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Wind Power in Worcester, Massachusetts: Siting and Permitting

An Interactive Qualifying Project Report: submitted to the Faculty of

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Abstract

The goal of this project was to aid the City of Worcester in reaching its commitment to promote renewable energy. First, we analyzed the potential for wind power in Worcester, finding that there is good potential for small wind turbines and limited potential for medium sized turbines. We then recommended a model ordinance allowing the installation of personal wind turbines and described a process for introducing it into the Worcester Zoning Ordinance as an amendment.

Acknowledgements

There are a number of people and organizations we would like to thank for their help and encouragement throughout this project. First and foremost, our advisors: Professors Scott Jiusto and Robert Krueger, who assisted us in designing a project that made a significant contribution while working with our limited schedule. Also for their helpful contacts, the attendance of regular meetings and efficient turnarounds whenever we needed assistance.

Many thanks also go out to the Regional Environmental Council of Central Massachusetts, and specifically to Carissa Williams for her interest and suggestions throughout our project. Thank you to the Massachusetts Technology Collaborative and the helpful information available through the Renewable Energy Trust. Also thank you to Colin Novick of the Greater Worcester Land Trust for his assistance with GIS.

Additionally we would like to thank the City of Worcester for their cooperation throughout this project, specifically to the people who took times out of their busy schedules to speak with us: Joe Boynton, Michael Pace, and Jody Kennedy-Valade.

We would also like to thank the companies that took the time to speak with us and share their experiences. We gained important knowledge hearing the perspectives of large utility scale providers in speaking with Paul Gaynor from UPC Wind and Erich Bachmeyer from Global Winds Harvest. Thank you also to the Alternative Energy store in Worcester, Massachusetts for the information and enthusiasm that they provided us with during every conversation.

Finally, we would like to thank the original wind IQP group: Calixte Monast, Christopher Kalisz, Michael Santoro, and Benjamin Trow for laying the ground work for an excellent cause. Also thank you for pointing us in the right direction from day one and sharing your resources and knowledge of wind power with us.

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Executive Summary

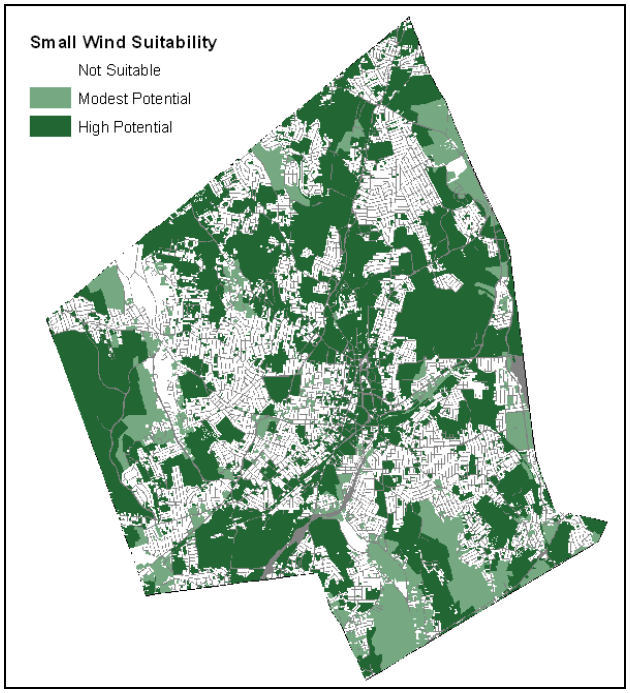
As the world's supplies of fossil fuels continue to diminish at an increasing rate, the demand for energy increases at an ever faster pace. Additionally, it has been scientifically determined that carbon dioxide and other greenhouse gasses released into the atmosphere lead to changes in Earth's climate and contribute to global warming. Currently, energy creation through dirty methods, such as fossil fuels, leads to more than 80% of U.S. greenhouse gas emissions (Pew Center, 2005). A global solution to these problems is needed; however, it is equally important that steps be taken at the local level. In March of 2005, Worcester's City Council adopted a resolution making it the first municipality in Massachusetts committed to purchasing 20% of its electricity from renewable sources by 2010. Worcester addresses this issue in response to its growing concerns for the state of the Earth's climate. The City of Worcester also believes that "local government actions taken to reduce greenhouse gas emissions and increase energy efficiency provide multiple local benefits by decreasing air pollution, creating jobs, reducing energy expenditures, and saving money for the local government, its businesses and its residents" (Rushford, 2005).

By making this choice, Worcester is declaring its intentions to be a city that promotes clean energy practices for itself and its residents while at the same time positioning itself to become a leader in renewable energy development in the state. There are a number of ways to reach this goal and it is important for Worcester to acknowledge these and pursue options that put Worcester in the forefront of renewable energy technologies. One option commonly opted for is to buy renewable energy certificates (REC's) which are certificates representing the generation of clean energy from an outside source. Another option for the City to consider is to produce its own renewable energy within city limits, reducing its demand on nonrenewable resources supplying the electric grid.

Wind turbines have become an increasingly utilized technology for producing energy from a renewable and often plentiful resource. According to our knowledge, there are currently no wind turbines operating in Worcester, leaving this clean, renewable resource to go unused. If the necessary resources for producing electricity from wind power are available in Worcester, erecting one or more medium sized wind turbines to produce a portion of the City's electricity would reinforce its commitment to renewable energy. The objectives of this study were to examine the levels of suitability for installing wind turbines of all sizes in Worcester, and to establish a basic process for citizens of the City to put up their own turbines.

The criteria used for determining a suitable location for wind turbines depend on the size of the turbine that is being considered. It is important to note that larger turbines require much higher wind speeds, more land, and more in-depth site studies than their smaller counterparts. Our preliminary investigation determined that small (rated at less than 50 kW) and medium (rated between 50 and 750 kW) sized turbines have reasonable potential in Worcester, whereas large scale wind farms (producing several MW) would not be suitable due to a lack of sufficient wind speeds. To further investigate the potential for small wind developments in Worcester, we used GIS software to analyze important criteria for siting small turbines, including average wind speed and parcel size. We developed a map representing the levels of potential for small wind development in Worcester. From the map, it is clear that many parts of the City are suitable for

small scale wind turbines. The City, the Regional Environmental Council of Central Massachusetts, or other interested groups could use a map such as the one presented here to promote small wind development within Worcester.



When considering the suitability of a site for medium sized wind turbines, there are different factors to look at compared to small wind turbines. A medium sized, municipally owned wind turbine can make a prominent statement in support of renewable energy. Such a turbine should ideally be placed in an area where it is clearly visible to advertise this concept, but not placed such that it is a nuisance to city residents. There is no replacement for a site with good wind; however, it is important to note that there are technical, societal, and environmental impacts to consider as well. A combination of visibility and non-intrusiveness, along with steady, non-turbulent wind is what defines an excellent site. To these ends, we have identified two potential sites in Worcester that may fit these criteria:

- **Green Hill Park** has adequate wind, is city owned, visible from major access roads, and is mostly non-obtrusive for nearby residents.

- **Worcester Regional Airport** has adequate wind, is city owned, may be somewhat visible from major access roads, and is non-obtrusive for nearby residents. It is important to note however, that the siting of any turbine at the airport would be dependent on compliance with FAA regulations which would require a separate detailed study.

In addition to raising residents' awareness of renewable energy, erecting a municipal wind turbine may also encourage the use of personal wind turbines in Worcester. There are already several cities and towns in the northeast that allow for residentially owned wind turbines, and there are some steps that Worcester could take to make it easier for residents to choose such an option. Currently there is no legislation regarding the use of such wind turbines (often referred to as personal wind energy conversion systems, or WECS), and if a home owner was to approach the building department with a request to install a wind turbine they would be denied. The best way to allow for a wind turbine in residential and other types of zones is to petition to amend the Worcester Zoning Ordinance to incorporate a section on WECS. The process for amending the zoning ordinance can take as short a time as 3 months or as long as several years, depending on if any problems arise. In general, it is important that the individual or organization that plans on pursuing an amendment is knowledgeable about wind power and willing to work with the City to establish a good process. A sample petition for implementing an amendment, as well as a model ordinance that could be used, can be found on the next two pages.

This report is designed to be read alone, or as a continuation of *Wind Power Suitability in Worcester, Massachusetts* (Kalisz et al., 2005). The previous project focuses on defining criteria for determining suitable wind turbine locations, applies those criteria to a potential small wind turbine in downtown Worcester, and investigates the various federal and state incentives that are available to people operating wind turbines of their own. This report will specifically address small and medium sized wind turbine siting in Worcester using some of the previous report's criteria, as well as permitting related to small sized wind turbines in Worcester.

While this report is intended for anybody who is interested in wind power, the following parties in particular may find this report useful:

- The Regional Environmental Council of Central Massachusetts
- The City of Worcester, particularly the City Council, the Planning Department, the City Manager, and any other City departments
- Individuals interested in erecting a personal wind turbine
- Individuals interested in encouraging renewable energy in the City of Worcester

The report would be useful for someone interested in further investigating sites for turbines within or outside of Worcester. As we have identified a few sites in the City, someone could use these sites as a starting point for more site specific wind data collection with an anemometer. Since we have determined that Worcester's potential for supporting medium sized wind turbines is limited to a few sites, other locations in Worcester County should be considered for further investigation. While sites outside of Worcester were not considered in this study, the GIS analyses we developed could be recreated for other surrounding towns and cities to identify similarly promising sites. This report could also be used to initiate the process for incorporating an amendment to the zoning ordinance addressing wind turbines in Worcester. The necessary steps are outlined in this report, which would allow someone familiar with wind turbines to use this report along with the Worcester Model Ordinance, the included petition, and the report *Wind Power Suitability in Worcester, Massachusetts* (Kalisz et al., 2005) to propose an amendment to the Worcester Zoning Ordinance. Finally, the report could be used by a resident or business interested in renewable energy to determine their property's suitability for a small wind turbine.

Sample Petition to City Council

Please print out this form, state your name, residential address, telephone number and return to:

Worcester City Clerk
City Hall Room 206
455 Main Street
Worcester, MA 01608-1889.

The undersigned, residing in the City of Worcester hereby petition the City Council as follows, request:

that the attached ordinance entitled "Wind Energy Conversion Systems" be added to the City of Worcester Zoning Ordinance. The objective of the ordinance is to allow for the installation of small wind turbines by individuals and businesses within the City of Worcester. This ordinance will enable and encourage the use of renewable energy within the City of Worcester and help the City to reach its goal of using 20% renewable energy by 2010. The ordinance sets guidelines that provide for the regulation and safe installation of small wind energy conversion systems throughout the City.

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Worcester Model Ordinance

Wind Energy Conversion Systems

Definitions

Wind Energy Conversion Systems (WECS) – Mechanisms designed or operated for the purpose of converting wind energy into electrical or mechanical power.

Residential WECS – A WECS designed and operated primarily for the purpose of providing energy to structures on a single plot of land, which has rated capacity of not more than [50 kW].

Tower height – The height above grade of the fixed portion of the tower, excluding the wind turbine itself.

Permitted Use

Residential WECS shall be a permitted use in all zoning classifications where structures of any sort are allowed, subject to certain requirements as set forth below. The Special Permit Granting Authority for exceptions to this ordinance, as noted in the ordinance, shall be the Zoning Board of Appeals.

1. Building permit application: Building permit applications for a WECS shall be accompanied by a plot plan drawn to sufficient detail, approved by a city engineer clearly describing the following:

    a. Property lines and physical dimensions of the site.

    b. Location and proposed elevation of the WECS.

    c. Make, model, picture and manufacturer's specifications, including noise in decibels, of the proposed WECS.

2. Maximum number of towers per lot: One, except that more may be allowed by special permit.

3. Set-back: Minimum tower set-back distance from the nearest property point is the distance measured from the mean grade surrounding the support to the tip of the blade in a vertical position measured along the vertical access of the tower. In addition, no part of the WECS, including guy wires, shall extend closer than 10 ft to the property boundaries of the installation site.

4. Tower Height: Tower height shall be limited to 60 ft total or 20 feet above structures and other obstacles on the same lot, whichever is higher, except that tower height may exceed these limitations by special permit.

5. Noise: No WECS shall produce sound pressure levels in excess of 5 dB(A) above the ambient noise as measured at the closest neighboring inhabited dwelling.

6. Compliance with FAA regulations: All WECS must comply with applicable FAA regulations, including any necessary approvals for installations close to airports.

7. Utility Notification: No WECS shall be installed until evidence has been given that the utility company has been informed of the customer's intent to install an interconnected customer-owned generator. Off-grid systems shall be exempt from this requirement.

8. Tower access: The tower shall be made inaccessible to unauthorized personnel.

Chapter 1: Introduction

Over the course of human history, people have had a tendency to use resources from the Earth without considering how their actions would affect the world on a broader scale. This is particularly true with fossil fuels such as oil and coal, whose supplies are not only being depleted at an astonishing rate, but their use is contributing to an equally significant environmental issue. The burning of these fossil fuels for electricity generation in the United States alone, most notably coal, contributes to more than 32% of the country's total carbon dioxide emissions (US EPA, 2001). Greenhouse gases, which include carbon dioxide, are believed to be one of the major causes of global warming. People have recognized for some time that global warming is contributing to climate change; however, there is no simple solution to the problem which is only getting worse (Wigley, 1999). The use of clean, renewable resources for generating electricity is an option that will help to reduce emissions contributing to climate change.

There have been steps toward promoting the use of renewable energy at all levels, from international conferences down to local interest groups. Non-profit organizations such as the ICLEI: Local Government for Sustainability recognize that initiatives taken by local governments provide an efficient way to achieve changes at national and global levels. Based on this premise, in March of 2005, the City of Worcester adopted resolutions to promote renewable energy policies and to commit to making 20% of its energy purchases from renewable sources by 2010. In the resolutions, Worcester recognizes the negative effects that greenhouse gas emissions have on the atmosphere and the climate as a whole, and expresses concern for the health of its residents (Rushford, 2005). These resolutions were brought about as a result of pressure from local groups including the Regional Environmental Council of Central Massachusetts and Massachusetts Interfaith Power and Light. Worcester has a few options for meeting the commitment to the 20% by 2010 campaign, including purchasing renewable energy certificates (REC's) from outside suppliers of renewable energy. Another option is for the City to produce its own renewable energy, within Worcester.

The idea of producing renewable energy in Worcester is an idea that has support from local groups, including the Regional Environmental Council of Central Massachusetts. One method for producing clean energy is through the installation of wind turbines, which convert wind energy into electrical energy. Wind energy is becoming an increasingly feasible option for producing electricity as their acceptance grows and technology develops. There has been a previous study into the suitability criteria for siting wind turbines, entitled *Wind Power Suitability in Worcester, Massachusetts* (Kalisz et al., 2005). The report investigated the factors that must be considered for potential wind power sites, and performed a case study on a potential site in downtown Worcester. The current state of wind power in Worcester is that there are no wind turbines operating within the City, despite the interests of the Regional Environmental Council and the City to pursue renewable energy options.

While the previously mentioned study established a clear set of criteria to consider for siting wind turbines, it did not provide an in-depth examination as to the potential for Worcester to support wind turbines. The criteria were applied to a specific possible site, without regard to other sites in Worcester or for the City as a whole. With this in mind, it would be useful to those interested in wind power to have a general guide as to whether or not Worcester possesses the necessary conditions for wind power development, and if so, where the conditions would be

most favorable. If wind power is a feasible option in Worcester, the next step would be to identify how someone interested in wind power would go about getting a permit to install a wind turbine.

We look at both of the issues considered above in this report. It is organized into two main chapters, *Chapter 2: Assessing Wind Power Potential in Worcester*, and *Chapter 3: Enacting a Wind Turbine Permitting Process in Worcester*. Chapter 2 investigates the potential for wind turbines of all sizes in Worcester, particularly small and medium sized turbines. The criteria developed in the previous study *Wind Power Suitability in Worcester, Massachusetts* (Kalisz et al., 2005) are used as a basis for our analyses. First, we examine the suitability for small wind turbines through the use of GIS software to create maps of the City with important data for siting small turbines. Next, we examine potential sites for medium sized turbines, which might be a consideration for the City or other significant power users in Worcester. The criteria for medium sized turbines, which are slightly different than those for smaller turbines, are applied to various sites throughout the City which had been mentioned to us by local residents. Chapter 3 investigates the permitting side of installing wind turbines, focusing on small turbines. The current lack of a permitting process in Worcester means that the adoption of a new ordinance for wind turbines would be the most desirable option. The chapter looks into the desirable characteristics of a permitting process using examples from other cities and towns, then uses them as a basis to develop a model ordinance that Worcester could use. Finally, the chapter ends with a description of the process that one must follow in order to get the ordinance incorporated into the Worcester Zoning Ordinance.

Chapter 2: Assessing Wind Power Potential in Worcester

Introduction

In March of 2005, Worcester's City Council adopted a resolution to purchase 20% of its electricity from renewable sources by 2010. There are a number of ways to reach this goal, including purchasing renewable energy (or renewable energy certificates) generated in other cities and towns in Massachusetts, or even from out of state. One option to consider is for the City to produce its own renewable energy, within the City limits. Erecting one or more medium sized wind turbines within the City to produce a portion of its electricity would bring major benefits. Worcester would establish itself as a leading city in Massachusetts in renewable energy, it would help the City reach its goal of 20% renewable energy (and in time pay for itself in the process), and it would send a message to Worcester residents that the City supports renewable energy and protecting the environment. The latter benefit is doubly important for the City, as it would likely encourage residents and business owners to consider putting up their own small wind turbines, further establishing Worcester as a regional leader in renewable energy. At a recent Massachusetts Climate Action Network (MCAN) Clean Power Training Day, speakers urged attendees to encourage their cities and towns to use clean energy as a means to arouse interest in clean energy amongst its citizens.

The intentions of this chapter are to determine whether the wind quality in Worcester is enough to prompt wind energy development and if so examine which types of turbines would be appropriate and where. First, an introduction to turbines in general will be given, comparing small personal wind turbines to medium sized wind turbines. Next, some general siting criteria are discussed. Desirable and undesirable characteristics for siting small and medium sized wind turbines are compared to each other. Finally, a detailed analysis of potential sites for a municipally owned medium sized wind turbine in Worcester is presented.

Appropriate Turbines for Worcester

There are many different sizes of wind turbines that exist, from very large turbines with blade spans approaching the length of a football field to very small turbines with blades that barely reach beyond a meter (3.28 ft). In addition to the many kinds of wind turbines that exist, there are numerous factors to consider when siting turbines of all sizes, making the process a complicated and controversial one. Wind turbines can roughly be separated into three different scales of power production ranging from small, to medium, to large. Large wind turbines are often pursued primarily for commercial interest and tend to be placed in large arrays called wind farms. Such wind farms are very expensive to put up; however, they typically produce several megawatts of electricity which is sold to utility companies. Large scale wind turbines also need much higher average wind speeds than their smaller counterparts, therefore limiting where they can be placed. As a result of our own analysis and our contacts with utility scale wind farm developers, we determined that Worcester is not a favorable location for large wind turbines, and will not be considered in this siting analysis.

In this chapter, we discuss the siting criteria for small and medium scale wind turbines (which require lower average wind speeds, smaller towers, and less property) and examine how they apply to the City of Worcester. We focus first on small sized turbines that individual homeowners or businesses would install primarily for their own use (see Figure 1). These turbines generally have rotors between 1 m (3.3 ft) and 2.7 m (9 ft) in diameter, and they are usually mounted 9.1 m (30 ft) to 24.4 m (80 ft) above the ground or possibly higher, and have power production levels ranging from 40 to 160 kWh/mo. The second type of wind turbine that we focus on is the medium sized, municipal scale turbine, much like the one that can be found in Hull, Massachusetts (see Figure 2). This turbine has a rotor-diameter of 47 m (154 ft), a hub-height of 50 m (164 ft), and a rated power of 660 KW (Hull Wind, 2003), placing it towards the larger side of medium sized turbines.

Figure 1 – Small Wind Turbine

Figure 2 – Medium Wind Turbine

Desirable Site Characteristics

There are many characteristics that must be taken into consideration when siting windmills. This section will introduce the most important characteristics regarding both small and medium sized wind turbines. *Wind Power Suitability in Worcester, Massachusetts* (Kalisz et al., 2005) is a previously completed IQP that provides a more detailed analysis of the entire siting process and all desirable characteristics of a wind turbine site. This report focuses on those characteristics that can be examined on a broad scale to begin the process of actually identifying suitable sites based on their physical characteristics. Once a site is identified based on the wide scale physical data presented here, it is recommended that the previous IQP be referenced as a guide for continuing with an in-depth, site specific analysis.

Small Wind Turbines

- *Wind Resource* - There should be an average wind speed of at least 4.0 m/s (9 mph) at the site. Higher speeds are preferable (Southwest Windpower, 2005).

- *Surrounding Area* - It is recommended that the site be located on a plot of land at least half an acre in size (Southwest Windpower, 2005). This recommendation lowers the chance of there being surrounding objects that cause turbulence and also serves as a good estimate that the turbine can be placed safely away from neighboring property lines.

- *Height Restrictions* - Taller turbines mean better wind speeds (more electricity production) and less turbulence caused by wind coming off surrounding structures (longer lifespan); however, they can also raise safety and aesthetic concerns for neighbors. The specific height limitations set in a city and how they arise as a compromise between

both sides is a permitting issue, and will be discussed further in *Chapter 3: Enacting a Wind Turbine Permitting Process in Worcester*. Zoning laws can limit the height that a given structure can be, in order to reduce visual impact on neighbors, therefore it is important that the necessary operating height of the turbine fall below this limit.

Medium Wind Turbines

- *Wind Resource* – The required wind speed varies by turbine, but in general the optimal wind speed is around 16.0 m/s (36 mph) (Vestas). There are also some medium sized turbines, such as the Vestas V82, that have been designed for operation in lower wind speeds. However, these turbines have an optimal operating wind speed of about 11.6 m/s (25 mph) which is still significantly higher than the 4.0 m/s (9 mph) for most small turbines.

- *Surrounding Environment* – The turbine should be located in an area that has a minimal effect on the existing environment. This includes the visual impact that a turbine might have on the environment. Some exceptions apply to this rule, for example in the case where an organization, or more likely a municipality, is attempting to promote renewable energy. Often times a large visible structure can act as positive monument promoting clean and renewable energy.

- *Access* - Due to the size of the turbines, it is important for there to be easy access to the site. It must be near roads that can support the heavy equipment needed to construct turbines of this size. Construction of these roads can lead to significantly increased costs and has the possibility of raising opposition due to the effect it will have on neighbors and the environment.

- *Power Distribution* – Since these turbines generate and transmit electricity, it is important that the site be located close to an existing power transmission infrastructure. The construction of a new power infrastructure can significantly increase the overhead costs of the project.

Site Analysis

Assessing Small Wind Turbine Potential

Small wind turbines have desirable site characteristics that are notably different from medium wind turbines, and therefore need to be analyzed separately. The biggest differences that arise between the two are the lower wind speed and the smaller land area required for smaller turbines. This section examines the specific data that have been used to analyze the site criteria for small turbines mentioned in the previous section. This study finds that there are significant areas of Worcester that may be suitable for small wind turbine installations, and maps are developed reflecting those areas. Based on the application of these criteria, we make recommendations to publicly promote Worcester's suitability for small wind turbines to its citizens.

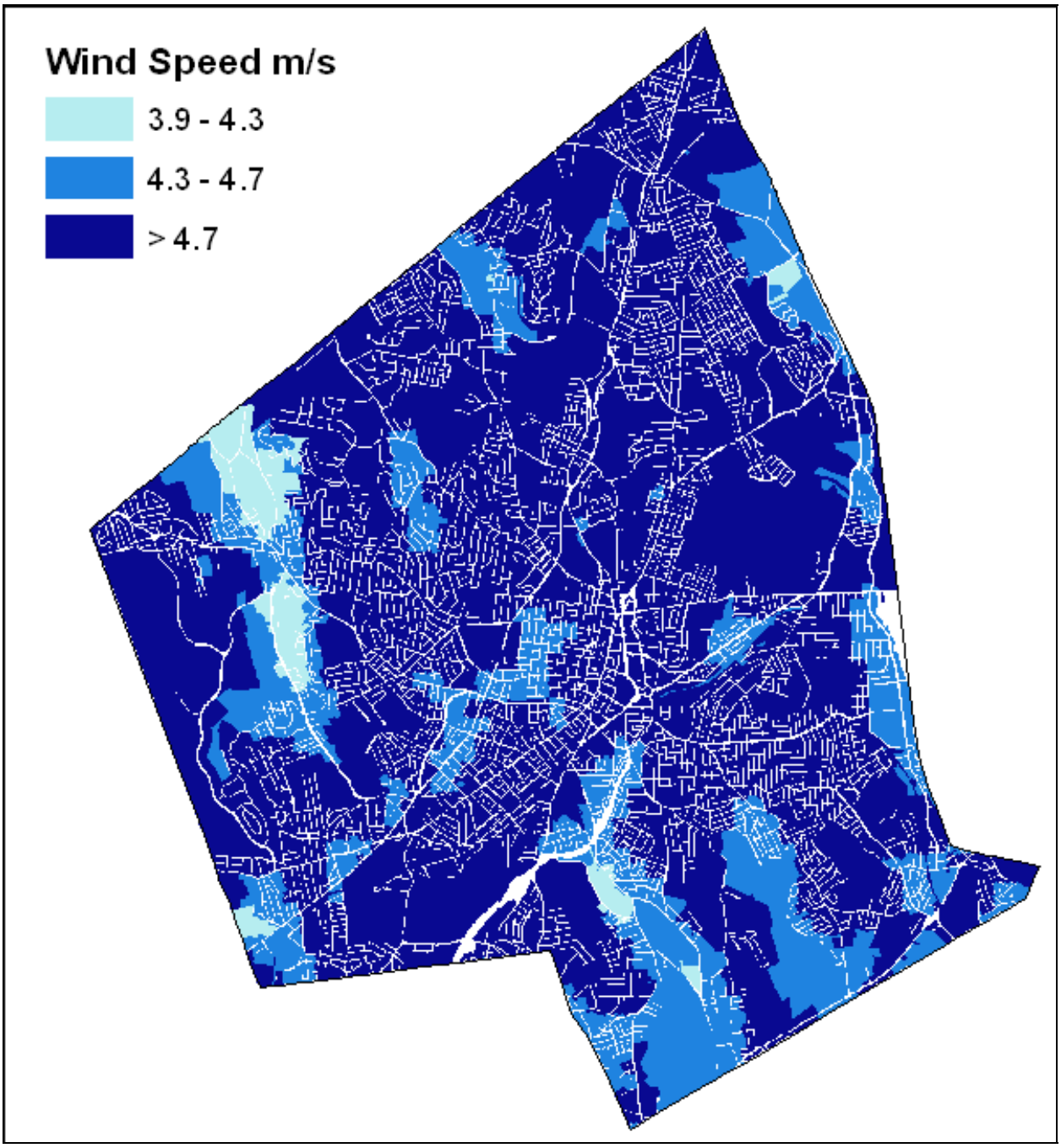
Data Analysis

In order to determine what areas of Worcester, if any, could possibly support small turbines, we examined large amounts of data. Visually representing the relevant data, namely wind speed and

parcel size as previously discussed, is the best way to analyze the data. To this end, the following maps of average wind speed, parcel acreage, and overall suitability were created. For notes on the creation of these maps and their accuracy please see *Appendix E: Methodology*. Also, interactive versions of these maps which allow a much higher level of detail are available in the form of a GIS layer (See *Appendix G: Interactive Map*).

Map of Average Wind Speeds

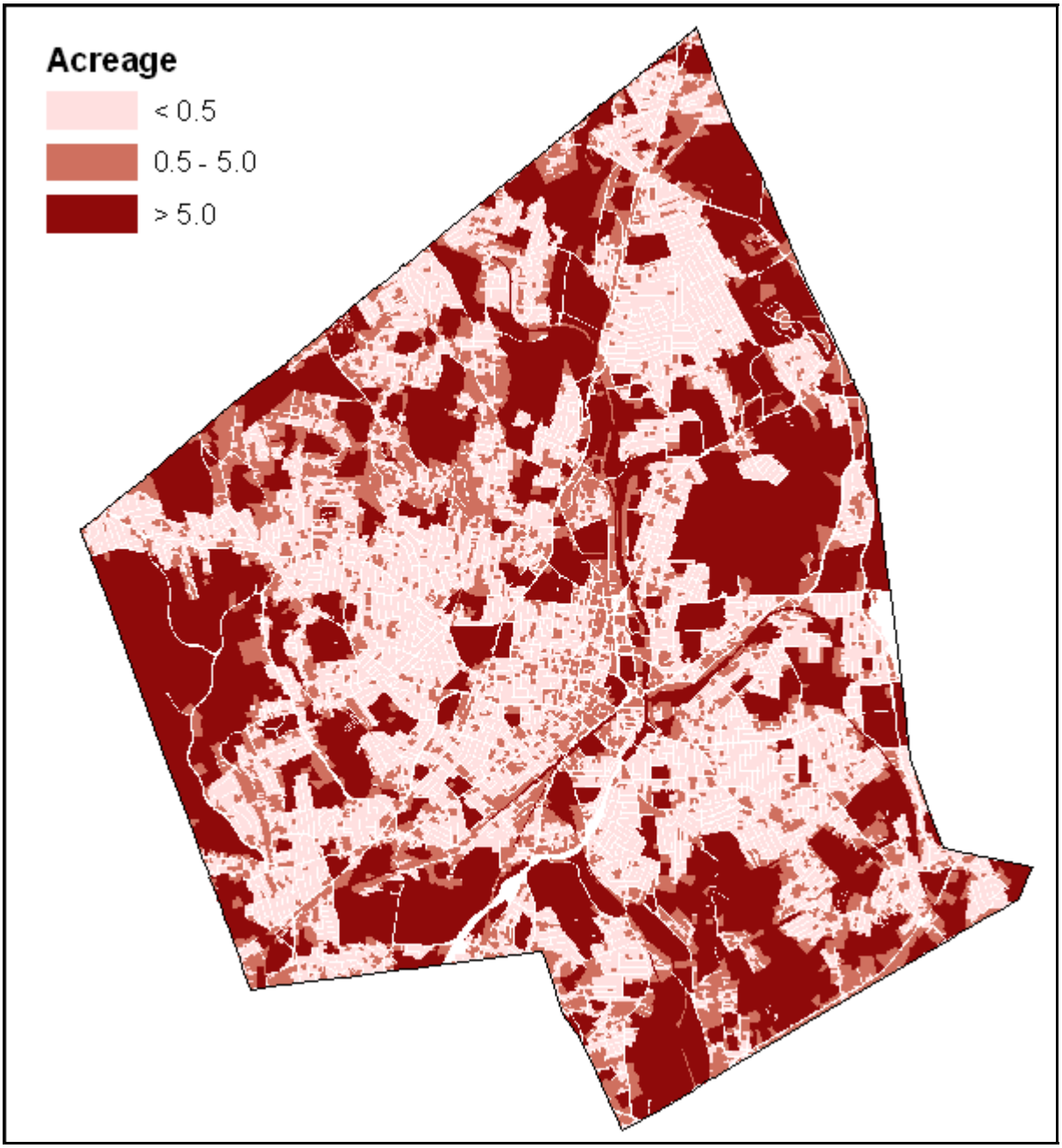
The map of average wind speeds (Map 1) can be used to quickly determine the areas in Worcester that meet the recommended wind speeds for small turbines. The darkest blue regions are the areas where the suggested wind speeds can be reached about 10 meters (33 ft) above the ground. In the medium shaded blue areas, the necessary wind speeds are attained at about 18.3 meters (60 ft) above the ground.



Map 1 – Average Wind Speeds

Map of Parcel Sizes

The map of parcel acreage (Map 2) can be used to quickly determine which parcels within the City of Worcester meet the recommended minimum parcel size of 0.5 acres for small wind turbine sites. Parcels colored with either of the two darker shades meet or exceed the



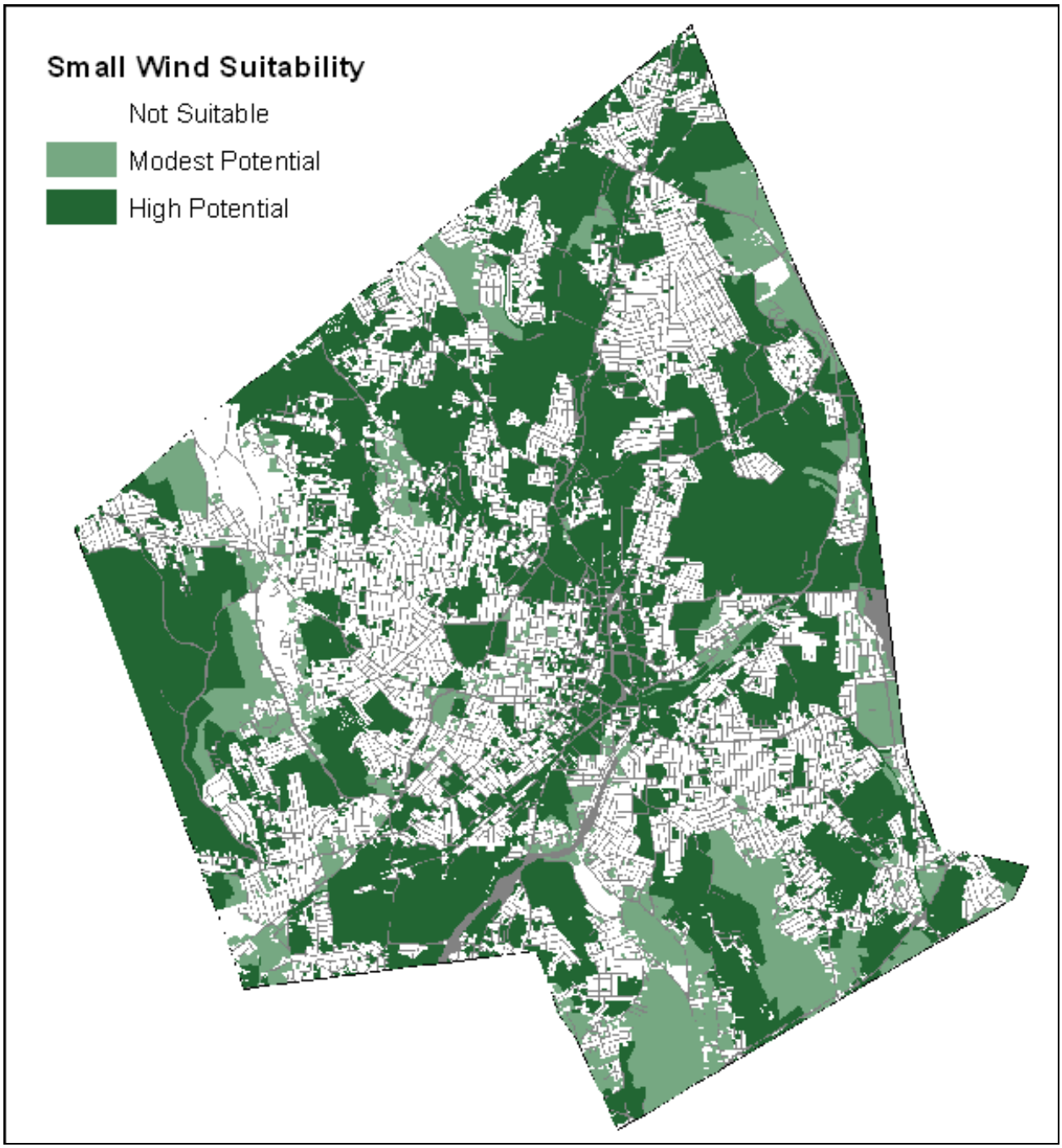
Map 2 – Parcel Sizes

recommended area. These darker colored parcels make up 14,045 of Worcester's 21,519 acres, or roughly two thirds of the land within the City. Parcel sizes are important to ensure that a plot of land is large enough to support a tower for a wind turbine. A site that is smaller than one half acre may not be able to safely accommodate a tower in the event that it falls. The suggestion of

0.5 acres as a minimum lot size is more of a way to estimate the more important set-back criteria that we will describe in detail in the Worcester Model Ordinance in Chapter 3. This ordinance states that the "Minimum tower set-back distance from the nearest property point is the distance measured from the mean grade surrounding the support to the tip of the blade in a vertical position measured along the vertical access of the tower." One half acre is simply a reasonable estimate for a lot that will be able to satisfy this condition.

Map of Overall Parcel Suitability

The map of overall parcel suitability (Map 3) is a combination of the previous two maps. The



Map 3 – Small Wind Suitability

high potential areas are the parcels that consist of at least half an acre of land and have an average wind speed of 4.7 m/s or more. It is these regions that represent the best areas in Worcester to think about putting up a small wind turbine. The modest potential regions also have at least half an acre of land, but only have wind speeds that are between 4.3 m/s and 4.7 m/s. The rest of the areas either do not meet one or both of the recommendations.

Recommendations

In this section, we analyze the previously explained maps to describe the suitability of Worcester for small wind development, and recommend some steps that could be taken by the City and other organizations such as the Regional Environmental Council (REC) to promote the installation of small wind turbines by Worcester residents and businesses.

Suitability for Small Wind Developments in Worcester

Regarding wind resources, there are sufficient wind speeds for small turbines to work satisfactorily in many areas throughout Worcester. Looking at Map 1, it is clear that there are adequate wind speeds for small wind turbines (darkest blue) spread around the City, with a few regions where the winds might be borderline low (lightest blue). We recommend that anyone in the two lighter blue regions use an anemometer to measure wind speeds for at least a year to get an idea of their average wind speed before putting up a turbine, as the actual wind speed at any location can be influenced by site specific features.

Our GIS analysis shows that there are many parcels containing the recommended minimum size lot of one half acre for small wind turbines (Map 2). This map does not take into account the presence or locations of buildings on any parcels, and therefore is not an entirely accurate indication of parcels that would be suitable for small wind turbines (particularly in more urban areas). It does, however, demonstrate the general picture that there are a significant number of parcels in Worcester that would have a sufficient lot size to build small wind turbines.

If it is assumed for now that a height restriction of 20 ft above surrounding structures and other obstacles (which is appropriate for reasons that are examined in the next chapter) is adopted, then the height restriction would be of little concern when siting small turbines. This height restriction should allow for adequate wind speeds, since the darkest blue regions of Map 1 represent sufficient wind speeds at 10 m (33 ft) above ground, and should be high enough to rise above turbulent winds in most cases (Southwest Windpower, 2005). A simple method to get a more accurate measurement of the height of turbulent wind at a specific location is described in *Appendix E: Methodology*.

Promoting Small Wind Development in Worcester

If an ordinance for permitting small wind turbines gets incorporated into the Worcester Zoning Ordinance, it would set the stage for small wind turbine installations throughout Worcester. With a new and likely little known ordinance, it will be important to endorse the benefits of personal wind turbines and the fact that Worcester provides suitable locations for small wind energy conversion systems. In this section, we discuss how the overall suitability map (Map 3) can function as an effective tool for promoting small wind development in Worcester, and examine the feasibility of creating a Wind Overlay Zone in the Worcester Zoning Ordinance.

Using the Overall Parcel Suitability Map

The City of Worcester, and others, should promote the criteria that make Worcester a good place for small wind power development. It is our determination that most of Worcester is suitable for small wind turbines; however, those areas that are particularly favorable should be targeted more assertively for considering installing a wind turbine. The map of overall suitability (Map 3) would be a particularly useful tool for targeting specific neighborhoods, as it provides a combination of adequate wind speeds and parcel sizes giving a clear visual representation of what areas are most suitable, moderately suitable, and not suitable.

An important question to consider is exactly how to use a map such as the one for overall suitability to promote small wind turbines in Worcester. The overall suitability should be taken as more of a general trend, and therefore should be used as a guideline for promoting small wind energy conversion systems within Worcester. With this is mind, the map could be used in a flyer or handout promoting small wind turbine installations. Such a flyer or handout could be created by the City of Worcester or the Regional Environmental Council to bring attention to and promote the newly passed ordinance. Refer to (See *Appendix F: Sample Brochure Promoting Small Wind Turbines)* for a sample brochure using the overall suitability map that could be used to inform citizens and promote wind development.

Wind Overlay Zone

We have considered that the City of Worcester could create a Wind Overlay Zone based on the most suitable areas for small wind development as identified in Map 3. An overlay zone is a specially designated district within the zoning ordinance that stipulates a specific use or other regulation that pertains only to that district rather than to a predefined zone (City of Worcester Zoning Ordinance, 1991).

We determined that such an overlay zone would not be useful for promoting small wind development; instead, a general, city-wide approach would be more favorable. For example, the City could consider adopting an ordinance whereby any small wind turbine erected would not count towards a property's value when determining the taxes owed to the City on that property. A benefit such as this should be applicable to any turbine erected in the City, not simply ones that fall within a predefined district. Another reason for not recommending a Wind Overlay Zone is the fact that such a map would not be accurate enough down to parcel lines to base any wind turbine specific regulations. The data used to develop such a map is a good estimate of wind speeds at best, and using it to develop any kind of specific regulations on the scale of a few city blocks would be inaccurate.

We have considered the most important siting criteria for small wind turbines, and analyzed them in the context of how they apply to Worcester. Using GIS maps created specifically for this purpose, we determined that many parts of Worcester would be suitable for small wind turbine installations. In the next section, the focus shifts towards medium sized wind turbines and the specific concerns associated with analyzing their potential in Worcester. The different approach taken to examine medium wind turbines reflects the difference in siting characteristics between small and medium sized wind turbines.

Assessing Medium Wind Turbine Potential

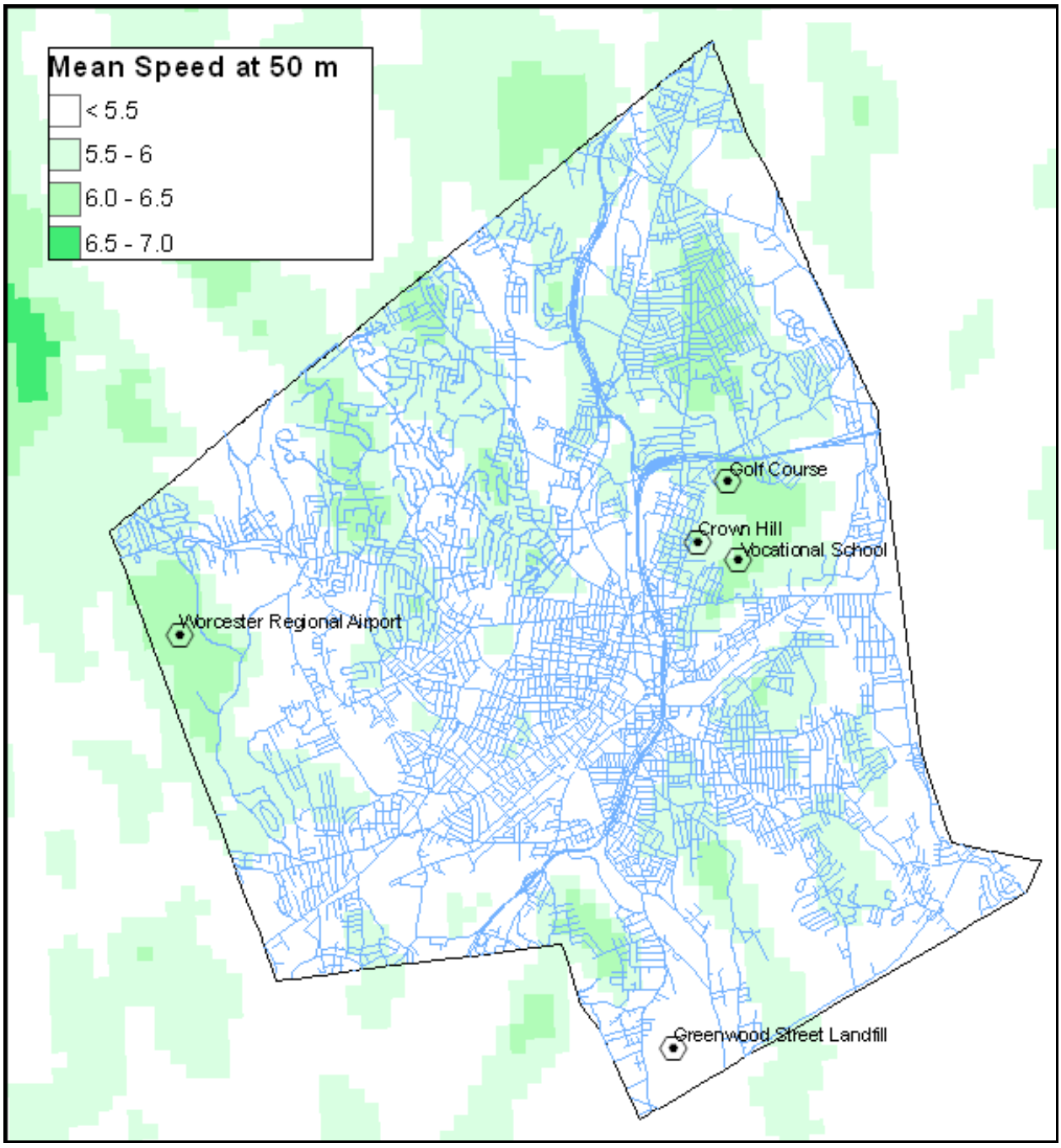
Medium sized wind turbines are the ideal solution for a municipality or large power user looking to contribute to the electrical grid and make a statement in favor of renewable energy. The following section will take a look at some sites around Worcester that have been suggested by local residents and renewable energy advocates as possible locations for the installation of city-owned wind turbines. The following desirable site characteristics, described above, are taken into consideration: wind resources, surrounding environment, tower access, and proximity to power distribution. In addition, land ownership will also play a major role in siting a municipally operated turbine, as land acquisition is not always a feasible option.

Although the listed sites are not the only sites in Worcester potentially able to support a medium sized wind turbine, we have focused on them specifically due to favorable wind conditions, elevation, and city ownership. If we had chosen to perform extensive GIS research prior to the site analyses it is likely that we would have chosen Green Hill Park and the Worcester Regional Airport as possible sites, but probably not the Greenwood Street Landfill.

Site Analyses

Average Wind Speed at 50 m

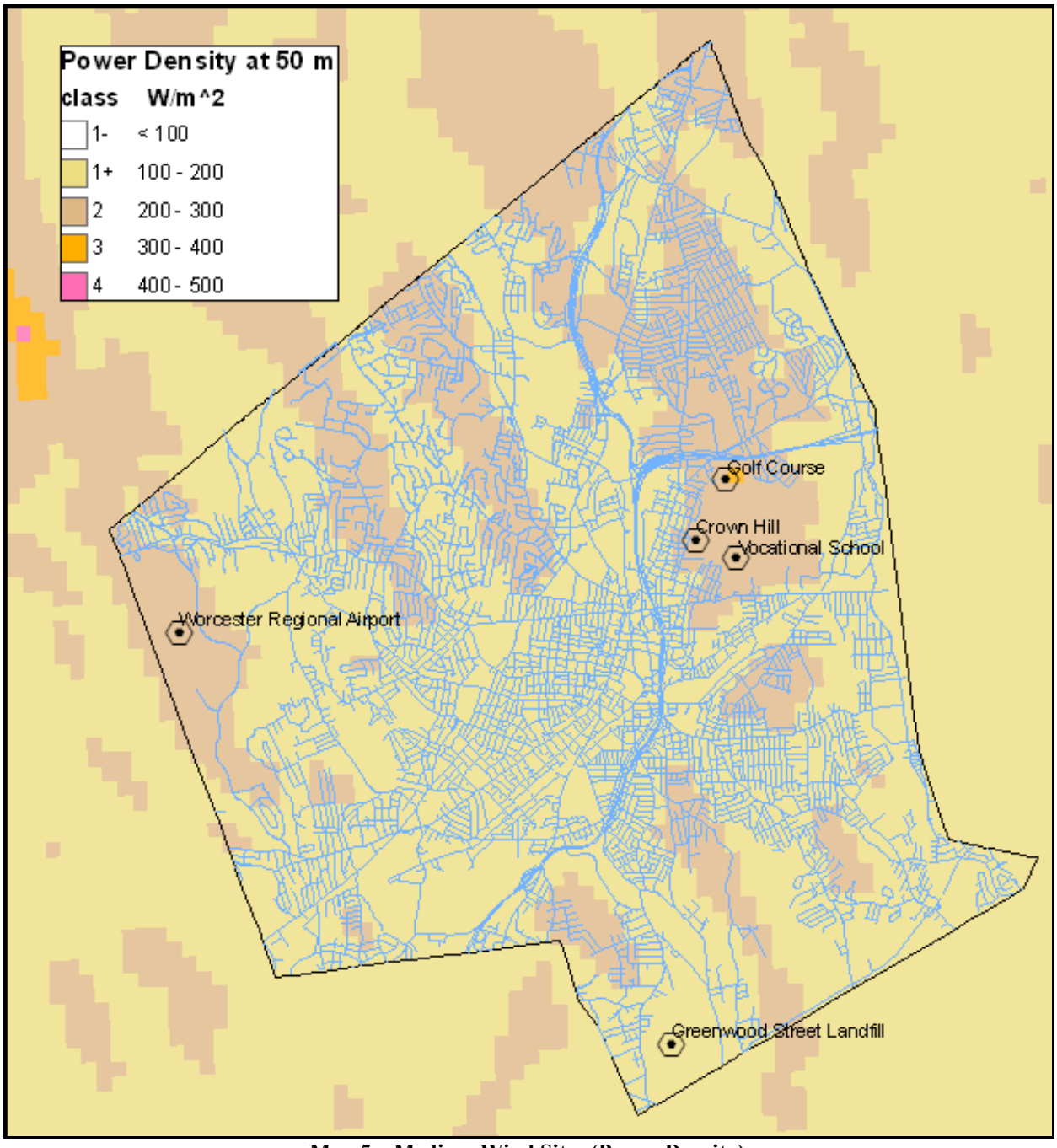
Map 4 illustrates mean wind speeds at a height of 50 meters for the City of Worcester. Of particular interest are areas that provide at least 6.0 m/s (19.7 ft/s) of wind speed. The five sites analyzed in this section are noted on the map. A note of interest is that there are practically no other areas in Worcester that provide desirable wind speeds without completely overlapping residential land.



Map 4 – Medium Wind Sites (Wind Speed)

Average Power Density at 50 m

Map 5 illustrates average power density. Wind power density is a function of the cube of the wind speed and is a more accurate way to determine if a site has desirable wind characteristics. Using the wind power density it is possible to assign a wind power class. A wind power class of less than two is not desirable for any medium sized wind turbine. The greater the wind power class, the more desirable a site becomes. Similar to Map 4, the five proposed sites are overlaid on Map 5.



Map 5 – Medium Wind Sites (Power Density)

Green Hill Park

Overview

Green Hill Park spans over 480 acres of land and is Worcester's largest municipal park (WPR, 2005). It is host to many outdoor recreational activities in Worcester and is used by many residents. There are three sites within Green Hill Park that have been individually analyzed, the first of which is located atop Crown Hill in the southwest corner of Green Hill Park, overlooking Green Hill Pond and a nearby parking lot. The second site is located at the highest point of the Green Hill Municipal Golf Course. The final site is located at the new vocational school by the playing fields, just outside of the park borders.

Preliminary Studies (Crown Hill)

Before onsite studies were conducted there were several pieces of information that had already made the Green Hill Park site look favorable. First, it is located on open, city owned land. This means the City would not need to acquire any additional land or demolish existing structures to accommodate a wind turbine. Also, the wind maps provided by the Renewable Energy Trust indicate wind speeds of approximately 6.0 m/s (19.7 ft/s) at 50 m (164 ft) above the ground at the summit. These speeds are reasonable compared with many other areas in Worcester, and would be adequate to fulfill the cut-in velocity of an average medium sized wind turbine.

On-site Analysis (Crown Hill)

A brief onsite analysis turned up many new characteristics that are easily overlooked when analyzing GIS data. At a glance there are several traits that stick out as ideal conditions for a wind turbine.

Figure 3 – Crown Hill

One notable characteristic is that the site has excellent visibility from major roads. Interstate 290 and downtown Worcester are both clearly visible from the summit. This would make a wind turbine an unambiguous statement of Worcester's commitment to renewable energy. It is also apparent upon observation that Crown Hill is within very close proximity of distribution lines. This would most likely save the city from having to run power lines for attaching a new turbine to the electrical grid. Because Green Hill Park is a municipally owned park, there are also service roads leading to various locations in the park. At the base of Crown Hill there is a service road leading to a slightly worn trail which would be sufficient for construction vehicles in the building process.

While there are many desirable characteristics within this site, they come with a cost. The most obvious problem with the site is related to the proximity of housing. A wind turbine placed at the highest point of the hill would be within a couple hundred feet of several households' front yards. Under some conditions it may be desirable to have a wind turbine close to residential areas, however being this close would almost certainly raise concerns amongst the nearest households.

Preliminary Studies (Golf Course)

The Green Hill Park Golf Course is a hopeful consideration, but does raise some concerns as it is actively used. It is located entirely on city owned land, meaning that there would be no burden of acquisition for the city. Depending on where a turbine is placed, it may or may not interfere with the use of the golf course. This location harbors wind speeds of approximately 6.4 m/s (21.1 ft/s) at 50 m (164 ft) above the ground. The wind power density is in the class 3 range and is the highest wind power density in Worcester at 310 W/m^2.

On-site Analysis (Golf Course)

A brief on-site analysis of the Green Hill Golf course affirms that the site has desirable physical characteristics for the installation of a wind turbine. The highest point of the golf course carries a noticeably stronger wind than other areas of Worcester, and trees at the site demonstrate noticeable flagging (Figure 4 – Golf Course), a good sign of consistent and non-turbulent wind. Also, being that the site is in the middle of a golf course, a large structure would certainly be visible by many people and would be a clear sign of the City's commitment to renewable energy.

Figure 4 – Golf Course

Unfortunately, the windiest areas of the course are located within a fairway. To install a wind turbine in an ideal location might require significant restructuring of the golf course. This is an undesirable aspect and would probably cause opposition, especially from members of the golf course. In addition, there are no distribution lines running to the middle of the golf course, and it is uncertain the amount of work that would be involved in running underground lines through other parts of the course.

Preliminary Studies (Vocational School)

The new vocational school is located just outside Green Hill Park, and appears very desirable with the available data. The most desirable portion of land is across the street from the school where the playing fields are. Similar to the other sites located in the park itself, all of the land is owned by the city and would not have to be purchased. The site harbors wind speeds of approximately 6.3 m/s (20.6 ft/s) at 50 m (164 ft) above the ground at the summit. The wind power density is in the class 2 range which is good compared with many other areas of Worcester and would be sufficient for a medium sized wind turbine.

Figure 5 – Vocational School

On-site Analysis (Vocational School)

An on-site analysis of the vocational school's playing field area provides good evidence that the site would be conducive to a wind turbine. The area is higher than any of the nearby hills, and is windier than any nearby areas. There are already large lights and a communications tower

installed behind the playing area which can be seen from surrounding locations. An argument could be made stating that erecting a windmill would be no more obtrusive than these structures, and would also provide clean energy to assist in Worcester's renewable energy promise. Access roads lead up to the playing fields as well, which would allow for construction vehicles during the installation process and maintenance operations. Power distribution should also not be a problem, as underground distribution lines have already been run to this site.

Conclusion

Although the summit of Crown Hill in Green Hill Park has many desirable characteristics, opposition from neighboring residents may be a very difficult obstacle to deal with. In addition, wind speeds could be better, which may make it difficult to justify the work that would go into such a project. This is definitely a site to keep in mind, but research into other sites is worthwhile to find an area where there will likely be less opposition.

The Golf Course in Green Hill Park may be a possibility. More research would be necessary to determine if it would be possible to get a wind turbine in place without interrupting the course's daily use or rendering parts of the course unusable, probably with an off-season installation.

The vocational school seems to have very desirable characteristics compared to other green hill sites. It is higher than surrounding areas, has reasonable winds, is visible but not too close to residential, and is accessible.

Worcester Regional Airport

Overview

Worcester Regional Airport is located at 375 Airport Drive, and is owned and operated by the Massachusetts Port Authority. The airport has two runways and a state of the art passenger terminal. The site is located about 1000 feet above sea level.

Preliminary Studies

Worcester Regional Airport has very desirable wind speeds compared to those of other areas of Worcester. In fact, it contains the largest area for high wind speeds in the City of Worcester by a great margin. The wind speeds of approximately 6.4 m/s (20.9 ft/s) can be found at 50 m (164 ft) above the ground. The wind density is classified as class 2/3 which is adequate for an average medium sized wind turbine. Another benefit of this site is that wind data for the past several years is already on file at the airport. This could save years of data collection that would be necessary at another site. The City of Worcester also owns the land that the airport is built on. This means that the City would not need to go through an acquisition process to obtain the land. In addition, access to most parts of the site would not be a problem due to the very open landscape. On the other hand, it may be difficult to ensure that FAA regulations are met when erecting a turbine in such an environment.

Figure 6 – Worcester Regional Airport

Conclusion

The large open area, proximity to major roads, very good wind speed, and accessibility make the Worcester Regional Airport a great site for consideration. On the down side, there are several federal regulations that need to be cleared to ensure that a tower will not interfere with flights. There may also be an issue with magnetic interference with the airport's air traffic control systems. These are special considerations that would need to be reviewed with a windmill manufacturer, the FAA, and the contracted installers. The city will be unlikely to consider this for a site unless it can be done with zero expense to the current or future viability of the airport.

Greenwood Street Landfill

Overview

The Greenwood Street Landfill is located along route 146 in the southern portion of Worcester. The site was operated until 1972 when it was capped. Since the capping, the landfill has gone through standard city reviews, but has not been used for anything useful. In April of 2005 a report was published detailing possible long term uses for the landfill. Although nothing related to wind power was mentioned at the time, it has been considered for analysis as it is a large, empty area of city owned land that needs a use.

Preliminary Studies

The Greenwood Street Landfill has a couple of desirable characteristics at first glance. To begin, it is near distribution lines and would not require excessive cabling to attach to the electrical grid. Also, the land is currently city owned and not being used for anything.

Some concerns include the fact that the city has already put extensive amounts of research into other uses for this site and has not even begun considering a wind turbine located here. Also, the foundation for a wind turbine may be an issue on a capped landfill site and would require special considerations. Another concern is the fact that the landfill is a nesting ground for the grasshopper sparrow, an endangered species of bird. This may cause controversy amongst local bird advocates who often have a predetermined apprehension in regards to wind turbines and the potential dangers of migrating birds unable to notice spinning blades. Lastly, the wind conditions for this site are not very desirable, consisting only of low class 1 winds.

Figure 7 – Greenwood Street Landfill

Conclusion

The Greenwood Street Landfill does not look like a very worthwhile site to consider for erecting a wind turbine. On one hand, the city is looking to do something with the site, and the proximity to a major road (Route 146) would be a good social aspect, reinforcing Worcester's commitment to renewable energy. On the other hand, the wind speeds are less than adequate, and there are deterring technical factors, as well as possible dangers to a sensitive breeding habitat.

Site Recommendations

Upon analyzing five possible sites, there are certain characteristics that stand out distinguishing the level of potential for wind turbine construction.

Green Hill Park seems to be a promising site, with the vocational school possibly being the most likely of the three areas investigated. Although the wind readings are slightly lower than that of the nearby golf course, the school site still has very good wind speeds. A turbine here would be visible, make a political statement, and would not be likely to interfere with surrounding activities.

The Worcester Regional Airport is also a desirable site. Having better wind speeds than most of the rest of Worcester would give the airport a meaningful technical advantage. The airport land is also owned by the City, allowing for easy implementation of the project. The major downside in constructing on or near an airport is interference with FAA regulations. Any structure being erected within 20,000 feet of an airport leads to more restrictive conditions set forth by the FAA. An FAA review may be required to determine whether or not the wind turbine would be a hazard to air navigation (US Department of Energy, 2005). This may or may not hinder development, but would be something that the related authorities would need to discuss. More studies will be necessary to analyze whether or not the airport is a feasible site.

Greenwood Street Landfill seems to have few desirable characteristics for erecting a wind turbine, and is not recommended for further research. The site has poor wind conditions, and several other related uncertainties due to the capping of the landfill and the other potential uses that may be significantly more beneficial to the city than a wind turbine which may not have the necessary wind speeds to cut-in.

Upon analyzing the three sites above, and also performing analysis of city GIS data, we have concluded that the only sites in Worcester that appear reasonably suitable for the installation of a city-owned medium sized wind turbine are Green Hill Park and Worcester Regional Airport. More research will be necessary to determine the best area of Green Hill Park, as well as to determine the real feasibility of an installation at the airport. There are no other sites in Worcester that show obvious signs of suitable winds, while at the same time not directly overlapping densely packed residential areas.

Summary

A clear distinction has now been made distinguishing small wind turbines from medium wind turbines. We have considered the most important siting criteria for each size wind turbine, and made recommendations regarding how they can be applied to sites in Worcester. We developed maps that helped establish Worcester's suitability for small wind turbines, which we recommend can also be used by the City or other interested groups to promote small wind developments. Another use for these maps was considered, the creation of a Wind Overlay Zone, however we determined that this would not be favorable.

We have determined that Worcester appears to be a good location for small wind turbines, an average location for medium wind turbines, and a poor location for large wind turbines. To this end, it is recommended that the installation of small wind turbines be encouraged within the City.

To do this, a permitting process will need to be defined, which is thoroughly explained in the next chapter.

We also specifically analyzed a number of potential sites that might support medium sized wind turbines as suggested to us by various individuals. We used criteria set forth earlier in the section which were adapted from the previous IQP (Kalisz et al., 2005). We have determined from GIS maps that there are no great sites for a medium sized wind turbine in Worcester, although there are some adequate sites which would need to be investigated further. While the most important siting criteria for both size turbines have been presented and analyzed, it has yet to be discussed how to go about installing a turbine and governing its use.

Chapter 3: Enacting a Wind Turbine Permitting Process in Worcester

Introduction

Although renewable energy is not a new idea, the concept of using windmills as a means of generating electricity has recently gained significant media attention and the support (and opposition) of many new advocates in the Northeast. The City of Worcester, like many other cities and towns in the area, makes no reference to wind energy conversion systems in their zoning ordinance.

The current lack of a permitting process may be a deterrent for people who consider installing a system and do not know what legal processes apply. It may also encourage people who are seriously interested to bypass local authorities and erect a structure on their own. Doing this can both be dangerous and create serious conflict with neighboring residents.

In the previous chapter a discussion of different types of wind turbines and their characteristics was presented. After defining some basic siting criteria, we determined Worcester has modest potential for medium sized turbines and good potential for small turbine development.

This chapter therefore, will focus primarily on the permitting of small sized wind turbines and is not written with the intent of passing legislation for commercial or municipal scale wind projects. While the information here may be useful for such a venture, it is recommended that this be undertaken by a utility company or wind turbine installation contractor familiar with designing such legislation. A full explanation of related research and methodology can be found in *Appendix E: Methodology*.

The intentions of this chapter are to familiarize the reader with the current state of legislation pertaining to wind power in the City of Worcester and supply the tools necessary for incorporating new wind power legislation into Worcester's current zoning codes. First, an analysis of the current regulatory status will be presented. Next, a summary of proposed changes will be outlined and justified. Finally, a detailed description of the process for implementing these changes will be presented.

Existing Regulatory Status

Overview of Wind Legislation

The use of wind as a renewable form of energy carries legislation at all levels of the government including federal, state, and local. In the interest of collecting background information and familiarizing the reader with a broad picture of wind energy in the United States, this introductory section will discus briefly the different types of legislation commonly enacted at each level of the government. This will assist in understanding a more specific analysis of zoning issues in Worcester and process of passing ordinance amendments.

Federal Government

The federal government influences the wind energy market primarily through incentives. They have virtually no influence over the placement or permitting of any sort of wind turbine, with the

exception of turbines erected on federal land or water. Various forms of financial incentives, mainly tax breaks, are available through legislation defined by the Energy Policy Act of 1992, the Farm Security and Rural Investment Act of 2002, and to a lesser extent, the Public Utilities Regulatory Policy Act of 1978 (Windustry, 2005).

State Government

Some state governments define a standard set of permitting guidelines for local cities to fall back on in the event they are lacking legislation of their own. A very good example of this is the state of California, which passed a bill defining some basic rules regarding the permitting of wind power. California's wind turbine laws limit the restrictions that counties can put on zoning requirements, and act as the standard when no regulations are in place. Some specifics of the laws pertaining to wind turbines in California are discussed in more detail later in this chapter in the section titled *Considerations for Siting and Building Wind Turbines*. While Massachusetts has no similar state law, there exists a group known as the Massachusetts Technology Collaborative (MTC). The MTC is the state's development agency for renewable energy and the innovation economy, and provides a significant amount of funding and grants for wind projects throughout the state. The Commonwealth of Massachusetts also exempts wind energy equipment from sales tax.

Local Government

The local level is where site specific legislation is written; the most significant of which is local zoning and building regulations. Many municipalities in Massachusetts, including Worcester, have no regulations in place to accommodate wind energy. The remainder of this section will compare the zoning laws written into the zoning ordinances of several municipalities in and around the Commonwealth of Massachusetts. This analysis, along with the information provided in the American Wind Energy Association's (AWEA) *Permitting Small Wind Turbines: A Handbook*, provides a good starting point for developing additions to local ordinances elsewhere.

Current State of Wind Turbine Permitting in Worcester

The City of Worcester Zoning Ordinance contains all of the relevant permitting and zoning regulations for various structures and uses in the City of Worcester. This is the first place to look when investigating how a new structure should conform to building code and zoning restrictions. A detailed scan of the Worcester Zoning Ordinance, however, makes no mention of how or where wind turbines can be erected in the City. A visit to the Department of Code Enforcement confirms this finding. This section examines how wind turbines are currently treated within Worcester, in the absence of any references to them in the zoning ordinance. In the analysis, we consider why wind turbines are treated as they are, and a way to actually put up a turbine in the City. It should be noted that although there are no specific references to wind turbines in the Worcester Zoning Ordinance, there is a recent amendment that specifically addresses permitting for personal wireless service facilities. An analysis of this section and how it might apply to a permitting process in Worcester can be found in *Appendix D: Personal Wireless Towers, a Suitable Starting Point?*

Since there are no regulations in the City of Worcester Zoning Ordinance specifically addressing the installation of wind turbines, the question of how to treat wind turbines with respect to building code needs to be interpreted from more general provisions within the code. When asked

about how the Department of Code Enforcement would treat an application for a wind turbine, Michael Pace and the Director of Code Enforcement, David Holden, determined that a wind turbine would be treated as manufacturing use, given that a turbine's primary function is to manufacture electricity. The Worcester Zoning Ordinance has specific regulations for manufacturing uses and what zones they are allowed in, and specifies that a manufacturing use would not be allowed in a residential, business, or institutional zone. Manufacturing activities are only allowed in manufacturing zones, and only by special permit (Pace, 2005). Even with the turbine being allowed as a manufacturing use by special permit, there are no structural or procedural guidelines regarding the building of a turbine, and it would be considered like any other structure in that zone.

This interpretation raises several questions, as well as opens a variety of possibilities. While considering each option, we keep in mind that one of the major objectives for this project is to establish a set of guidelines for a small wind turbine permitting process in the City of Worcester. It is an important step towards this objective to investigate and analyze any existing regulations in the City; however, the bigger goal remains finding a generally applicable set of guidelines for putting up small wind turbines.

One question to consider is why wind turbines would be considered as a manufacturing use, if there is no such similar designation applied to solar panels? Solar panels do the same thing as wind turbines; they collect a natural energy resource and convert it to electrical energy, yet one can be installed on private property without much interference from the town. The reason for this can be found in Massachusetts General Laws (M.G.L.), which states that "No zoning ordinance or by-law shall prohibit or unreasonably regulate the installation of solar energy systems or the building of structures that facilitate the collection of solar energy, except where necessary to protect the public health, safety or welfare" (M.G.L., Ch. 40A, Sect. 3). According to this law, there is a direct statement about the only conditions that would allow local governments to regulate solar panels. There are no such references to wind energy conversion systems in the M.G.L., and therefore, cities and towns need to treat wind turbines in a way that is in consistent with their own zoning ordinances. This explains why Worcester might treat wind turbines under a manufacturing use, and not solar panels.

Another question to consider is how to treat small gas powered electric generators versus wind turbines. They convert the chemical energy of gas to electrical energy much like wind turbines convert wind to electrical energy. They are just as much of a manufacturing use as wind turbines are, however, they are much more common and harder to permit. Anyone can walk into a hardware store and buy a generator and use it outside of a manufacturing zone. While generators do manufacture electricity, they are widely accepted as personal appliances and it is unlikely they would be compared to wind turbines by the Department of Code Enforcement. In addition, these generators are not often used as a primary or even significant energy source; they are mostly only used when the grid loses power temporarily or at a site that is removed from any other power supply. A wind turbine, on the other hand, would be built to continuously run and manufacture electricity any time there is wind. Therefore, this comparison with gas powered generators cannot be pursued to form an argument against considering wind turbines as a manufacturing use.

There are options available, however, if one still wanted to put up a windmill on one's property even if it was not zoned for manufacturing. At the office of the City Clerk, we were informed by an assistant that you can petition the City Council for an extension of a zone. For this option to apply to this example, the property in question would have to border a manufacturing zone. The owner of the property would petition the City Council through the Office of the City Clerk to have the manufacturing zone extended to their property. If the zone extension was granted, then the owner would then have to apply for a special permit to use the property for manufacturing (the wind turbine). At this point, there would need to be a public hearing with the zoning board of appeals to obtain the special permit. This is a rather cumbersome process, with many places for the process to get caught up and go wrong.

When considering this option with respect to our project, it does not address our objectives. It may work for certain cases; however, it would not even be applicable to the majority of situations since most properties do not border a manufacturing zone. In addition, we are looking for a process by which there are clear guidelines to place turbines. Even if a special permit were granted to erect a wind turbine as a manufacturing use, there are no guidelines to ensure the safety of the property owner, or that of neighbors.

Another option to consider, which Mr. Pace suggested, was to make an amendment to the zoning ordinance. He referred to the section on personal wireless towers and explained how a few years ago, an amendment was proposed for the personal wireless towers, which was accepted and became part of the Worcester Zoning Ordinance. It was emphasized that an amendment for wind turbines would be a separate part of the ordinance, unrelated to the section for personal wireless towers (Pace, 2005). This presented the most desirable option for establishing a permitting process according to our objectives, as it could be developed by taking into consideration the characteristics for a desirable permitting process described above. Therefore, this section of the report is focused on developing a model ordinance to address wind turbine permitting, and detailing the process one would follow to incorporate it into the Worcester Zoning Ordinance.

Recommendations for establishing a permitting process

Desirable Permitting Process

This section will look at major features to consider when developing a permitting process for wind turbines, and what is desirable in such a process. What one considers desirable will differ depending on the perspective taken; whether it is the person looking to put up the turbine, the city officials that work with the permitting process, or nearby neighbors that may have concerns about the turbine going up in their backyard. All of these are important perspectives to consider when trying to develop a permitting process that is advantageous for everyone.

There are a number of factors that can make a permitting process either favorable or unfavorable for installing wind turbines, and for public acceptance. The way in which the process is set up, in addition to the cooperation of local officials, will go a long way towards establishing the effectiveness of the process itself. For someone erecting a wind turbine, the most important features of a turbine permitting process are the costs associated with obtaining a permit, the time required to get the permit, and the restrictiveness of requirements for siting the turbine (Permitting Small Wind Turbines, 2003). Equally as important when considering these aspects are the impacts on others within a city, in particular the city officials dealing with the

administrative side of giving a permit and neighbors who will benefit from clear, well established guidelines that ensure their privacy and safety. A city that is interested in promoting renewable forms of energy, as Worcester is, can send a clear message about its intentions by taking these factors into consideration when developing a permitting process for wind turbines (Kotsopoulos, 2005).

Cost Considerations

The costs involved with obtaining a wind turbine permit are a significant concern to someone putting up a turbine, particularly private homeowners looking to save on electric bills. A permitting process should be developed so as to reduce unnecessary costs, both on the side of the city and on the side of the individual looking to put up the turbine. In the interest of knowing where costs can be reduced in a permitting process, this section looks at the various costs, both implicit and explicit, that could be associated with putting up a wind turbine.

Processing fees and other associated costs can include everything from the cost to get a special use permit to the costs for required public hearings. The extent to which fees are required depends on the city or town in which a permit is requested as well as the type of permit under consideration. Some examples of places where fees have proven to be unfavorable for turbine installations can be found in California. In Los Angeles and Sonoma Counties, for example, there are conditional use permits in excess of $1,000, plus additional fees if hearings are necessary. In Riverside County, an individual interested in installing a turbine ended up paying over $5,000 in fees and other associated costs (Permitting Small Wind Turbines, 2003).

When looking at the cost involved in obtaining a permit for wind turbines, one must look at more than just the cost of a permit and fees associated with possible hearings. Other associated costs to be considered include site plan drawings, noise level studies, site inspections, maps, artist renderings, and engineering analyses. These are all costs incurred where the individual interested in putting up the turbine would have to hire a contractor or engineer to perform and/or approve the previously mentioned tasks. The costs associated with these requirements can be reduced or eliminated by carefully selecting what is absolutely necessary to obtain a permit. For example, requiring manufacturer supplied turbine drawings and specifications in place of an engineering analysis, or eliminating the need for superimposed images of the turbine in the surroundings from different viewpoints, can reduce unnecessary costs.

Cost is particularly important to small wind installations intended for private homeowners. When a private homeowner is the principle investor, financial considerations are often a significant factor in the decision to erect a turbine. Someone interested in putting up a turbine for personal use can quickly be deterred if they face fees and other costs that will approach thousands of dollars. Depending on the size of the turbine, these could approach the cost of the turbine itself.

Time Considerations

Like cost, time is an important factor to consider when developing a good permitting process. The length of time required to obtain a permit can be closely related to the costs involved. Inevitably, as the process for obtaining a permit drags on, additional costs will be incurred by both the city and the individual looking to put up the turbine. Also, a process that may take

months or even years can be a deterrent to someone looking to put up a turbine. In this section, the factors involved in lengthening the permitting process are examined, including how they can affect the cost of the project.

Similar to the costs involved, the time required to obtain a permit can vary greatly among municipalities depending on the structure of the permitting process. The time frame could vary from weeks to months to over a year depending on whether or not hearings are involved, how strong any opposition might be, and the efficiency of the local boards and departments. The majority of these factors, while addressable by appropriate permitting legislation, also depend on the infrastructure of the municipality's planning, zoning, and building departments. Given that a permitting process can be put into place in a city or town, the inefficiencies of the boards and departments that need to communicate with each other can serve to hinder the issuance of a permit. This will undoubtedly extend the time required. Municipal governments that have previously dealt with wind turbine permitting tend to be much more efficient and able to move paperwork through the system faster than one that does not have prior experience.

Often times, local opposition is a major factor in prolonging the process for obtaining a wind turbine permit. Local opposition should not be considered lightly, as neighbors should be allowed to ask questions and express concerns about what is going on around them. When dealing with local opposition, their concerns, both reasonable and unreasonable, should be addressed respectfully and without long delays. As more time is taken to address these concerns, it costs the city and taxpayers more money, and delays the start of putting up the wind turbine. An example for this can be found in the town of Penfield, NY, where a resident wanted to put up a windmill on his property. There were already special use permits for windmills in the town's zoning ordinances, and even though the project plans would conform to the ordinances, an open hearing was required. At the meeting, residents raised concerns about noise levels, declining property values, children climbing the tower and getting injured, the fact that power was already provided to the house by the local utilities so a windmill was unnecessary, and various other objections. More meetings needed to be scheduled because of this opposition, and the process went on for months with opponents hoping the turbine applicant would simply decide to drop the application (Stockman, 2005).

Considerations for Siting and Building Wind Turbines

Some of the most critical considerations for small wind turbine permitting are the siting criteria specified in the zoning ordinance. Both specific requirements for turbines at any site and general zoning requirements are examined in this section with respect to their influence on the permitting process. This is the area of permitting where the city or town can have the most influence on where turbines can be placed, and the various restrictions on the size of the turbine and the height of the tower. By carefully specifying siting requirements in the permitting ordinance, the concerns of neighbors, turbine applicants, and city officials can be addressed.

As mentioned previously, virtually all regulations for wind turbines are established at the local level in Massachusetts. A comparison to a recently similar situation in California will provide a good direction for developing guidelines in Worcester, and eventually in Massachusetts in general. In response to the difficulties associated with obtaining a permit for a turbine in different municipalities, particularly places that have no such laws in place, the state passed legislation standardizing certain regulations. The law states that "The implementation of

consistent statewide standards to achieve the timely and cost-effective installation of small wind energy systems is not a municipal affair … but is instead a matter of statewide concern" (California Government Code, Section 65892.13). This law, also referred to as Assembly Bill 1207 (AB 1207), sets limitations on the number and types of restrictions that municipalities can place on permitting requirements for wind turbines. AB 1207, while applicable only in California, can serve as a helpful guide for municipalities in other states where state-wide wind turbine permitting legislation is not in place.

AB 1207 allows for local governments to keep and maintain their own ordinances regarding turbine permitting, however, it sets restrictions on how limiting the requirements for a permit can be. In places within California where there are no ordinances for permitting windmills, the provisions in AB 1207 serve as the requirements for putting up a turbine. Some of the limitations set forth in the bill include: not requiring developers to notify neighbors whose properties are not within 300 feet of the property of the proposed turbine, and specifying that sound levels at neighboring houses cannot exceed 60 dB(A). As far as the actual design of the turbine, the only requirements are to have a structural analysis and drawings certified by an engineer, and an electrical line drawing which shows compliance with the National Electric Code (Permitting Small Wind Turbines, 2003).

When considering turbine height in relation to average wind speed, it is agreed that higher elevations correspond to higher wind speeds. In the interest of finding higher wind speeds it would be desirable to put a turbine up as high as possible; however, that is not always desirable for neighbors and due to safety concerns. According to AB 1207 in California, the most restrictive height limitations are 65 feet on sites between one and five acres or 80 feet on sites larger than five acres (Permitting Small Wind Turbines, 2003). Another option is to set a height restriction of 20 feet above nearby structures and other obstacles. The idea behind this restriction is to allow turbines to be above any turbulent wind created by those objects.

AB 1207 sets up siting criteria that can be inviting for a homeowner who would like to install a small wind turbine on their property. By standardizing many of the restrictions on ordinances for turbine installations, this bill prevents local governments from coming up with arbitrarily restrictive and unnecessary requirements for siting a turbine. There is still flexibility with the local governments, as they are free to make the requirements less restrictive than what is provided for in AB 1207. In addition, aside from requirements for permits, local zoning ordinances still apply to siting turbines, which is another way that local governments can have some flexibility in regulating turbine installations. For example, turbines may be prevented from being built in a historical district that is set by the city's zoning ordinances.

Although these guidelines apply only to counties and municipalities in California, the limitations set forth can serve as a fine example for local governments in any state. This is especially true for cities or towns where no criteria exist, and where there is some demand for a permitting process. This deficiency of local legislation seems to be a common theme throughout cities and towns in Massachusetts. A law similar to AB 1207 in California would certainly be beneficial to Massachusetts to help standardize permitting processes at the state level. In the absence of Massachusetts state law, however, these California guidelines can be helpful in setting up wind turbine ordinances in specific municipalities, particularly Worcester.

Comparison of Other City Ordinances

In order to better understand key factors of zoning laws, we decided to analyze the zoning ordinances of five nearby municipalities that included definitions for wind turbines. Table 1 - Nearby Zoning Ordinances shown below gives a brief comparison of significant factors and how they vary between locations. When analyzing other ordinances it was discovered that most covered very similar concepts that sometimes deviated from AWEA's recommendations. For a complete analysis of these sites refer to *Appendix B: Nearby Zoning Ordinance Analyses*.

	Dover, MA	West Bloomfield, NY	Southampton, NY	Nantucket, MA	Nantucket, MA	Eden, NY
Use	Any	Any	Personal	Residential	Commercial	Any
Power may be distributed	N/A	N/A	No	Local Property Only	Yes	N/A
Classified with	Special Permits	Special Permits	Accessory Structures	N/A	N/A	N/A
District Restricted	No	No	No	Yes	Yes	No
Towers per lot	N/A	N/A	N/A	1	By Permit	N/A
Rotation Governed	No	Yes	40 mph	No	No	Yes
Maximum Tower Height	75ft	By District (50ft or 75ft)	None	60ft	By Permit	N/A
Minimum Blade Clearance	10ft	15ft	15ft	N/A	N/A	30ft
Minimum Lot Size	N/A	N/A	N/A	N/A	N/A	N/A
Distance From Property Line	Mean grade to tip of blade	Mean grade to tip of blade	Mean grade to tip of blade	Mean grade to tip of blade	Mean grade to tip of blade	Mean grade to tip of blade
Guy Wire Distance From Property Line	N/A	10ft	10ft	15ft	15ft	10ft
Blade Color	N/A	N/A	N/A	Wight or Light Grey	White or Light Grey	N/A
Tower Secured	N/A	Yes	Yes	Yes	Yes	Yes

Table 1 - Nearby Zoning Ordinances

Zoning Ordinance Amendment

When looking at establishing a permitting process for wind turbines, a city or town should first understand its intentions. If the goal is to promote forms of renewable energy, as it is for Worcester, then the legislation regarding a turbine permitting process should reflect that. The process should be made easy to understand, be cost and time efficient, and should not be unreasonably restrictive in its criteria for where turbines may be placed. At the same time, cities should stand to protect their citizens by placing restrictions on noise levels, proximity to property lines, and holding public hearings for concerned neighbors to raise their opinions.

The most effective way to permit personal wind energy conversion systems in Worcester is to amend the current Worcester Zoning Ordinance to allow for the installation of such a system, therefore an amendment adopted in the same way that the Personal Wireless Service Facilities

was recently enacted should be proposed and implemented. Such an amendment could take as short a time period as 3 months or as long as several years to implement, depending on opposition put forth by local community members and city departments.

To reduce delays throughout the implementation process, it is important to have a firm understanding of wind power and its implications, as well as a clearly written proposition to present to the planning board. The proposition should include a recommended ordinance for integration into town codes, as well as examples of surrounding areas that have had success with wind power.

The American Wind Energy Association (AWEA) provides a model ordinance for cities to use when regulating wind turbines through local statutes (included in *Appendix A: American Wind Energy Association Model Ordinance*). While this is a very good basis for beginning to write up an amendment to a city ordinance, it is generally not adequate to implement in its unchanged form. It is important to take into consideration factors such as the density of housing, public input, and current laws when deciding how to draft a new ordinance.

Following is a model ordinance that could be considered when implementing zoning laws for Worcester. Although based partially on the sample AWEA template, it includes influences from many other nearby city ordinances, many of which are analyzed in *Appendix B: Nearby Zoning Ordinance* but specifically addresses certain needs of Worcester. It is important that the following ordinance is reviewed with a lawyer as well as the City's Planning Board for a successful integration. The best way to keep the implementation smooth is to make sure that all of the proper authorities are involved from the beginning and the needs of all related parties are addressed.

Worcester Model Ordinance

Wind Energy Conversion Systems

Definitions

Wind Energy Conversion Systems (WECS) – Mechanisms designed or operated for the purpose of converting wind energy into electrical or mechanical power.

Residential WECS – A WECS designed and operated primarily for the purpose of providing energy to structures on a single plot of land, which has rated capacity of not more than [50 kW].

Tower height – The height above grade of the fixed portion of the tower, excluding the wind turbine itself.

Permitted Use

Residential WECS shall be a permitted use in all zoning classifications where structures of any sort are allowed, subject to certain requirements as set forth below. The Special Permit Granting Authority for exceptions to this ordinance, as noted in the ordinance, shall be the Zoning Board of Appeals.

1. Building permit application: Building permit applications for a WECS shall be accompanied by a plot plan drawn to sufficient detail, approved by a city engineer clearly describing the following:

    a. Property lines and physical dimensions of the site.

    b. Location and proposed elevation of the WECS.

    c. Make, model, picture and manufacturer's specifications, including noise in decibels, of the proposed WECS.

2. Maximum number of towers per lot: One, except that more may be allowed by special permit.

3. Set-back: Minimum tower set-back distance from the nearest property point is the distance measured from the mean grade surrounding the support to the tip of the blade in a vertical position measured along the vertical access of the tower. In addition, no part of the WECS, including guy wires, shall extend closer than 10ft to the property boundaries of the installation site.

4. Tower Height: Tower height shall be limited to 60 ft total or 20 feet above structures and other obstacles on the same lot, whichever is higher, except that tower height may exceed these limitations by special permit.

5. Noise: No WECS shall produce sound pressure levels in excess of 5 dB(A) above the ambient noise as measured at the closest neighboring inhabited dwelling.

6. Compliance with FAA regulations: All WECS must comply with applicable FAA regulations, including any necessary approvals for installations close to airports.

7. Utility Notification: No WECS shall be installed until evidence has been given that the utility company has been informed of the customer's intent to install an interconnected customer-owned generator. Off-grid systems shall be exempt from this requirement.

8. Tower access: The tower shall be made inaccessible to unauthorized personnel.

Recommendations for implementing proposed ordinance

We recommend that a new, separate ordinance be added to the City of Worcester Zoning Ordinance to facilitate this recommendation, this section explains the process for amending the Worcester Zoning Ordinance, from preparing the proposal to the final adoption of the amendment. As we determined before, this would be the best way to implement permitting guidelines for wind turbines in Worcester. The information here is applicable to any change to the Zoning Ordinance; however, it is specifically used in this section in reference to an ordinance addressing Wind Energy Conversion Systems. Refer to Figure 8 for a step by step flow chart outlining the steps required to pass an amendment to the City of Worcester Zoning Ordinance.

The first step in preparing a proposal to the Worcester Zoning Ordinance is to perform the proper background research about small wind turbines and about examples regarding how they are permitted in other cities and towns (Section A in Figure 8). The next step would be to write a model ordinance that both incorporates the features desired in a wind turbine permitting process and that appears to be consistent with the City's existing ordinances. Both of these steps were performed as a part of this report. It is important to note, however, that one willing to pursue the proposal through the amendment process should be familiar with common permitting issues and should review the AWEA handbook for permitting, *Permitting Small Wind Turbines: A Handbook*. The reason for doing this research is that the applicant should be able to defend and make arguments in support of the proposal, should any questions or complaints arise during the process of implementing the amendment.

In addition to the proposed ordinance, the proposal should include information that would be important to any group within the City that would be responsible for making a decision about wind turbines (Section B in Figure 8). It can not be assumed that any city authorities are familiar with wind turbines, or anything else regarding them. Keeping this in mind, the applicant should develop a proposal that gives examples of other cities and towns that have permitting ordinances for wind turbines, especially those in Massachusetts and New England. The proposal should also contain pictures of the size turbines that would be the target for the ordinance, as it helps someone reviewing the proposal to see how the turbines would fit into the landscape (Kennedy-Valade, 2005). A final proposal for introducing a wind turbine permitting ordinance to the Worcester Zoning Ordinance is not developed in this report, however, the model ordinance along with the information in *Appendix B: Nearby Zoning Ordinance Analyses*, should serve as a good starting point for someone deciding to write a proposal.

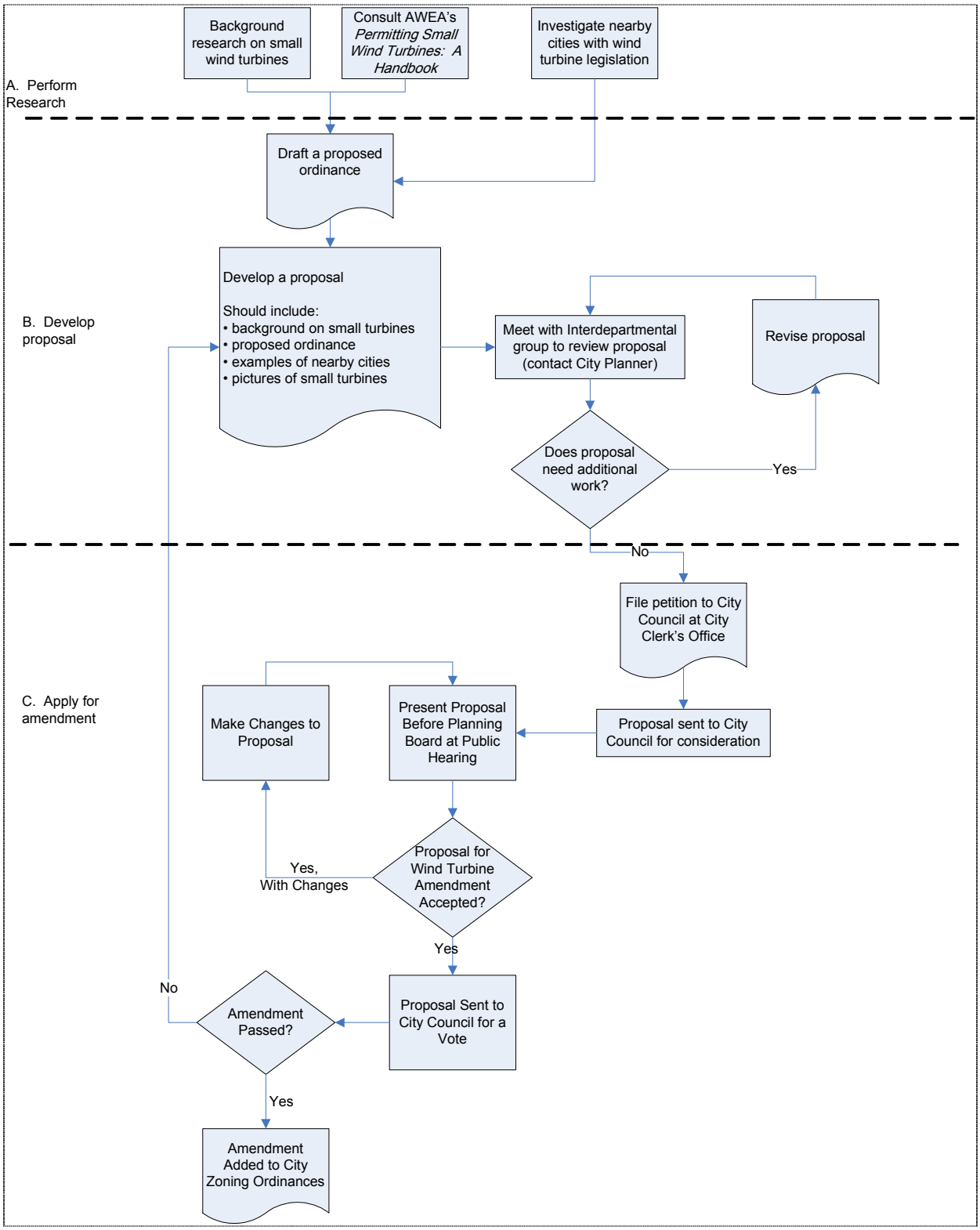


Figure 8 – Amending the Worcester Zoning Ordinance

Once written, an actual proposal can be reviewed by an interdepartmental group within Worcester that includes officials from Public Works, Code Enforcement, the Conservation Commission, the Planning Board, and the Law Department. These meetings are typically held once a week, and can be scheduled by contacting the City Planner (currently Joel Fontane). This preliminary review can be performed even before presenting the proposal to the City Council, and can provide valuable feedback as to what the different departments think about the proposed ordinance. They will discuss the proposal, including the proposed ordinance, and make suggestions to the applicant for how to develop something that would be incorporable to the Worcester Zoning Ordinance. The applicant can revise the proposal and meet with these officials until something is developed that both sides are comfortable with (Kennedy-Valade, 2005). With a proposal ready, the applicant can start the process of officially applying for an amendment to the Worcester Zoning Ordinance.

The first step in proposing an amendment to the Worcester Zoning Ordinance (Section C in Figure 8) is to file a petition to the City Council (Pace, 2005). The petition form can be picked up from the Office of the City Clerk at City Hall, or a link can be found online at the City Clerk's page on the City's website at http://www.ci.worcester.ma.us/cco/petition.htm. A sample petition can be found in *Appendix C: Sample Petition to City Council*.

Once the City Council receives the petition, they need to refer the proposal to the planning board. The planning board then has 65 days to schedule a public hearing to discuss the proposal, in agreement with M.G.L. Chapter 40A, Section 5 (Boynton, 2005). The planning board then reviews the proposal and makes a recommendation to the City Council as to either accept the proposal or reject it. The planning board can make a recommendation as soon as the same night it receives the proposal, or it could take several meetings before it makes its recommendation (Boynton, 2005).

The time required depends on several things; the first being how well prepared the proposal is. A well prepared proposal that is clear in its objectives and addresses concerns appropriately will start out much better than one which is hard to follow and ambiguous. Another consideration is how citizens oppose or support the proposed ordinance. Widespread opposition will compel the planning board to be stricter in its review, and require more out of the proposal. This can delay the recommendation as the planning board asks the applicant to revise the proposal accordingly for further review at a later meeting.

After the planning board completes its review, it sends a recommendation to the City Council where it will face a vote. It can be either accepted as is, rejected, or accepted with changes (Boynton, 2005). The City Council's vote does not need to follow the recommendation of the planning board (Pace, 2005).

Once the proposal is accepted by the City Council, it officially becomes an amendment to the City of Worcester Zoning Ordinance. The last step is approval by the Massachusetts Attorney General. If accepted by the Attorney General, then the amendment remains; however, if it is rejected, the previous ordinance returns and the amendment is repealed (M.G.L. Chapter 40A, Section 5).

Summary

We have looked at the Worcester Zoning Ordinance and determined that there is not presently a practical process in place to put up a wind turbine in the City. Therefore, we determined that the best way to establish a permitting process for small wind turbines in Worcester would be to make an amendment to the Zoning Ordinance. We developed a proposed ordinance that could be used as a starting point to propose an amendment, and have outlined the process that would need to be followed in order to enact the ordinance. A group or individual with some background knowledge of wind turbines and a desire to move on with this ordinance will now be able follow through with the amendment process using this chapter as a guide.

Chapter 4: Conclusions

The Future

In a forever changing, technologically advancing society there will always be obstacles to overcome. Renewable energy technology is something that has advanced significantly in the past 20 years and is likely to continue to advance for many years to come. Although this report is not intended to provide a quick fix to all energy problems that our society faces, it is with continuing research and advocacy that any significantly beneficial change is acknowledged and pushed forth.

Despite the fact that the only factor that is absolutely necessary for a wind turbine to function is adequate wind, data easily collected by an anemometer, the siting of turbines is still very much a science. The financial and oftentimes even more significant social issues are no less important than wind. Especially as our society begins to acknowledge the need for clean sources of power, it is important that turbines are put up in such a manner that does not impede normal living conditions, and make a positive statement towards wind as a renewable form of energy.

By taking initiative on the nearest level of government, the City of Worcester in this case, we are making steps towards a larger goal of sustainable renewable energy throughout the entire country. Other cities already have initiatives in place including zoning ordinances for wind turbine permitting, city owned turbines, and incentives for purchasing renewable energy credits.

The City of Worcester has recently recognized the importance of clean energy, and shows this in their commitment to purchase 20% renewable energy by 2010 promise. As Worcester continues to research methods for achieving such a goal, it would be equally beneficial to push forth with implementing a zoning ordinance to allow any homeowner to contribute. Massachusetts as a whole already has an excellent start towards utilizing more renewable energy with groups such as the MTC. As the second largest city in Massachusetts, it is important that Worcester keeps in the forefront of such activities and becomes a leading example for surrounding cities and towns.

Next Steps

This project lays the ground work for a lot of potential to encourage renewable energy in Worcester. Beyond what has been presented here, time and dedication will be needed to continue driving Worcester forward. A good next step would be to begin working to amend the Worcester Zoning Ordinance to include a section for WECS. It is recommended that somebody who is very familiar with wind power, its implications, and common misconceptions draft a petition and zoning ordinance based off of the models given here and begin the proposed processes.

In addition to pushing forward with smaller wind turbines, it would also be beneficial for a knowledgeable individual or organization to draft permitting guidelines for a larger scale WECS (for example, that could be used with medium scale turbines), and propose the guidelines in the same fashion as suggested for personal WECS.

Lastly, it is recommended that the two potential turbine sites, Green Hill Park and Worcester Regional Airport, are studied in depth. Ideally, an anemometer should be erected to begin collecting wind data for at least two years at Green Hill Park; the airport should already have this type of data on file. The FAA should be contacted and the possibilities of turbines around the airport should be investigated further as well.

Reflections

It is agreed by experts around the world that there is reason to be concerned about global climate change issues. The leading cause of these issues is fossil fuel combustion and the power sector is the single largest contributor to this in the United States. Over the past century alone the Earth's surface temperatures have been shown to have risen by about one degree Fahrenheit; the years 1998, 2001, and 2002 being three of the hottest ever recorded (Malcolm and Pitelka, 2005).

Climate change is an important factor to acknowledge, as it can have a significant impact on the stability of ecosystems around the globe. There are several documented cases of changes in important ecological events related to unusual climate conditions; some examples of this include the timing of animal breeding and plant flowering, geographic ranges of plants and animals, processes such as carbon cycling and storing, and species composition within communities (Parmesan and Galbraith, 2004). The effects of climate change may also directly affect humans in many undesirable ways. Vector borne diseases such as malaria may spread to other regions and occur more frequently. The risk of flood and landslides will increase, especially in smaller, and less developed coastal communities that do not have ideal protection against such a natural disaster. Additionally, agriculture will be affected, for some areas it will mean longer growing seasons, but other areas may suffer a smaller seasonal yield than in the past.

Scientists around the world have acknowledged these problems and are searching for possible solutions. One international effort that attacked this problem was the United Nations Framework Convention on Climate Change. Adopted in 1992, this convention "agreed to develop national inventories of greenhouse gas emissions, establish national programs to reduce emissions, and mitigate change" (Environmental Literacy Council, 2005). The convention also set targets for developed countries to cut their greenhouse gas emissions. Unfortunately, because there were no legally binding implications forcing countries to adhere to their goals, many countries fell behind on their support. In response, another effort referred to as the Kyoto protocol was developed. This international agreement was negotiated in December of 1997 and specifies legally binding emissions targets for developed countries by the period 2008-2012. Specifically, the countries agree to reduce their collective emissions of six key greenhouse gases from the levels they were at in 1990 by at least 5% (European Commission, 2005).

While international efforts such as the Kyoto protocol address the problem from the top down, many individuals and small organizations are trying to make a difference from the bottom up. Worcester has taken a stand as a city, and has even agreed to the regulations of the Kyoto protocol, despite the lack of U.S. commitment, to do their part in promoting cleaner power generation. It is because of pressure from concerned individuals in the Worcester area belonging to organizations such as the Massachusetts Climate Action Network (MCAN) that the city has decided to take such actions. If there is to be a worldwide change to address such significant issues, it is important that it is addressed from all angles.

The ideas presented in this report reflect an effort to encourage city officials, as well as residents of Worcester, to take an even greater stance in the move towards renewable energy. While Worcester has made significant strides towards becoming a leader in renewable energy technologies on a municipal scale by making the "20% by 2010" commitment, there are still actions that can be taken. For example, the City of Hull has made an important statement by installing a sizable wind turbine, and at the same time has been able to justify plans to continue erecting more turbines.

Worcester has made contributions on paper with their renewable energy efforts, such as the 20% by 2010 campaign. Unfortunately though, people who do not actively study issues of global climate change or are not active in their local government may not even be aware what their city is doing in response to global warming issues. A wind turbine would catch many more eyes and put Worcester's commitment out in the open for everybody who passes by. Making such a strong statement from the city level would likely encourage support from the state, as well as further encourage support from local residents.

Another concept that we have addressed in this report is the effort to encourage the installation of small wind turbines. While an individual contribution such as the installation of a single residentially owned wind turbine in Worcester may seem insignificant, it is put into a different perspective when your city is taking similar steps, only on a slightly larger scale. By continuing to push forward with the guidelines presented in this report, Worcester will continue to emerge as a strong contributor to renewable energy. The installation of a city owned wind turbine, as well as many smaller individually owned wind turbines is a very worthy effort to contribute to clean energy in Worcester. This is important in setting an example for other cities to follow, as well as encouraging the expansion of state renewable energy programs and the research and support of groups such as the MTC.

This combination of a "top down" and "bottom up" approach is important in trying to make a timely, global impact. If action is not quickly taken, there are estimates based off of current historical trends indicating a global temperature increase of 2.5° F to 10.4° F by the year 2100 (Pew Center, 2005). There are already visible ecological effects and speculated health effects related to the one degree change observed over the last century. It is to that end that we hope this report has effectively demonstrated options for city officials and individuals to work from the bottom to encourage greater global change.

Appendix A: American Wind Energy Association Model Ordinance

About AWEA

The American Wind Energy Association (AWEA) is involved with everything from small to utility scale wind energy systems. They have published a document: *Permitting Small Wind Turbines: A Handbook. Learning from the California Experience* to aid with small wind energy projects. Of specific interest to us is Chapter 3, where a model zoning ordinance is given along with a list of best practices for counties. The model ordinance can be found in the latter section of this appendix, and is the basis for the proposed Worcester Model Ordinance.

In the sample zoning ordinance, the AWEA breaks down the legislation into four sections: purpose, findings, definitions, and permitted use. Different towns tend to have very different ways of writing zoning laws and for consistency it is not always feasible to follow this format verbatim, however the permitted use section is absolutely necessary to convey certain crucial concepts. Standard requirements that tend to be defined under the permitted use section are: tower height, set-back distance, noise allowances, approved wind turbines, compliance with Uniform Building Code, compliance with FAA regulations, compliance with National Electric Code, and utility notification. For a complete description of these sections the AWEA publication is available in its entirety at the official AWEA website. Many of these most common sections have been analyzed below for several towns in the northeastern United States.

Another helpful section in the AWEA publication is "Do's and Don'ts" under the Best Practices for Counties section of the permitting handbook. Points are emphasized that encourage law makers to be strict about wind turbine installation, but not so restrictive that nobody will make the effort to install them. For example, it is very reasonable that a registered professional be required to review all design plans. On the other hand, permitting fees should be set within a reasonably attainable boundary.

It can be observed in *Appendix B: Nearby Zoning Ordinance* that many towns have adopted several of the AWEA's suggestions, whereas certain suggestions such as noise issues may not be applicable for sites that, for example, are almost entirely on agricultural land.

AWEA Model Zoning Ordinance

Permitted Use Regulation for Small Wind Turbines

Section 1: Purpose

It is the purpose of this regulation to promote the safe, effective and efficient use of small wind energy systems installed to reduce the on-site consumption of utility supplied electricity.

Section 2: Findings

The [city or county] finds that wind energy is an abundant, renewable, and nonpolluting energy resource and that its conversion to electricity will reduce our dependence on nonrenewable energy resources and decrease the air and water pollution that results from the use of

conventional energy sources. Distributed small wind energy systems will also enhance the reliability and power quality of the power grid, reduce peak power demands, and help diversify the State's energy supply portfolio. Small wind systems also make the electricity supply market more competitive by promoting customer choice.

The State of _____ has enacted a number of laws and programs to encourage the use of small-scale renewable energy systems including rebates, net metering, property tax exemptions, and solar easements. [as appropriate] However, many existing zoning ordinances contain restrictions, which while not intended to discourage the installation of small wind turbines, that can substantially increase the time and costs required to obtain necessary construction permits.

Therefore, we find that it is necessary to standardize and streamline the proper issuance of building permits for small wind energy systems so that this clean, renewable energy resource can be utilized in a cost-effective and timely manner.

Section 3: Definitions

Small Wind Energy System: A wind energy conversion system consisting of a wind turbine, a tower, and associated control or conversion electronics, which has a rated capacity of not more than 100 kW and which is intended to primarily reduce on-site consumption of utility power.

Tower Height: The height above grade of the fixed portion of the tower, excluding the wind turbine itself.

Section 4: Permitted Use

Small wind energy systems shall be a permitted use in all zoning classifications where structures of any sort are allowed; subject to certain requirements as set forth below:

4.1 Tower Height: For property sizes between ½ acre and one acre the tower height shall be limited to 80 ft. For property sizes of one acre or more, there is no limitation on tower height, except as imposed by FAA regulations.

4.2 Set-back: No part of the wind system structure, including guy wire anchors, may extend closer than ten (10) feet to the property boundaries of the installation site.

4.3 Noise: Small wind energy systems shall not exceed 60 dBA, as measured at the closest neighboring inhabited dwelling. The level, however, may be exceeded during short-term events such as utility outages and/or severe wind storms.

4.4 Approved Wind Turbines: Small wind turbines must have been approved under the Emerging Technologies program of the California Energy Commission or any other small wind certification program recognized by the American Wind Energy Association.

4.5 Compliance with Uniform Building Code: Building permit applications for small wind energy systems shall be accompanied by standard drawings of the wind turbine structure, including the tower, base, and footings. An engineering analysis of the tower showing compliance with the Uniform Building Code and certified by a licensed professional engineer

shall also be submitted. This analysis is frequently supplied by the manufacturer. Wet stamps shall not be required.

4.6 Compliance with FAA Regulations: Small wind energy systems must comply with applicable FAA regulations, including any necessary approvals for installations close to airports.

4.7 Compliance with National Electric Code: Building permit applications for small wind energy systems shall be accompanied by a line drawing of the electrical components in sufficient detail to allow for a determination that the manner of installation conforms to the National Electrical Code. This information is frequently supplied by the manufacturer.

4.8 Utility Notification: No small wind energy system shall be installed until evidence has been given that the utility company has been informed of the customer's intent to install an interconnected customer-owned generator. Off-grid systems shall be exempt from this requirement.

Appendix B: Nearby Zoning Ordinance Analyses

Dover

About Dover

The Town of Dover is located in eastern Massachusetts and has acknowledged windmills in their zoning code since at least 1982. Dover consists mostly of forest and has a low population density of only 395 people per square mile. The Boston Metropolitan Area Planning Council refers to Dover as "an affluent suburban community set between the western and southwestern axis of metropolitan Boston expansion" (MAPC, 2005). Table 2 shows land use classification data collected by MAPC in 1999. Because of the low population density and moderate amount of agriculture and light residential districts, Dover is a very reasonable town to consider personal wind energy conversion systems as a supplement to conventional methods of generating electricity.

Use		Acres	Percent
Forest		5719	57.89%
Urban	Multi-Family Res.	5	0.05%
	Medium Res.	581	5.88%
	Light Res.	2206	22.33%
	Commercial	16	0.17%
	Open and Public	100	1.01%
	Waste Disposal	2	0.02%
Total Urban		2910	29.46%
Agriculture	Cropland	431	4.37%
	Pasture	366	3.70%
Total Agriculture		797	8.07%
Wetlands	Wetland	113	1.15%
	Water	138	1.39%
Total Wetland		251	2.54%
Open Lands		134	1.36%
Recreation	Participation	56	0.67%
	Water Based	1	0.01%
Total Recreation		67	0.68%
Total		9878	100%
(Dover 2005)			

Table 2 – Dover Land Use

Zoning Regulations

Dover zoning codes set forth certain guidelines for town residents regarding the installation of windmills on their property. In some ways Dover is less restrictive than many other towns when considering the siting of windmills. For example, there are no restrictions regarding the placement of guy wires, permitted districts, the rotation speed of the turbine, or even stating that the tower must be secured. While Dover seems to lack regulations in some of these areas, there are still several standard points that are covered.

Similar to other towns in the Commonwealth of Massachusetts, no permit will be issued until all related planning has been written up and approved by a registered professional engineer. At this point a special permit can be issued allowing the use of a wind turbine. While an engineer needs to approve the plans, there are very few other dimensional requirements that are written into the

Dover Zoning Code. Table 3 illustrates the basic regulations for the purpose of comparison to other towns analyzed in this report.

A short and general section on nuisance is included stating "No windmill shall be the cause of excessive noise or any interference to radio or television reception nor otherwise derogate substantially from the public good" (Dover, 1982). Using this as a catchall allows them to interject when there are any types of issues that concern the public without needing any other technical evidence to back them up.

Also included is an abandonment code which seems to appear in few cities zoning regulations. If a windmill is not put to use in some form over a period of two years it can be considered abandoned and legally "the structure must be dismantled at once by the property owner or his or her agent" (Dover, 1982).

Regulations – Dover	
Use	Any
Power may be distributed	N/A
Classified with	Special Permits
District Restricted	No
Towers per lot	N/A
Rotation Governed	No
Maximum Tower Height	75ft
Minimum Blade Clearance	10ft
Minimum Lot Size	N/A
Distance From Property Line	Mean grade to tip of blade
Guy Wire Distance From Property Line	N/A
Blade Color	N/A
Tower Secured	N/A

Table 3 – Dover Regulations

West Bloomfield

About West Bloomfield

The Town of West Bloomfield is located about 20 minutes southeast of Rochester, NY in Ontario County. Approximately 75% of the land use is currently dedicated to agriculture. Large open areas tend to make for a better environment for personal windmills, and often farmers find them useful to power certain difficult to access areas of their property. Wind power may prove to be very helpful in this type of an environment.

Zoning Regulations

West Bloomfield provides zoning regulations that refer to the permitting of windmills on any property with only slight restrictions between certain districts. A special use permit is required to install a windmill and is granted by the planning board after certain provisions are met.

All related planning must be drawn up and include specific dimensions for all portions of the windmill. The town also requires certification by a professional engineer or a statement from the manufacturer of the wind turbine ensuring the tower design is sufficient to withstand the load requirements.

Certain regulations are placed on the height and placement of the tower as illustrated in Table 4. The Town of West Bloomfield also goes out of its way to reiterate certain state and federal regulations that windmills must comply with. These types of guidelines include fire codes and FAA

Regulations – West Bloomfield	
Use	Any
Power may be distributed	N/A
Classified with	Special Permits
District Restricted	No
Towers per lot	N/A
Rotation Governed	Yes
Maximum Tower Height	By District (50ft or 75ft)
Minimum Blade Clearance	15ft
Minimum Lot Size	N/A
Distance From Property Line	Mean grade to tip of blade
Guy Wire Distance From Property Line	10ft
Blade Color	N/A
Tower Secured	Yes

Table 4 – West Bloomfield Regulations

regulations. While the zoning code does not supersede any legislation set forth by the aforementioned documents, the code specifically refers a researcher to them.

Like other towns the regulations are sometimes written up in such a way that gives the governing authority (in this case the Planning Board) ultimate discretion. One of the catchall phrases that West Bloomfield uses is that a windmill may not be installed where "the impact on the neighborhood character is determined by the Planning Board to be detrimental to the general neighborhood character" (West Bloomfield, 2005).

Southampton

About Southampton

The town of Southampton is located in Suffolk County at the southern fork of Long Island, about 80 miles from New York City. Currently about 8.5% of Southampton's 81,948 acres of land is comprised of farms. Also of note is the fact that Southampton is a large vacation spot. Its population of 55,210 persons is likely to double in the summertime as people begin vacationing. Southampton is also very rich in history and preserving their community. There are two historical windmills located at Hildreth Road and Montauk Highway that are registered with the State and National Registers of Historic Places.

Zoning Regulations

Southampton provides regulations for windmills under the same section that they define several other accessory structures. A wind energy conversion system is formally defined as "An accessory structure designed and constructed or erected for the purpose of converting wind energy into mechanical or electrical power" (Southampton, 1984). Wind energy conversion systems may be used only for personal means and require similar consent that other towns do. A scale drawing is required to be submitted, and all computations must be submitted by a licensed engineer stating that the tower is designed to comply with wind load requirements of the New York State Building Construction Code.

Regulations - Southampton	
Use	Personal
Power may be distributed	No
Classified with	Accessory Structures
District Restricted	No
Towers per lot	N/A
Rotation Governed	40 mph
Maximum Tower Height	None
Minimum Blade Clearance	15ft
Minimum Lot Size	N/A
Distance From Property Line	Mean grade to tip of blade
Guy Wire Distance From Property Line	10ft
Blade Color	N/A
Tower Secured	Yes

Table 5 – Southampton Regulations

Table 5 shows a list of some of the more significant dimensional and other regulations set forth in the city's zoning code. In addition to the standard provisions, a couple of interesting things to note include several clauses reiterating both state and federal regulations, as well as a clause allowing the Town Building Inspector or Engineer to enter the premise at any time with the accompaniment of the owner.

Nantucket

About Nantucket

Nantucket is an island located off the southern tip of Cape Cod. It is a popular vacation spot and is reachable by ferry, plane or boat. The town has a population of only 10,724 (US Census,

2003), and a population density of only 199 people per square mile. The island is located 30 feet above sea level.

Zoning Regulations

Regulations – Nantucket (Residential)	
Use	Residential
Power may be distributed	Local Property Only
Classified with	N/A
District Restricted	Yes
Towers per lot	1
Rotation Governed	No
Maximum Tower Height	60ft
Minimum Blade Clearance	N/A
Minimum Lot Size	N/A
Distance From Property Line	Mean grade to tip of blade
Guy Wire Distance From Property Line	15ft
Blade Color	Wight or Light Grey
Tower Secured	Yes

Table 6 – Nantucket Regulations (Residential)

Regulations – Nantucket (Commercial)	
Use	Commercial
Power may be distributed	Yes
Classified with	N/A
District Restricted	Yes
Towers per lot	By Permit
Rotation Governed	No
Maximum Tower Height	By Permit
Minimum Blade Clearance	N/A
Minimum Lot Size	N/A
Distance From Property Line	Mean grade to tip of blade
Guy Wire Distance From Property Line	15ft
Blade Color	White or Light Grey
Tower Secured	Yes

Table 7- Nantucket Regulations (Commercial)

Nantucket has a great deal of zoning laws in place for both interested residents (see Table 6) and businesses (see Table 7) looking to develop wind farms. This in itself makes it a desirable place to develop wind, along with its low population density and precedence of already having an 18th century windmill.

In Nantucket's zoning regulations a commercial wind energy conversion system is defined as a completely separate device in comparison to a residential wind energy conversion system, this allows the town to make very granular specifications to each instance very easily.

One area that is very explicitly defined in Nantucket's zoning laws that is not seen in many other cities is the definition of what is too much noise. A chart is provided which explains an allowable increase in noise (measured in dB) after a windmill has been installed. If a newly installed windmill is in violation of this chart, it must either be fixed or taken down.

Nantucket is also very cautious when it comes to the structural integrity of installed windmills and requires a bi-yearly structural report to be submitted to building inspector.

Eden

About Eden

The Town of Eden is a rural community located in western New York between Buffalo and Lake Erie. It is comprised mostly of agricultural districts and occupies about 40 miles. Eden strives

off of the revenue generated by the local agriculture, as well as by several light manufacturing firms.

Zoning Regulations

Eden's zoning model is very similar to that of the model template provided by AWEA. Structurally it is broken up into the four sections that AWEA feels are essential, followed by a section on special permitting and a section on penalties.

Regulations	
Use	Any
Power may be distributed	N/A
Classified with	N/A
District Restricted	No
Towers per lot	N/A
Rotation Governed	Yes
Maximum Tower Height	N/A
Minimum Blade Clearance	30ft
Minimum Lot Size	N/A
Distance From Property Line	Mean grade to tip of blade
Guy Wire Distance From Property Line	10ft
Blade Color	N/A
Tower Secured	Yes

Table 8 - Eden Regulations

While Eden has an entire chapter dedicated to wind energy conversion systems, they also make it a point to require a special permit. No maximum height is defined for a personal wind energy conversion system, but to be in accordance with chapter 217 of the town zoning codes, the swept area of the blade must be 1,000 square feet or less.

There are several precautions taken that are less common in many other towns with windmill guidelines. Liability insurance is required when erecting a windmill and it is stated that "The applicant, owner, lessee or assignee shall maintain a current insurance policy which will cover installation and operation of the wind energy conversion system at all times. Said policy shall provide a minimum of $300,000 property and personal liability coverage" (Eden, 2004).

The dimensional requirements that Eden specifies are more complex than other towns and more options are offered for interested parties. For example, a cluster of land owners may opt to erect a windmill communally where setback distances are relative to the involved parties rather than a single plot of land.

Appendix C: Sample Petition to City Council

The following is a sample petition like the one that would be submitted to the City Clerk's Office to request that the City Council consider an amendment to the City of Worcester Zoning Ordinance. It is written to include the proposed ordinance as an attachment, rather than as text on the form (since it would not fit).

Please print out this form, state your name, residential address, telephone number and return to:

Worcester City Clerk
City Hall Room 206
455 Main Street
Worcester, MA 01608-1889.

The undersigned, residing in the City of Worcester hereby petition the City Council as follows, request:

that the attached ordinance entitled "Wind Energy Conversion Systems" be added to the City of Worcester Zoning Ordinance. The objective of the ordinance is to allow for the installation of small wind turbines by individuals and businesses within the City of Worcester. This ordinance will enable and encourage the use of renewable energy within the City of Worcester and help the City to reach the goal of using 20% renewable energy by 2010. It sets guidelines that provide for the regulation and safe installation of small wind energy conversion systems throughout the City.

John Smith
1 Main St.
Worcester, MA 01608
(508) 757-8305

Appendix D: Personal Wireless Towers, a Suitable Starting Point?

The purpose of this section is to examine the applicability of a current Worcester ordinance as it applies to installing small wind turbines, and analyzing it as an option for basing a permitting process. The closest comparison that can be made is to the process for obtaining a special permit for a personal wireless service facility. The requirements for obtaining a special permit for such a facility are examined here and analyzed in relation to the feasibility of incorporating wind turbines into the same model.

Personal Wireless Service Facilities

Worcester's zoning ordinance provides for the permitting of personal wireless towers. These special permits are granted through the Zoning Board of Appeals, and have very specific guidelines pertaining to their installation. One of the limitations on the siting of wireless facilities is the height of ground-mounted towers. These height restrictions range from 40 feet to 150 feet depending on the zone of the specific site. It is important to note, however, that the wireless facilities are not allowed in any residential district. In addition to height restrictions, ground-mounted towers have a setback requirement known as a fall zone where the distance from the base of a tower to "any property line, road, habitable dwelling, business or institutional use, or public recreational area shall be the height of the facility/mount including any antennas or other appurtenances" (City of Worcester Zoning Ordinance, 1991, Revised 1998).

Aside from these dimensional requirements, other specifications are that the wireless facilities and any equipment may not generate any noise in excess of 50 decibels at the base of the building closest the antenna. The applicant needs to file measurements of the preexisting ambient noise as well as an estimate of the noise from the proposed facility, both signed by an acoustical engineer.

The filing requirements include specifications as to the proposed vegetation around the site, camouflage of the facility, views from different sight lines from the north, south, east, and west at a 50 foot radius, views from all public roads within 300 ft, and proposed views from each previous viewpoint with a superimposed image of the facility.

Adapting Wind Turbine Permitting to Personal Wireless Service Facilities

The special permitting guidelines for personal wireless facilities can provide a basis for developing permitting for wind turbines. The fact that they both sit on towers would lead one to believe that it would be simple to incorporate wind turbines into the legislation for the wireless facilities. This section will look at some of the benefits and downfalls of adapting the personal wireless service facilities section to include wind turbines.

One reason for using the personal wireless towers as a starting point is that it gives good guidelines as far as noise requirements. This is something that would be important to neighbors concerned about the noise levels produced by wind turbines. The wireless towers ordinance specifies what sound level is acceptable at nearby lot lines which can assure neighbors that a turbine will not be too noisy.

The first major limitation in using the personal wireless facility guidelines is that no facilities are allowed in residential districts, ruling out one of the major targets for private homeowners wanting to erect turbines in their yard. An important feature of a wind turbine permitting ordinance is that they be allowed to be placed in residential zones, and not simply be limited to business, institutional, and manufacturing zones. One of the main goals for this project is to make permitting a wind turbine a streamlined process for anyone in Worcester, and excluding residential zones would be unacceptable.

The next major limitation is the requirement for a setback where the minimum distance from the base of the tower to virtually any structures, roads, and property lines is the height of the tower. This seems contrary to the fact that telephone poles are allowed to be set right next to the road or near structures. The logic behind a setback requirement is presumably to protect residents and property from a falling structure. While its intentions are good, the specifics of the setback should not be as restrictive as they are in the personal wireless towers ordinance. There is no reason to believe that a properly designed tower for a wind turbine would have any more chance of falling, or that it would be any more dangerous, than a telephone pole carrying electric distribution wires.

Another limitation on using the wireless facilities is the preparation required for site filing. This section requires two sets of pictures from numerous different viewpoints, the first of which shows current photographs, while the second includes superimposed images of the proposed tower. This along with camouflaging requirements, security barriers, and vegetative cover involve significant preparation work by, and potentially cost to, the applicant. This time investment could be enough to deter homeowners from considering erecting a wind turbine.

Appendix E: Methodology

This appendix explains the methods we used for the analyses in our project. First, we describe how we obtained our GIS data, and how that data was manipulated and used to create the maps we used in our analyses. Next, we describe the approach that we took when visiting sites for the medium sized wind turbine analysis and indicate the factors we took into consideration at every site. Finally, we give a summary of how we collected data regarding to permitting issuers, including officials that we interviewed.

GIS

The production of the maps of Worcester showing possible sites for the medium sized turbines and also the areas of the city that would be most appropriate for smaller, private turbines was accomplished through the use of ESRI's ArcView 9.0. This software, when combined with the right data, provided powerful means to not only efficiently analyze the entire city in order to select sites for a medium turbine and to find the general areas conducive to small turbines, but also to create maps that represent these findings in a very straight forward manner.

Data Collection

Data for the GIS program come in the form of layers. Table 9 below lists all of the layers that were available for the creation of maps. All layers were obtained from Colin M. J. Novick, Project Coordinator of The Greater Worcester Land Trust with the exception of the building layer which was obtained from Professor Robert Krueger, and the wind related layers which were obtained from the Renewable Energy Trust (a division of the Massachusetts Technology Collaborative). The New England wind maps that were used were developed by TrueWind Solutions, LLC under contract to AWS Scientific, Inc. as part of a project jointly funded by the Connecticut Clean Energy Fund, The Massachusetts Technology Collaborative, and Northeast Utilities System. Table 9 – GIS Layers lists the layer's name, type (vector or raster[1]), description, and the ways in which it is useful.

[1] Vector data are represented by lines, points, and polygons. Rasters are "images" that divide the world into discrete cells, or pixels. Each pixel represents an area and has a value associated with it.

Name	Type	Description	Uses
buildings	vector	building footprints	Determine what parts of a parcel are free for siting, if any.
ponds	vector	ponds	Avoid sites too close to water
streams	vector	streams & rivers	Avoid sites too close to water
spotelev	vector	spot elevations	Quickly determine the rough elevation of a location
contours	vector	contour lines	More accurately determine the elevation of a location
streets_new	vector	city streets	Determine possible accessibility to sites
Zoning	vector	zones	Determine uses and regulations for particular areas of the city
Zoning_Mixedusedistricts	vector	Mixed use districts	Determine uses and regulations for particular areas of the city
Zoning_Overlaydistricts	vector	Overlay districts	Determine uses and regulations for particular areas of the city
Parcels	vector	parcels	Determine amount of land available for a site. Determine owner of land
Parks	vector	parks	Quickly determine where parks are (large, open, city owned land)
city	vector	city outline	Useful starting point for maps
Roughness	raster	terrain roughness	Preliminary method for finding areas with favorable wind conditions
Power Density at 50 m	raster	Wind power density	Preliminary method for finding areas with favorable wind conditions
Mean Speed at 30 m	raster	Avg. wind speed at 30 m above the ground	Preliminary method for finding areas with favorable wind conditions
Mean Speed at 50 m	raster	Avg. wind speed at 50 m above the ground	Preliminary method for finding areas with favorable wind conditions
Mean Speed at 70 m	raster	Avg. wind speed at 70 m above the ground	Preliminary method for finding areas with favorable wind conditions
Mean Speed at 100 m	raster	Avg. wind speed at 100 m above the ground	Preliminary method for finding areas with favorable wind conditions

Table 9 – GIS Layers

Manipulation

After obtaining all of the layers, some of the data they contained had to be converted to a more useful form. While the wind layers are sufficient for visually determining wind data in the city, they do not lend themselves to query based analyses due to the nature of raster based layers. In order to overcome this we had to export the relevant data from the wind layers into the parcel

layer. This was accomplished through a custom Visual Basic for Applications (VBA) script. The script works by stepping through each parcel in the layer and programmatically performing an "Identify" at a point that is guaranteed to be within the area of the polygon representing the parcel (this is similar to using the 'Identify' tool from within ArcMap to click on the wind map in the area above a given parcel). The script then uses the value returned from the wind map at this spot as the wind value for the whole parcel. While this isn't the most accurate of methods, it is sufficient for parcels of a small to medium size, as wind values only change gradually over a distance thus minimizing the error. However, for larger parcels, which could contain large differences between wind data within its borders, it is important not to use this value as an indicator of the whole parcel. It is guaranteed to represent at least some area within the parcel though. This script was run to export wind speed data at 30 m to the parcel layer into a newly added field name "WndSpd_30". Since we were using this data to find areas most suitable for small wind turbines, we chose to export the wind data from the 30 m layer because 30 m is the height closest to that of small turbines for which we had data.

We used another VBA script to populate the "Wnd_Rating" field that we added. This field was used to represent the suitability of a given parcel as a small wind site based on certain criteria. These criteria also had a weight associated with them to represent their importance relative to other criteria. These criteria are represented in the script as queries. All of the parcels that match the query have the weight of the criterion added to the current value of their "Wnd_Rating" field. This simple rating system was designed to allow for additional criteria to be added as needed. While we applied this system to the parcel layer, it can be applied to any feature layer. We have provided a front end to the script in the form of a dialog box that can be used to accomplish this. However, as written, all of the conditions must only reference data within the same layer as the one containing the field being updated (in our case this field was: "Wnd_Rating").

Map Creation

The Map of Parcel Sizes was created by simply manipulating the symbology of the parcel layer. The layer was broken into three classes (colors) based on the "Shape_Area" field. This field was present when we obtained the layer. The data in this field was calculated by the software from the shape used to represent each parcel within the layer, rather than from measurements taken directly at the parcel. This may not be the most accurate field present in the layer; however it is the only complete one. The other fields that report area for a parcel are not filled out for every parcel, so if they were to be used, they would leave holes in our data. However, this slight inaccuracy is insignificant since all sites will have to be investigated "in the field" before a turbine is erected. This is used just to give a general overview of areas that might have enough space to support a turbine.

$$\frac{x}{4.01} = \left(\frac{30}{10}\right)^{\frac{1}{7}} \qquad x = 4.69142$$

$$\frac{x}{4.01} = \left(\frac{30}{18.3}\right)^{\frac{1}{7}} \qquad x = 4.3038$$

Figure 9 – Calculation for extrapolating wind speed at 30m to 10m

The Map of Average Wind Speeds was also created by changing the symbology of the parcel layer. The classes were based on the "WndSpd_30" field, which as previously described, we added to the parcel layer via a script and the wind maps from the RET. We determined where the breaks in classes would be based on the recommended speed for small turbines (4.01 m/s). Since the wind data we used was for 30 meters above the ground, we used a formula obtained from a study published on the National Renewable Energy Laboratory's website (Barchet et al., 1986), as seen in Figure 9, to extrapolate a wind speed of 4.01 m/s at 10 m up to what it would be at 30 m and also from 18.3 meters (60 ft) to 30 m. This provided us with a reasonable estimate of wind speeds at 10 m and 18.3 m. It is these two values that determine the breaks in the symbology classes.

The Map of Overall Suitability was created as a combination of data represented in the previous two maps. The symbology was adjusted to reflect the "Wnd_Rating" field, which we created as we discussed earlier. The criteria we used to create this rating were based on "Shape_Area" (measured in square feet) and "WndSpd_30". The criteria were represented by the following queries.

Criterion 1: "Shape_Area" >= 21780 AND "WndSpd_30" >= 4.3038

Criterion 2: "Shape_Area" >= 21780 AND "WndSpd_30" >= 4.69142

Each was assigned a weight of 1, but since a parcel that meets criterion 2 is guaranteed to also meet criterion 1, every parcel that meets criterion 2 will end up with a "Wnd_Rating" of 2. See table for a description of "Wnd_Rating" values.

Wnd_Rating	Description
0	Not Suitable
1	Modest Potential
2	High Potential

Table 10 – Wind Suitability

The maps of potential sites for medium sized turbines were created by overlaying our wind_sites layer onto the "Mean Speed at 50 m" and "Power Density at 50 m" layers that were provided by the RET. Our wind_sites layer is a simple point layer consisting of 5 points, one for each site we examined.

Site Visits

When visiting sites in Worcester for the portion of the project regarding potential sites for medium sized turbines, we had a standard set of objectives for gathering information. Each site presented different situations and therefore we were not able to collect exactly the same information from each site; however, the key methods we used for obtaining data are explained below. The siting considerations that we kept in mind were adapted from the previous IQP, *Wind Power Suitability in Worcester, Massachusetts* (Kalisz et al., 2005).

Wind Resource

Figure 10 – Tree Flagging

The wind resource to be considered at a given site includes the wind speed and direction as well as the height of turbulent air. Wind speed and direction both need to be based on long term, site specific measurements. We did not have the time required for such a study; therefore we used the GIS wind maps described in the previous section. An individual interested in measuring the wind at a given location, however, can contact the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts Amherst about an anemometer loan program that they offer. Another way to judge the wind at a site without actually taking anemometer readings is to consider the vegetation. If the winds tend to be strong, an effect known as flagging may occur, and branches on trees will be bent in the direction of the prevailing wind (Small Wind Installers Workshop, 2005). Figure 10 demonstrates an example of this condition, and was actually taken on the Worcester Municipal Golf Course, indicating strong average winds.

The height of turbulent air can be determined by a method that involves flying a kite or balloon at a site of interest. This method can be used by anyone looking to find out how much turbulence there is at a site. We used a kite, and tied streamers to the string at 8 foot intervals. After tying on streamers, we flew the kite to look for any turbulence. The idea behind this method is that with the kite flying, each of the streamers will blow with the direction of the wind. If the wind is turbulent, the streamers will waver in various directions. If the wind is not turbulent, the streamers will waver in a relatively constant direction (Small Wind Installers Workshop, 2005). Since the distance between the streamers is known ahead of time, it is easy to determine the height at which the first streamer encounters little or no turbulence. See Figure 11 for a picture of our kite setup. We did not end up getting any measurements for turbulence at any site, however, as there was little or no wind on the days that we went.

Figure 11 – Kite Setup

Additional Considerations

There was not much we could do at sites to determine how the surrounding environment would impact the installation of a wind turbine. The only thing that we could consider was the visibility factor, or the visual impact that a wind turbine might have. We observed what was in the immediate vicinity of each site including houses, public facilities, and major roads. Anything that might have been affected by the visual impact of a wind turbine, either beneficially

or damagingly, was taken note of.

The access to a site was based on the presence and condition of any roads or paths leading to it. If a path or road existed, it was noted whether or not it would be able to handle the equipment and vehicles that would be necessary for the installation of the turbine and any maintenance.

An important thing to note at each site was the presence of electrical distribution lines. This was necessary to consider because any turbine would need to be connected to the electrical grid in order to carry the electricity produced to a location where it could be used. While the rated capacity of the distribution lines may also be a factor in the ability to support a wind turbine, this information was not as readily available and was not collected. The proximity to any distribution lines on the other hand was noted to be included in an analysis.

Permitting Data Collection

We collected data pertaining to the permitting side of the project from a variety of sources, including interviews with city officials, looking at zoning ordinances from various cities and towns including Worcester, and by consulting the AWEA Small Wind Turbine Permitting Handbook. Table 11 contains information about some of the individuals we interviewed, their position, and what they contributed to out project.

Name	Position	Helped with
Anthony Calo	Inspector of Buildings Dover, MA	Explaining wind turbine building codes in Dover, MA and how they have been applied
Michael Pace	Chief Building Inspector Worcester, MA	Reviewing the Worcester Zoning Ordinance and interpreting how wind turbines would be treated in Worcester
Jody Kennedy-Valade	Coordinator, Division of Land Use Worcester, MA	Explaining how to develop a proposal for a zoning ordinance amendment in Worcester and steps to take before submitting to the City Council
Joe Boynton	Former Chairperson of Planning Board Worcester, MA	Explaining what happens with a proposed zoning ordinance amendment when it is referred to the Planning Board in Worcester
Erich Bachmeyer	Global Winds Harvest	Giving insight into commercial scale wind projects and their experience with municipal permitting.

Table 11 – Permitting Interviewees

In addition to speaking with various individuals about permitting in Worcester and elsewhere, we reviewed the local zoning codes for a number of cities and towns that have regulations pertaining to wind turbine permitting. The City of Worcester Zoning Ordinance was also reviewed to search for any instances relating to wind turbines, or similar comparisons, and to obtain an understanding of how zoning and permitting are treated in the City. These reviews of the Worcester Zoning Ordinance also helped to prepare for interviews with city officials.

Finally, a careful review was made of the American Wind Energy Association's *Permitting Small Wind Turbines: A Handbook*. This handbook was designed for individuals looking to

help establish a permitting process in their city or town, and even provides a model ordinance to use as a starting point. We used this ordinance, along with what we learned about wind turbine permitting in other towns and general permitting in Worcester, to help develop a customized model ordinance for Worcester.

APPENDIX F: SAMPLE BROCHURE PROMOTING SMALL WIND TURBINES

WIND TURBINE PERMITS

The City of Worcester recently adopted an amendment to the City Zoning Ordinance that allows for Worcester residents and businesses to erect small wind turbines. If you have determined a wind turbine is for you, the following steps should be taken to put up a turbine of your own.

- Choose a model and manufacturer that fits your needs by referring to the web links on the inside of this brochure.
- Obtain the turbine manufacturer's specifications for the model of turbine chosen, including noise level in decibels and a picture.
- Submit a site plan along with manufacturer's specifications to the Office of Code Enforcement, 25 Meade St., Worcester, MA, to obtain a permit for the turbine
- Begin installing your wind turbine! (NOTE: You should contact an experienced small wind turbine installer if you are not familiar with the process.)

The Bergey Excel turbine is America's most popular residential and small business wind turbine.

- 22 ft rotor diameter
- 7 mph start-up wind speed
- 5 year limited warranty
- Rated for 10,000 watts at 31 mph wind speed

ENERGY EMISSIONS FACTS

DID YOU KNOW?

◊ Concentrations of carbon dioxide in the atmosphere are naturally regulated by a process known as the "carbon cycle". While this process absorbs about 6.1 billion metric tons of anthropogenic carbon dioxide, an estimated 3.2 billion metric tons is added annually.

◊ Energy-related carbon dioxide emissions, resulting from fossil fuel combustion, represent 82% of total U.S. human-made greenhouse gas emissions.

◊ The U.S. produces about 25% of global carbon dioxide emissions, primarily because our economy is the largest in the world and we meet 85% of our energy needs through burning fossil fuels.

◊ You can help! Wind energy is the fastest growing energy generation technology, expanding by 30% to 40% annually. With Worcester's support for wind turbines you can contribute to making those numbers even higher.

Facts obtained from The U.S. Department of Energy

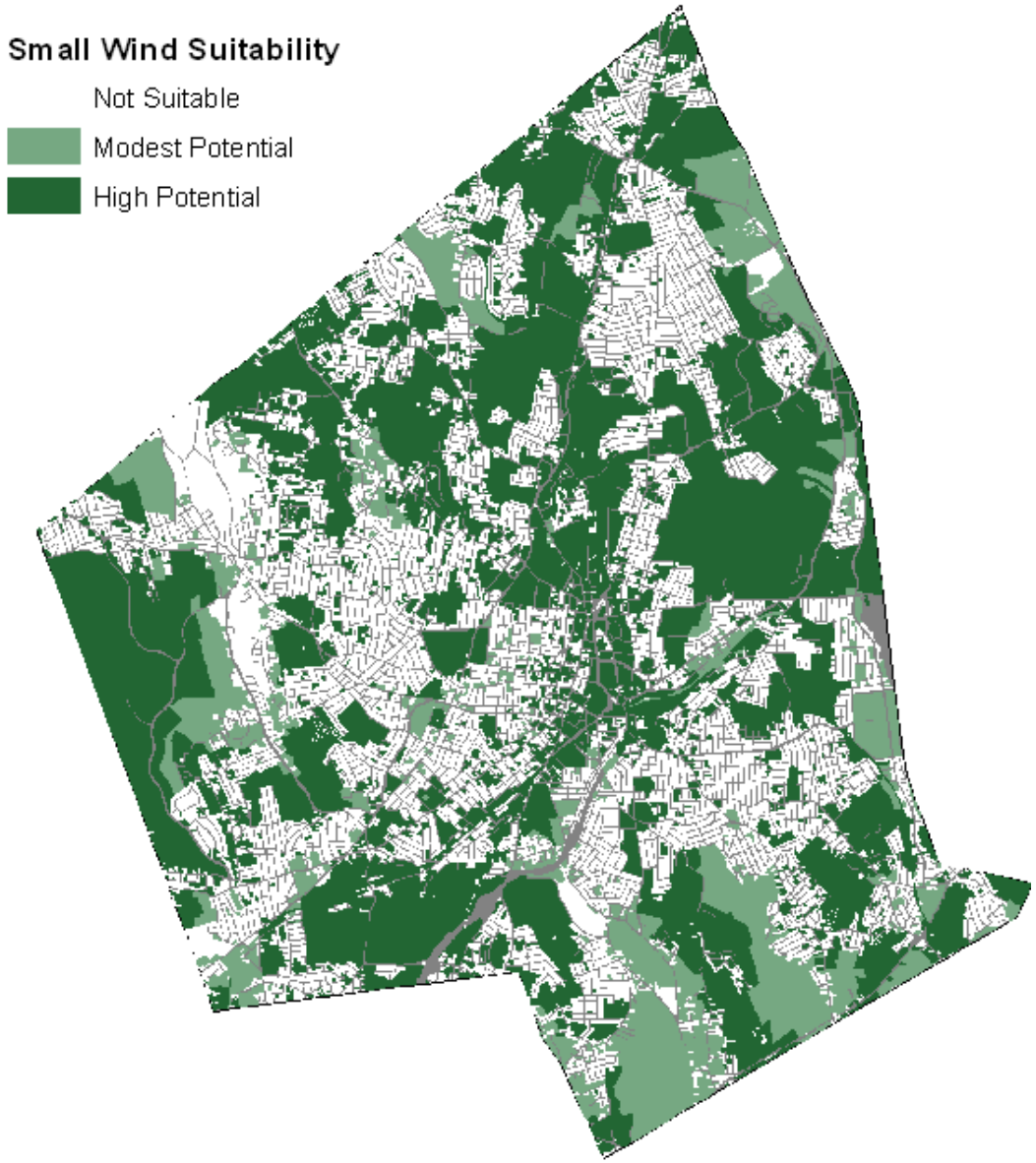
City Hall
455 Main Street
Worcester, MA 01608

SMALL WIND TURBINES IN WORCESTER

THE CITY OF WORCESTER:

A PARTICIPANT IN THE ICLEI'S CITIES FOR CLIMATE PROTECTION CAMPAIGN

WHERE IN WORCESTER?



IS A WIND TURBINE FOR ME?

The area you live in and your personal intentions are important factors in deciding to put up a wind turbine. The following sections give a brief outline of how to decide whether or not a wind turbine is appropriate for you.

LOCATION

The location of a wind turbine will be the most significant factor deciding how well it will work for you.

- Locations with an average wind speed of about 9 mph are recommended
- Properties which have at least 1/2 acre of land are recommended
- The map on the left takes both of these into consideration, if your property falls in a green colored area, a small wind turbine may have potential
- Siting a wind turbine can be influenced by very immediate surroundings, refer to the web links below for more information about siting small wind turbines

REASONS FOR A WIND TURBINE

You should consider the following statements regarding how they fit your personal goals.

- Contributes to clean energy generation, reducing the need for electricity produced from non-renewable sources
- Reduces electricity usage from the grid, lowering monthly electricity bills

SMALL WIND POWER WEB LINKS

General Information

American Wind Energy Association — www.awea.org

Wind Turbine Suppliers and Manufacturers

Aeromag — www.aeromag.com

Bergey — www.bergey.com

Southwest Windpower — www.windenergy.com

Southwest Windpower's Air-X is the world's best selling small wind turbine.

- 46 in rotor diameter
- 8 mph start-up wind speed
- 3 year limited warranty
- Rated for 400 watts at 28 mph wind speed

Appendix G: Interactive Map

We have included the GIS layers we used to create the maps in this report as well as any scripts that assisted in their generation. We have also included an ArcMap document (Wind.mxd) that presents all of the layers included. These can be found either on the included CD or obtained by contacting Tyler Benoit (trunksbnt@adelphia.net) or Professor Scott Jiusto (sjiusto@wpi.edu).

Appendix H: Works Cited

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