Energy Certificates and GIS Certificates. Boston: Massachusetts Technology Collaborative. Retrieved September 8, 2004, from the World Wide Web: http://www.mtpc.org/RenewableEnergy/green_power/recs.htm

The International Council for Local Environmental Initiatives (2003). U.S. Cities for Climate Protection Campaign. Berkeley: Author. Retrieved October 6, 2004, from the World Wide Web: http://www.iclei.org/us/ccp/

Economics

Utah Wind. Retrieved September 9, 2004, from the World Wide Web: http://www.wind.utah.gov/assumptions.htm

Wind Energy Systems. (2000). Wind Energy Manual. Des Moines: Iowa Energy Center. Retrieved September 26, 2004, from the World Wide Web: http://www.energy.iastate.edu/renewable/wind/wem/wem-07_systems.html

Wind System Siting. (2004). Renewable Energy Works. Retrieved September 15, 2004, from the World Wide Web: http://www.renewableenergyworks.com/wind/WindSiting.html

Country Guardian (2000). What's Wrong with Windfarms? Retrieved September 24, 2004, from the World Wide Web: http://www.countryguardian.net/case.htm

Environmental Protection Agency (1999). A Guidebook of Financial Tools: Paying for Sustainable Environmental Systems. Retrieved October 6, 2004, from the World Wide Web: http://www.getf.org/file/toolmanager/O16F8897.htm

Federal Renewable Energy Resources. (2002). Power Point Presentation. Electronic. Retrieved September 31, 2004, from the World Wide Web: http://www.ceere.org/rerl/events/ne_islands_2002/3_Forsyth_PTC_REPI_overview_Dec02.pdf

Financial Incentives for Business Investments in Renewable Energy (2004). Information Resources. Washington: U.S. Department of Energy. Retrieved October 1, 2004, from the World Wide Web: http://www.eere.energy.gov/consumerinfo/factsheets/la7.html

Iowa Energy Center (2003). Alternate Energy Revolving Loan Program (AERLP). Retrieved September 30, 2004, from the World Wide Web: http://www.energy.iastate.edu/funding/aerlp-index.html

NICE3 Program Close Out. (2004). Weatherization and Intergovernmental Programs. Washington: U.S. Department of Energy. Retrieved September 29, 2004, from the World Wide Web: http://www.eere.energy.gov/wip/program/nice3.html

NICE^3. (2003). Ohio Department of Development. Washington: Office of Energy Efficiency. Retrieved September 24, 2004, from the World Wide Web: http://www.odod.state.oh.us/cdd/oee/c_i_nice3.htm

Renewable Energy Production Incentive (REPI). (2004). Weatherization and Intergovernmental Programs. Washington: U.S. Department of Energy. Retrieved September 29, 2004, from the World Wide Web: http://www.eere.energy.gov/wip/program/repi.html

Small Business Administration (SBA) Programs (2004). Industrial Technologies Department. Washington: U.S. Department of Energy. Retrieved October 3, 2004, from the World Wide Web: http://www.eere.energy.gov/industry/financial/fedsba1.html

Regulatory

Energy Information Administration. (2002). Legislation Affecting the Renewable Energy Marketplace. Retrieved September 7, 2004, from the World Wide Web: http://www.eia.doe.gov/cneaf/solar.renewables/page/legislation/impact.html

General Laws of Massachusetts. Chapter 131. Retrieved Septermber 20, 2004, from the World Wide Web: http://www.mass.gov/legis/laws/mgl/gl-131-toc.htm

Legal Information Institute (2004). § 668. Bald and golden eagles. Retrieved September 27, 2004, from the World Wide Web: http://assembler.law.cornell.edu/uscode/html/uscode16/usc_sec_16_00000668----000-.html

Legal Information Institute (2004). SUBCHAPTER II—MIGRATORY BIRD TREATY. Retrieved September 27, 2004, from the World Wide Web: http://assembler.law.cornell.edu/uscode/html/uscode16/usc_sup_01_16_10_7_20_II.html

Massachusetts Department of Energy (1990). DEP Bureau of Waste Prevention Noise Policy. Boston: Author. Retrieved September 15, 2004, from the World Wide Web: http://www.mass.gov/dep/energy/noispol.htm

Massachusetts Department of Environmental Protection (1990). City of Worcester Wetlands Protection Ordinance and Wetlands Protection Regulations. Boston: Author. Retrieved September 17, 2004, from the World Wide Web: http://www.ci.worcester.ma.us/cco/ordinances/wetlandordinance/index.html

Massachusetts Division of Energy Resources. (2001). Renewable Energy & Distributed Energy Guidebook: A Developer's Guide to Regulations, Policies and Programs that Affect Renewable Energy and Distributed Generation Facilities in Massachusetts. Boston: Author. Retrieved September 8, 2004, from the World Wide Web: http://www.mass.gov/doer/pub_info/guidebook.pdf (Amazing Resource for the particulars about how to develop a site)

Monahan, J. (2004, April 29). Wind farm impact study not required. Telegram & Gazette. pp. A1, A7.

NWCC Permitting of Wind Energy Facilities. Retrieved September 16, 2004, from the World Wide Web: http://www.nationalwind.org/pubs/permit/permitting.htm

Renewable Energy Research Laboratory, University of Massachusetts at Amherst. (2004). Wind Power: Permitting in Your Community, Wind Power on the Community Scale – Fact Sheet #7. Amherst: Author. Retrieved September 2, 2004, from the World Wide Web: http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_7_Permitting.pdf

U.S. Fish and Wildlife Service (2004). Endangered Species Habitat Conservation Planning. Washington: Author. Retrieved September 15, 2004, from the World Wide Web: http://endangered.fws.gov/hcp/#contents

U.S. Industry Consensus Standards Development Activities. (2004). Retrieved September 7, 2004, from the World Wide Web: http://www.awea.org/standards/aweastds.html

Case Studies

Altamont Pass Wind Resource Area. Retrieved September 18, 2004, from the World Wide Web: http://www.biologicaldiversity.org/swcbd/programs/bdes/altamont/altamont.html

Cape Wind. Retrieved September 8, 2004, from the World Wide Web: http://www.capewind.org/modules.php?op=modload&name=FAQ&file=index&myfaq=yes&id_cat=3&categories=Questions+about+Environmental+and+Tourism+Impact&parent_id=0

Leaning, J. (2002, May 12). Wind Mountain. Cape Cod Times. http://www.endlessenergy.com/general_public_support.shtml

Top of Iowa Wind Farm Case Study. Retrieved September 17, 2004, from the World Wide Web: http://www.state.ia.us/dnr/energy/MAIN/PROGRAMS/WIND/documents/topofiaWindFarmCaseStudy.pdf

Electrical

Distributed Generation Interconnection Collaborative (2003). Proposed Uniform Standards for Interconnecting Distributed Generation in Massachusetts. Boston: Raab Associates.

Smith, K. (2003). Characteristics of Financeable Wind Energy Projects. Kirkland: Global Energy Concepts. Retrieved September 2, 2004, from the World Wide Web: http://www.nwcouncil.org/energy/powersupply/wind%20workshop%202003_12/2003_12/Kevin%20Smith%20NPCC%20Presentation.ppt

The Governor's Task Force on Electric Reliability and Outage Preparedness (2004). Status of the Electric Grid in Massachusetts. Boston: Author. Retrieved October 3, 2004, from the World Wide Web: http://www.mass.gov/dte/226govreport.pdf

Wind Power Electronics (May/June 2004). reFocus. Oxford: Elsevier. Pg. 36

Technical

Burton, T., Sharpe, D., Jenkins, N., & Bossanyi, E. (2001). Wind Energy Handbook. New York: John Wiley & Sons.

Great Expectations: Large Wind Turbines. (2001, May). Renewable Energy World. London: James & James. Retrieved September 20, 2004, from the World Wide Web: http://www.jxj.com/magsandj/rew/2001_03/great_expectations.html

The 1.5 MW Wind Turbine. (2004). GE Energy. Tehachapi: GE Energy. Retrieved September 20, 2004, from the World Wide Web: http://www.gepower.com/prod_serv/products/wind_turbines/en/downloads/ge_15_brochure.pdf

Versteegh, C. J. A., GarradHassan, & Partners NL, Sterrelaan 7, 1217 PP, Hilversum NL. (2004). Design of the Zephyros Z72 wind turbine with emphasis on the direct drive PM generator. Trondheim: NTNU Trondheim Normandy. Retrieved September 6, 2004, from the World Wide Web: www.elkraft.ntnu.no/norpie/10956873/Final%20Papers/068%20-%20Norpie%20paper

Miscellaneous

Bergey Windpower Co. Retrieved September 9, 2004, from the World Wide Web: http://www.bergey.com/

Dufour, C. & Belanger, J. (2001). Real-Time Simulation of Doubly Fed Induction Generator for Wind Turbine Applications. Montreal: Opal-RT Technologies inc. Retrieved September 6, 2004, from the World Wide Web: www.opal-rt.com/downloads/pdfs/dufour_windturbinepaper2004.pdf

Verbruggen, T.W. (2003). Wind Turbine Operation &Maintenance based on Condition Modeling WT-Ω. Retrieved September 6, 2004, from the World Wide Web: www.ecn.nl/docs/library/report/2003/c03047.pdf

Wikipedia (2004). 1973 Oil Crisis. Retrieved October 2, 2004, from the World Wide Web: http://en.wikipedia.org/wiki/1973_energy_crisis

Williams, J. & Alhajji, A. (2003). The Coming Energy Crisis. Retrieved October 4, 2004, from the World Wide Web: http://www.wtrg.com/EnergyCrisis/

FIGURE REFERENCES

Figure 1: Local wind class regions.
Siting Your Tower, http://www.renewableenergyworks.com/wind/TowerSiting.html
Figure 2: Horizontal Axis Wind Turbines: Upwind and Downwind, respectively
Alternative Energy Institute, http://www.wtamu.edu/research/aei/p2brochers.htm
Figure 3: Vertical Axis Wind Turbines: Giromill, Savonius, and Darrieus, respectively
Alternative Energy Institute, http://www.wtamu.edu/research/aei/p2brochers.htm
Figure 4: Wind Farm Capital Cost Breakdown
Wind Energy Explained. Pg. 427
Figure 5: Comparison of decibel levels from a hypothetical wind turbine.
American Wind Energy Association, http://www.awea.org/
Figure 6: New England Wind Velocity and Worcester Area Wind Velocity
US Dept. of Energy State Wind Maps,
http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp
Figure 7: Wind regions of Massachusetts, Connecticut, and Rhode Island.
Wind Energy Resource Atlas,
http://rredc.nrel.gov/wind/pubs/atlas/maps/chap3/3-21m.html
Figure 8: Initial Return on Investment
Personnel Calculations
Figure 9: Power Output for Different Wind Speeds
The Alternative Energy Store - http://shop.altenergystore.com/
Figure 10: ROI for Air-X 24V
Personnel Calculations

Figure 11: ROI for Lakota 900
Personnel Calculations
Figure 12: Princeton Wind Farm
Princeton Municipal Light Department, http://www.pmld.com/windfarm.asp
Figure 13: Altamont Pass Wind Farm
Wind Energy in California, http://www.energy.ca.gov/wind/overview.html
Figure 14: Cape Wind Project Siting and Visual Stimulus. The yellow area denotes proposed wind turbine sites while the brown dots represent points three miles from beaches.
Cape Wind, http://www.capewind.org/
Figure 15: Top of Iowa Wind Farm
Zilkha Renewable Energy, http://www.zilkha.com/whatwevedone.asp?id=3
Figure 16: Wind turbines at Cornwall, England
Helen Stephenson's Summer Holiday Pictures,
http://www.baronmoss.demon.co.uk/Cornwall_2002_Windfarm.html#top
Figure 17: Wind turbine at Hull, Massachusetts
RERL: Wind Power on the Community Scale,
http://www.ceere.org/rerl/about_wind/RERL_Case_Study_Hull_Wind_One.pdf
Figure 18: Map of Hull
RERL: Wind Power on the Community Scale,
http://www.ceere.org/rerl/about_wind/RERL_Case_Study_Hull_Wind_One.pdf
Figure 19: Searsburg, Vermont Turbines
Endless Energy Corporation, http://www.endlessenergy.com
Figure 20: The main components of a wind turbine
Wind Energy Manual, http://www.energy.iastate.edu/renewable/wind/wem/wem-07_systems.html

Figure 21: Vertical axis rotors
Wind Energy Manual, http://www.energy.iastate.edu/renewable/wind/wem/wem-07_systems.html