Customer Sited Wind Handbook

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New York State
Energy Research and
Development Authority

The New York State Energy Research and Development Authority (NYSERDA) is a public benefit corporation created in 1975 by the New York State Legislature.

NYSERDA derives its revenues from an annual assessment levied against sales by New York's electric and gas utilities, from public benefit charges paid by New York rate payers, from voluntary annual contributions by the New York Power Authority and the Long Island Power Authority, and from limited corporate funds.

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2010

Customer Sited Wind Handbook

Source: Bergey Windpower

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FOREWORD

The Customer Sited Wind Handbook was developed under the New York State Energy Research and Development Authority (NYSERDA) under the PON 995, Agreement 9998. NYSERDA is a public benefit corporation created in 1975 under Article 8, Title 9 of the State Public Authorities Law through the reconstitution of the New York State Atomic and Space Development Authority.

This publication was written by AWS Truewind, LLC. The intent of this handbook is to contain background information and practical guidelines for typical on-site generation and small wind installations.

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1 INTRODUCTION

The Customer Sited Wind Handbook was developed for the New York State Energy Research & Development Authority (NYSERDA), to help educate and guide end-users of small wind energy systems. The document's intended audience includes those interested in purchasing a wind energy system and small wind installers located throughout New York State. The handbook focuses on small-scale wind turbines, but much of the content will serve as a useful introduction to wind energy in general and can be applied to wind projects of all sizes.

For many small wind and community wind installations, a detailed wind resource assessment and feasibility study may not be economically justified. Therefore, this handbook was created to help facilitate the future siting, planning, and development of these types of installations. Overall, this handbook is aimed at helping the end customer make informed decisions regarding the viability of wind generation at their site and will recommend steps and procedures that increase the likelihood of successful projects. While the handbook focuses mostly on smaller wind systems, it also provides insight on when resource assessment campaigns or detailed feasibility studies may be warranted on larger scale, end-use installations.

This handbook will present the basics of wind energy and the steps involved in determining the available wind resource at a specific site, analyzing the proposed site's surroundings, and calculating the estimated annual energy production of the system. This discussion will help home owners determine the wind energy potential of their property before contacting an eligible installer and will help installers conduct consistent and accurate site evaluations.

The graphical flowchart in Figure 1 displays steps for a successfully implemented small wind system. The flowchart also provides an overview for the chapters of the handbook.

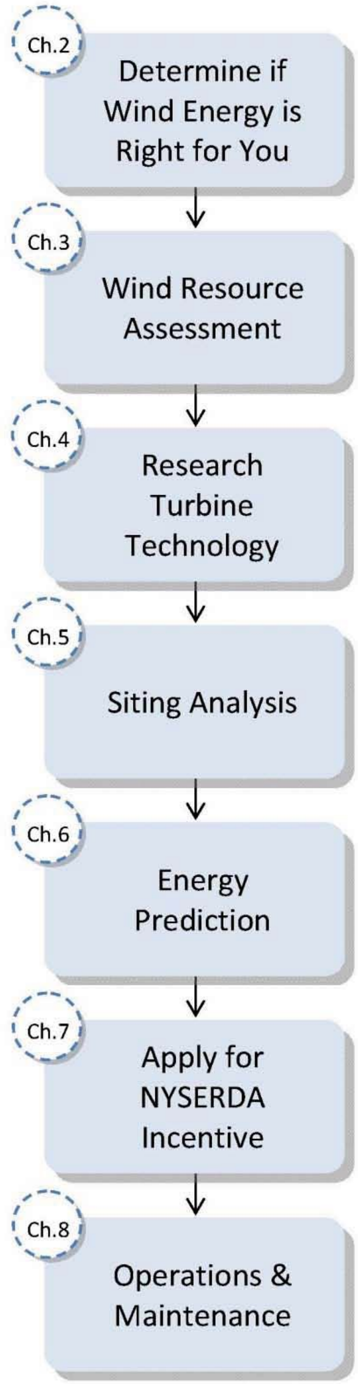


Figure 1. Steps to successfully implement a small wind system.

1.1 Small Wind Implementation Guidelines

Ch.2 Is Wind Energy Right for Me?

1. Reduce energy consumption
2. Increase energy efficiency
3. Research renewable energy technologies
    a. Wind, solar PV, solar thermal, geothermal, etc.

Ch.3 Wind Resource Assessment

1. Print/Review *Basic Report* from the Small windExplorer
    a. Is the average annual wind speed greater than 10mph?
2. At least one acre of land with no major obstacles upwind?
3. Contact eligible installer with *Basic Report*

Ch.4 Research Turbine Technology

1. Work with installer to choose the most suitable wind turbine
    a. Technology, size, nominal power
2. Work with installer to determine system components
    a. Tower type, tower height, inverter, etc.

Ch.5 Siting Analysis

1. Work with installer to determine the installation location
    a. Performance, safety, social, and legal considerations
2. Re-evaluate the wind resource at the exact project location
3. Feedback energy estimate with the above considerations to further refine turbine siting

Ch.6 Energy Prediction

1. Use specific turbine model and location to estimate annual energy production
    a. Installer will create an *Advanced Report* from the Small windExplorer
    b. Installer will estimate the system losses to include in the analysis
2. Installer will provide an economic analysis that will include the above energy production estimate, installation and maintenance costs, NYSERDA incentive, and the federal tax credit

Ch.7 Apply for NYSERDA Incentive

1. Installer will apply for all applicable permits and NYSERDA incentive
    a. Project must meet all system and siting requirements
2. NYSERDA will receive application and will award incentive based on a technical review
    a. Application must include all relevant material and system documentation

Ch.8 Operations and Maintenance

1. Eligible installer will install the turbine and system components
2. Installer will provide warranty and annual maintenance instructions
    a. Five-year warranty covering the entire system
3. Turbine owner will collect regular production data to track turbine performance

2 IS WIND ENERGY RIGHT FOR ME?

While wind energy currently plays only a small role in the world's energy supply, its use is growing rapidly. Along with the larger, utility scale projects, more and more home owners are taking advantage of the power in the wind by installing small wind turbines on their property.

Before installing a small scale wind turbine at your home or business, it is important to consider the energy consumption and efficiency of the property. These options can significantly reduce your property's energy requirements and will subsequently reduce the required size of the renewable energy system. Additionally, money spent increasing the efficiency of your home will typically result in a better energy payback than a renewable energy system.

Renewable energy systems can help further reduce your electricity bill and could possibly feed electricity back into the grid. They also offer attractive environmental alternatives to the electricity from the grid.

Before purchasing and installing a renewable energy system, determine if it is right for you and your property. Depending on your location and surroundings, different renewable energy technologies will produce different amounts of energy. A small wind energy system may be economical and provide a resonable amount of energy if:

- you have reduced consumption and increased the energy efficiency of your property
- your property has a sufficient wind resource
- your property has an open field or is void of major obstacles
- long term investments are acceptable

If you determine that wind energy is right for you and want to continue investigating your property's wind energy potential, the following chapters in the handbook will help guide you through the subsequent steps to successfully implement a small wind energy system.

Example

There are many options for decreasing your property's energy consumption and increasing its efficiency. Simple steps to decrease consumption include:

- Turn off lights when not in use and unplug rarely used appliances
- Reduce the temperature of your water heater
- Adjust your thermostat to a cooler setting in the winter and a warmer setting in the summer

Additional steps that can be taken to increase the long term efficiency of your property include the following:

- Minimize air leakage by air sealing your home
- Install compact fluorescent light bulbs
- Increase the property's outer wall insulation using rigid foam or spray material
- Install low-E, argon gas, casement windows
- Purchase high efficiency appliances

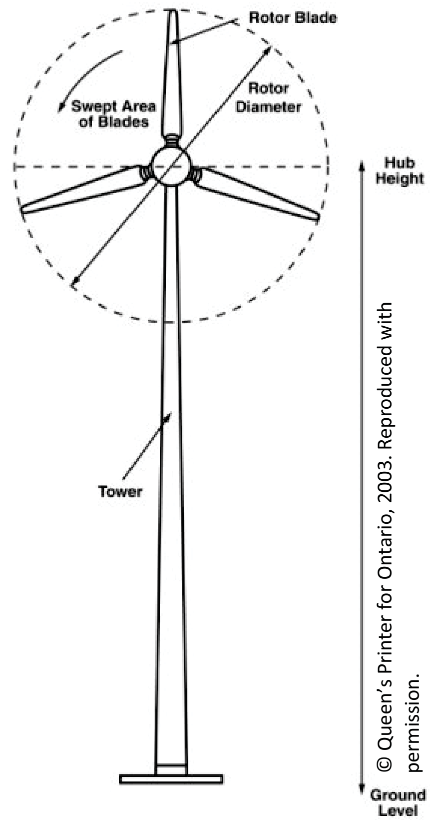
Additional resources for improving the energy efficiency can be found at the NYSERDA Get Energy $mart Web site: www.getenergysmart.org

3 THE WIND RESOURCE

Once you have decided to further pursue a wind energy system, it is important to understand the wind resource and know how it will affect your turbine's energy production. This chapter will familiarize you with wind energy and the main tools used to quantify your property's available wind resource.

3.1 What is the Wind Resource?

Wind turbines are designed to capture a portion of the wind's kinetic energy and convert it into mechanical energy to generate electricity. The amount of energy that a turbine can harvest from the wind depends on a number of factors, including turbine design, wind speed, and wind quality. The term wind resource is a broad term that is used to describe the characteristics of a site's available wind. Potential installation sites are initially evaluated based on wind speed and direction data for the project location and hub height. Since a sufficient wind resource is crucial for an efficient and economically viable turbine installation, it is used to both site the turbine and predict system performance.



Available Power

To evaluate potential sites and estimate the available wind resource, the factors that influence the wind speed and subsequently the power in the wind must be understood. To begin, the effect that the wind speed has on the wind's available power will be discussed. Air has mass, and when in motion, it possesses energy known as kinetic energy. The amount of available power in the wind is dependent on a number of factors including air density, wind speed, and the swept area of the turbine blades.

As is evident from the equation on the right, an increase in the air density, swept area, or wind speed will increase the available power. Still, the available power in the wind is proportional to the cube of the wind speed. For instance, if the wind speed is doubled, the available power in the wind is increased by a factor of eight. This nonlinear dependence makes the wind speed the most important factor at the installation site.

Equation

The power available in the wind is calculated using the following equation:

$$P = \frac{1}{2}\rho A V^3$$

Where:
ρ = Air density
A = Swept area of blades
V = Wind speed.

Variability and Shear

A site's wind speed will vary greatly for a given project area due to many influencing factors, including time of day, season, height, terrain, and land cover. The speed changes over time can be difficult to estimate, therefore the wind resource is usually characterized by its average annual wind speed. As a general rule and a requirement for NYSERDA sponsored incentives (www.PowerNaturally.org), the average annual wind speed at the turbine location and hub height must be at least 10mph; this guideline is usually a good indicator of a potentially good wind resource.

In addition to inter-annual variations, the wind speed is related to the height above ground. The speed of the wind decreases near the earth's surface due to a frictional drag experienced between the wind and the surrounding environment's surface roughness, caused by items like terrain, ground cover, and buildings. The magnitude of this occurrence, known as wind shear, will vary with changes in the environment and surface roughness.

The surrounding environment's effect on the wind decreases with increasing height above ground, resulting in an increase of speed with increasing distance from the ground. A slight increase of wind speed due to an increase in height will lead to a significant increase of wind power. This relationship highlights the importance of having a sufficiently tall tower to place the turbine in high velocity winds. Towers of 80 to over 120 feet are typically used in New York for this reason. The graph in Figure 2 further illustrates the typical relationship between height and power production. The relationship between height and power production at a particular site will be affected by the mean wind speed, surface roughness, and terrain.

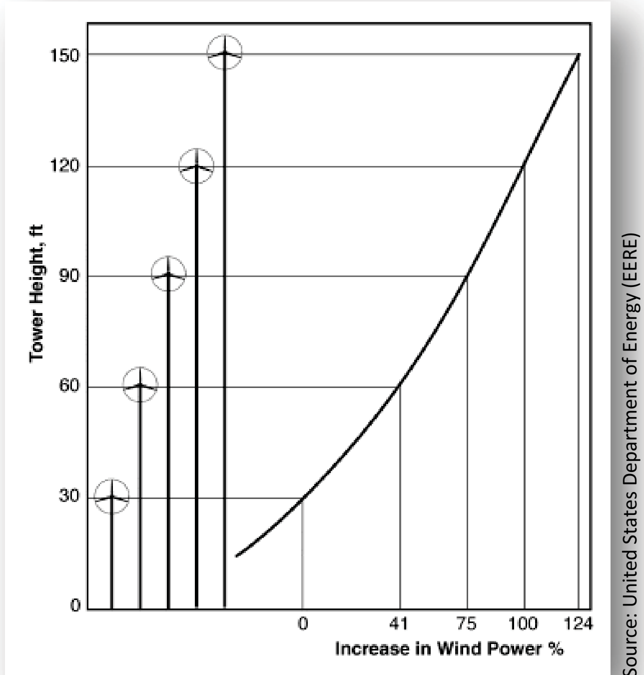


Figure 2. Relationship between turbine height and power output

Turbulence

Small scale variations in the wind resource can be detrimental to the turbine. These variations, known as wind turbulence, are described as rapid disturbances or irregularities in the wind speed, direction, and vertical component. Turbulence will vary with height and location and is caused by many different factors, including manmade structures, vegetation, and topography. It is an important site characteristic since high turbulence levels may decrease power output and cause extreme loading on wind turbine components, which will result in increased fatigue and possible failure. The most common indicator of turbulence for siting purposes is the standard deviation (σ) of wind speed. Normalizing this value with the mean wind speed gives the turbulence intensity (TI). This value allows for an overall assessment of a site's turbulence. TI is a relative indicator of turbulence with low levels

Equation

Turbulence intensity is calculated using the following equation:

$$TI = \frac{\sigma}{V}$$

Where:
σ = Standard deviation of wind speed
V = Mean wind speed.

indicated by values less than or equal to 0.10, moderate levels to 0.25, and high levels greater than 0.25.[1]

3.2 Wind Resource Assessment

In order to properly identify the wind energy potential of a site and determine the feasibility and economic viability of a small wind system, the wind resource must be quantified to produce a reasonable energy production estimate for the turbine. Specifically, the annual average wind speed, wind rose, and wind speed's probability distribution for the proposed turbine location and hub height are important parameters. The following sections will describe the process of collecting this information and the tools used to display the characteristics of the wind resource.

Details

Anemometers and wind vanes are meteorological instruments that are used to measure the available wind resource. Anemometers are used measure the wind speed and wind vanes are used to measure the wind direction. Examples of the two instruments are shown below.

Anemometer
& Wind Vane
(Photos courtesy of NRG Systems, Inc.)

Collecting Wind Resource Data

Wind resource data is typically collected using meteorological towers with anemometers and wind vanes at multiple heights and a collection time of at least one year in order to properly describe local seasonal variations. This type of measurement campaign is needed for utility scale wind energy projects and can be justified for community scale projects with a small number of utility scale turbines. Nevertheless, this type of campaign is rarely economically justified for small wind installations due to the high cost of equipment, installation, and monitoring. Therefore, a simpler and quicker method of characterizing the wind resource is necessary. To help determine the wind resource in New York State, NYSERDA has developed an interactive online tool specifically created for small wind installations, ***Small windExplorer***. This tool is discussed in detail in Chapter 6 along with the discussion of turbine energy production. On-site resource assessment campaigns or feasibility studies may be warranted for end-use or community wind projects greater than 100 kW.

Resource

Small wind installations in New York State can take advantage of the Small windExplorer. This is an important first step in determining if the property is suitable for wind energy. A Basic Report can be created for the site, which will help determine if there is enough wind on the property.

The property owner should contact an eligible installer with the Basic Report information. The installer will guide the end-user through the entire process of assessing the wind resource, siting the turbine, applying for the NYSERDA incentive, installing the turbine, and conducting regular maintenance on the system.

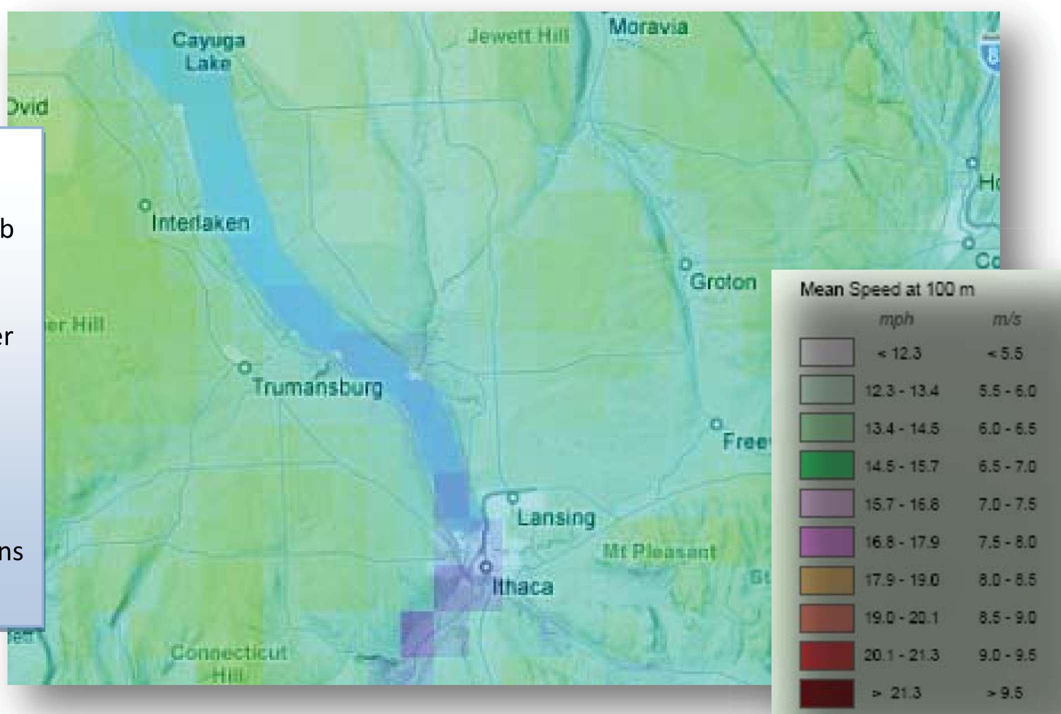
[1] http://www.nrel.gov/wind/pdfs/22223.pdf

Wind Resource Map

As mentioned earlier, the annual average wind speed is one of the most important parameters used to describe a site's wind energy potential. This information can be displayed as a table of wind speeds for varying heights at the project location or in a graphical wind resource map for a specific height. As shown in Figure 3, a typical wind resource map displays the average annual wind speed for varying locations at a defined height. Wind maps are generated using observed historical data and numerical weather models; they provide the user with an estimate of the wind resource without on-site measurement.

High quality wind maps depict the approximate annual average wind speed over small (200m) grid cells at the indicated height above ground and allow the user to determine the locations with the best wind resource. While this tool can be used in determining site specific wind data, it must be made clear that the estimates are averaged over the grid cell. For instance, in determining the wind speed at a specific latitude and longitude, the tool will choose the closest grid point to the chosen location and display the averaged wind data for the entire cell area. This grid point is based on averaged site data for the grid cell and may not accurately depict small scale changes in wind speed and roughness throughout the cell. Therefore, a given wind speed for a grid cell may be higher or lower than the exact location being studied.

In order to receive a reasonable return for your investment, the hub height annual average wind speed must be greater than 10 miles per hour. If the Small windExplorer estimates that property has an insufficient wind resource, other renewable energy options should be explored.



Source: AWS Truewind

Figure 3. Example of a wind resource map for New York State

Wind Rose

Wind direction varies on both small and large time scales and all directions have different amounts of available energy. An estimate of the amount of energy from each directional sector at the proposed installation site is needed to help quantify how local obstacles and the surrounding environment may influence the system's energy production.

The typical method for characterizing and displaying the distribution of the wind speed is through the use of a wind rose. A wind rose graphically displays the percent time and percent energy of the wind for the directional sectors and is usually divided into eight or sixteen sections. The percent energy differs from the percent time because the energy in the wind is proportional to the cube of the wind speed, as discussed earlier. Therefore, a certain direction that has a low wind speed for a long period of time may have less energy than a direction that has high wind speeds for a shorter amount of time.

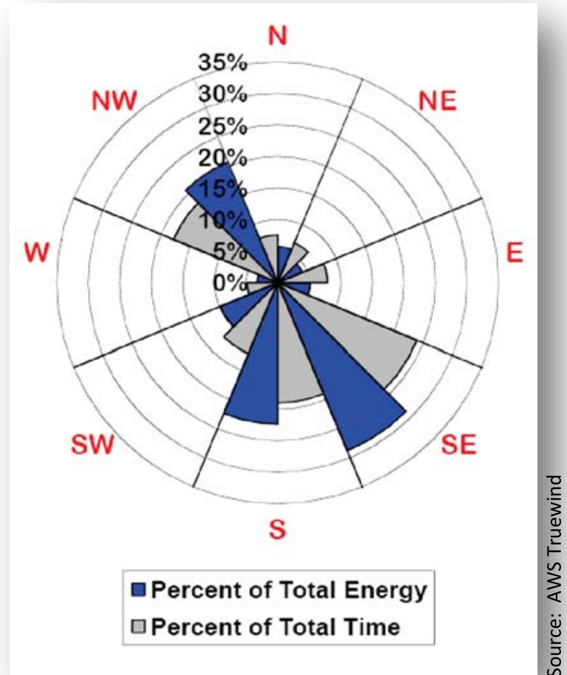


Figure 4. Diagram of a typical wind rose

This graphical tool is extremely helpful in the siting of small wind systems; it helps to determine the prevailing wind directions that will be impacted most by local obstacles. The wind rose, used in conjunction with the wind map and other siting criteria, helps the land owner and installer determine the best possible location throughout the installation property to maximize the turbine's energy production.

Example

As shown in the above wind rose, the percent of total time is represented with gray wedges and the percent of total energy is represented with blue wedges. The radius of each wedge gives the respective percentage for each directional sector, as defined by the radial markings from the center.

The wind rose has a prevailing wind direction from the southeast with approximately 29% of the total energy. The south and northwest also have substantial wind energy, totaling 22% and 21%, respectively. Trees or other obstacles in these directions could significantly reduce the output of a turbine.

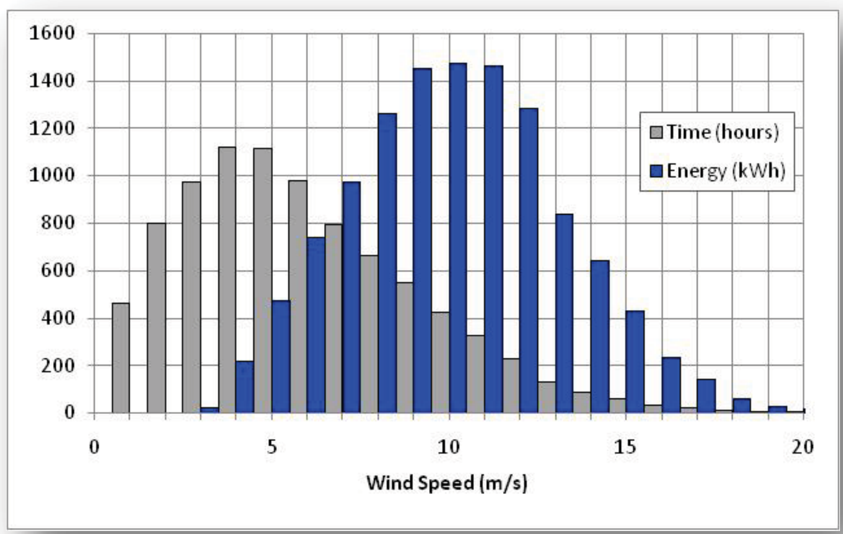
Frequency Distribution

Wind is an intermittent resource and varies in strength with time of day, season, and year. If wind speed measurements were taken at a project site for an entire year and graphed, the speed distribution would resemble a bell shape, with a low probability of zero wind speeds and a low probability of very high wind speeds. Additionally, the wind speed is usually skewed with higher velocity winds occurring less often than the lower speeds, as shown in Figure 5.

Since the energy in the wind is proportional to the cube of the wind speed, the amount of energy in the wind at higher velocities is much higher than that at lower velocities. Therefore, two sites with the same annual average wind speed may have different wind energy potentials due to different wind speed distributions. For this reason, it is very important to understand the frequency distribution of the wind speeds to accurately estimate the amount of power available at the site.

Since it is not economically feasible to conduct a long-term measurement campaign to determine the speed distribution for small wind projects, the wind speed frequency distribution is usually modeled using mathematical functions. Wind speeds are typically divided into 1m/s increments, or bins, and described using a Weibull distribution. This distribution is calculated using a shape factor (k), a scale factor (A), and the average annual wind speed. Furthermore, the distribution will change from site to site and for different hub heights, so the parameters are needed at the turbine's specific location and hub height.

The Small windExplorer automatically inserts the site specific Weibull parameters to calculate the wind's frequency distribution. Additionally, the Small windExplorer advanced report provides the shape (k) and scale (A)factors for advanced users to use in other energy estimating tools.



Source: AWS Truewind

Figure 5. Frequency distribution of wind speed and energy

Equation

The Weibull distribution is described using the following equation:

$$p(U) = \int_{U}^{U+1} \left(\frac{k}{A}\right)\left(\frac{u}{A}\right)^{k-1} exp\left[-\left(\frac{u}{A}\right)^{k}\right] du$$

Where:
p(U) = Probability wind speed will be between U and U+1 (in m/s)
k = Weibull scale factor
A = Weibull shape factor.

4 WIND TURBINE TECHNOLOGY

Once the wind resource is identified and the decision to move forward with a wind energy project is made, it is important to understand turbine technology and the many components of a small wind system. This chapter will give land owners and installers a deeper understanding of the various types of turbines and will help home owners learn more about the technology before investing in a system.

4.1 What is Small Wind?

Wind turbines are generally categorized based upon their nominal power, which is the power output at a rated wind speed. Based upon the nominal power output, turbines can be classified into one of three categories: small, medium, and utility scale. Small-scale wind turbines typically include units with a nominal power output under 100 kW and are predominantly used by homeowners and businesses to offset local energy consumption. Medium-scale turbines typically include those with a nominal power between 100 kW and 1000 kW and are used by larger businesses or small wind farms. Utility-scale wind turbines, with a typical nominal power greater than 1000 kW, are used in large wind farms where the electricity is sold to an energy utility. While these categories are by no means concrete, they serve a helpful classification when referencing turbines of similar production capacity and technology. Figure 6 below gives a relative size comparison for small, medium, and large turbines.

The consumption of the property must be analyzed to help choose the correct size turbine and ensure optimum electrical production.
Electrical demands can require a turbine of as small as a few kilowatts for a small house to several dozen kW for a small commercial property.
The property's annual consumption should be compared to the estimated production of the turbine.

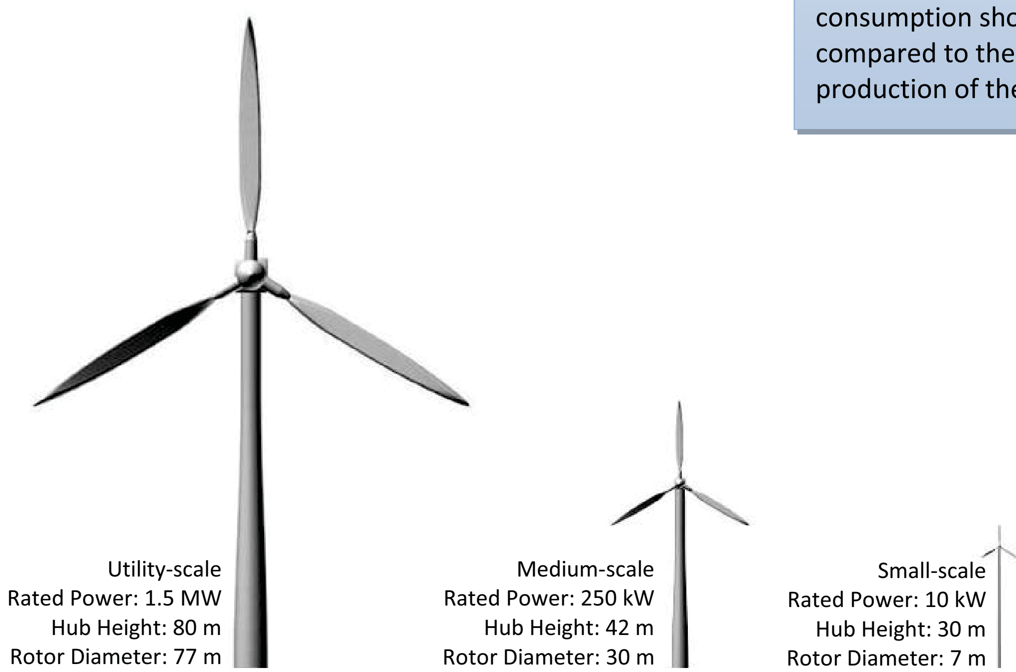


Figure 6. Size comparison of various wind turbines

4.2 Wind Energy Applications

Wind energy is currently used in many different areas and for many different applications. Wind can be captured to pump water for livestock or irrigation or can be used to generate electricity. Each different application requires different components and equipment.

Source: Airlift Technologies

Water Pumping

Water pumping is often required in remote locations for drinking water for personnel or livestock. Since water is easily stored, the intermittent nature of the wind is easily mitigated by pumping water when the wind is available and storing it for times when the wind is not blowing. Wind turbines can either drive water pumps directly via a shaft, or produce electric power, which in turn is used by an electric water pump. Since electric water pumps are able to directly use the variable frequency AC generated by a wind turbine with a permanent magnet generator, no inverter or battery bank is required. Wind power can be used to pump other liquids, such as petroleum, but water pumping is far more common.

Battery Charging

The power generated by a wind turbine is often stored in a battery bank for use at a later time. Deep-cycle batteries are best for this type of application because they can charge and discharge 80% of their capacity hundreds of times. A charge controller is needed to prevent battery damage as a result of overcharging; the controller will protect the batteries by either dumping or diverting excess electricity.

As discussed earlier, many small wind turbines have permanent magnet generators that output variable frequency AC, which is subsequently converted to DC. Batteries store DC energy, and for small end-use applications, DC-compatible appliances can be operated directly from the battery bank. In order to use the electricity generated by the turbine in a household, a power-conditioning unit, known as an inverter, is generally used to convert the DC electricity into 60 Hz, 120 V AC.

Grid-Connected

When the electrical grid is easily accessible, the turbine is usually connected to the grid. This configuration allows the end-user to use electricity from the grid when the turbine is not producing sufficient power and eliminates the user's need for a battery bank. An inverter is required to connect a permanent magnet generator to the electric grid. No inverter is required to connect an induction generator to the grid.

Through a program called net metering, excess electricity is sold to the utility at the same price that the utility charges the turbine owner for utility-supplied electricity. Under this type of arrangement, producers of renewable energy receive credits for every kWh they generate beyond their own needs. When a turbine owner produces more electricity than can be used locally, the power meter runs backwards, sending the excess electricity to the grid. New York State currently has system size limitations for net metering with wind energy: 25 kW for residential systems, 500 kW for farm-based systems, and 2 MW or peak load for non-residential systems. If more than 100% of consumption is produced by the system, the excess energy is paid back at the avoided cost of production by the closest production source. Since the avoided cost of production is usually a fraction of the retail electricity rate, it does not make financial sense to over-size a turbine with the intent of making money on excess electricity that is sold back to the utility.

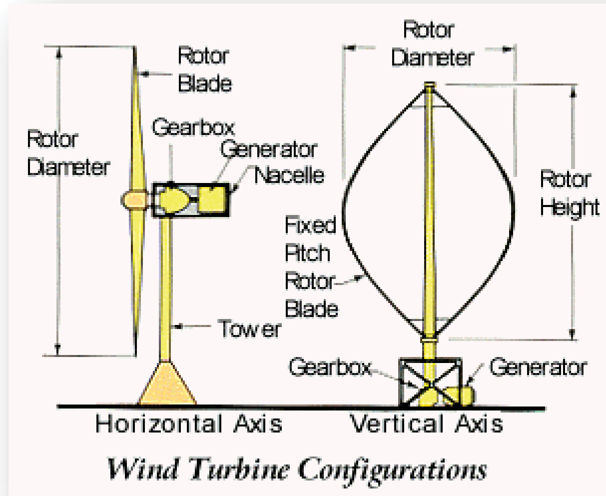
While all three applications play an important role in the generation of usable energy from the wind, the water pumping and battery sections are only provided for context. The following sections of the handbook will refer only to grid connected systems.

Resource

Additional information on New York State's net-metering and interconnection requirements can be found at the NYS distributed generation Web site (www.dps.state.ny.us/distgen.htm) and the NYSERDA Web site (www.nyserda.org).

4.3 Turbine Technology

There are two basic wind turbine designs: the horizontal-axis wind turbine (HAWT) and the vertical-axis wind turbine (VAWT). As the names imply, the HAWT features a rotor that is mounted horizontally with a rotational axis parallel to the ground, while the VAWT has a rotor that rotates about an axis perpendicular to the ground. Since VAWTs rotate about a vertic al axis, they are always oriented into the wind. HAWTs can be subdivided further based upon the turbine's orientation to the wind. Upwind turbines are oriented into the direction from which the wind is blowing, while downwind turbines face away from the direction of the wind. Figure 8 below shows the two basic types of wind turbine designs.



Source: American Wind Energy Association

Figure 7. Diagram of VAWT (L) and HAWT (R) turbine designs

Horizontal-Axis Wind Turbines (HAWT)

Horizontal-axis small-scale wind turbines are the most prevalent design and usually consist of the following components:

- Rotor to convert wind energy to the rotating shaft
- Generator to convert the rotational energy to electricity
- Yawing mechanism to control turbine orientation
- Tower to support the above components
- Control system for high wind events

Rotor

The rotor captures the kinetic energy of the wind and converts it into torque, which is then transmitted through a rotational shaft to the generator. The rotor usually consists of two or three blades that are connected to a hub and central shaft, that drives the generator. The blades are typically constructed out of composite material such as fiberglass, due to its strength and flexibility, and range in length from 2.5-50 feet. The complexity of the rotor system can vary greatly based upon the size and sophistication of a turbine's design.

The blades of most small-scale wind turbines have a simple fixed pitch system, where the blade's pitch angle is constant. Larger, utility-scale variable speed turbines have a more advanced pitch system that adjusts the blade angle to control the rotation of the rotor in varying wind conditions.

Resource

For a list of turbines participating in NYSERDA's incentive program, see www.PowerNaturally.org.

Generator

The generator converts the rotational energy of the shaft into electricity, using electromagnetism. There are two different types of generators used in small wind turbines: permanent magnet and induction. Many small wind turbines, up to 50 kW, use permanent magnet generators. In this type of system, the rotor is connected directly to the rotational shaft of a permanent magnet alternator, which produces alternating current. However, the frequency of the alternating current is proportional to the rotational speed of the blades. Since this variable frequency AC power is incompatible with standard 60 Hz AC systems, it is typically converted to DC power. This DC power can then be used directly by DC devices, stored in batteries, or converted to 60 Hz AC power.

Most turbines above 50 kW use induction generators. Induction generators require grid power to magnetize the generator and produce 60Hz AC that is compatible with the electrical grid. Therefore, induction generators do not require an inverter for power conditioning.

Additionally, many small wind turbines use a direct drive system, meaning that the rotational shaft is connected directly to the generator. Larger wind turbine designs often use a gearbox to increase the rotational speed of the slowly rotating main shaft.

These components are usually housed at the top of the turbine's tower in an enclosure known as the nacelle.

Yawing Mechanism

Yaw refers to the rotation of the turbine about its vertical axis and is used to align the turbine with the wind. Most medium- and utility-scale turbines have active yawing mechanisms where a control system linked to a wind vane determines the wind direction. When the control system detects a change in wind direction, yaw motors are activated to turn the rotor into the wind to maximize energy capture.

The majority of small-scale turbines use a passive yaw system, which uses the wind rather than motors to orient the position of the turbine. Passive yaw systems for upwind designs consist of a tail or vane that extends out from the rear of the turbine. The turbine's tail operates similar to a weather vane; it orients the rotor to face into the direction of the wind. Turbines with a downwind design also yaw passively and self-align with the wind without the use of a tail.

Horizontal Axis

Advantages:

- HAWTs are usually mounted on tall towers, exposing them to stronger winds, which greatly improves the potential for energy production and reduces the harmful effects of ground-induced turbulence.

Disadvantages:

- The major components of small-scale HAWTs are located at the top of the tower, making them difficult to access without the use of a tilt-down tower.
- HAWTs require a yawing mechanism to orient the rotor into the direction of the wind, thereby creating a risk of yaw misalignment.

Upwind vs. Downwind

Unlike upwind oriented turbines, downwind turbines do not require a yawing mechanism because they are designed to self-align with the direction of the wind. Downwind turbines are subjected to increased fatigue loading due to the distorted flow behind the tower.

Source: Bergey Windpower

Tower

Small wind turbines can be mounted on tall towers (80 ft or higher) and are either self-supporting or guyed. The towers are composed of smaller sections of triangular lattice, pipe, or tubing and are typically constructed on-site. Self-supporting towers rely on a strong steel frame and concrete foundation to keep them upright, while guyed towers are supported by tensioned cables and anchors, positioned around the base of the tower for stability.

Figure 8. Self supporting lattice tower

Guyed towers are usually less expensive and easier to install than self-supporting towers. Additionally, some guyed towers have a hinge at their bases, allowing them to be tilted up or down using a gin pole and a winch for maintenance and repairs. Due to the guyed tower's large footprint, it may not be suitable for certain situations; the radius of the guy foundation needs to be one-half to three-quarters the height of the tower, while a freestanding tower only occupies the area of the tower foundation.

The tower itself can consist of lattice section, pipe, or tubing. Lattice towers are typically constructed out of triangular lattice sections that bolt together; this type of tower can be self-supporting or guyed, depending upon the design of the structure. A tower can be assembled from several sections of metal tubing that fit together end-to-end. Tubular towers can be either self-supporting or guyed.

Control System

In larger, utility-scale turbines, the blades are able to rotate about their axes, altering the angle at which the blade intercepts the wind. This system, known as pitch control, is used to optimize power output at low wind speeds and regulate operation during high wind speeds, which prevents overspeeding by shedding excess energy. Small wind turbines generally don't have pitch control, so they use different methods to shed excess energy and protect themselves in high winds. Small wind turbines deal with excessively high wind in one or more of these three ways: they stall, turn out of the wind, or deploy tip brakes. With a passive stall control system, the turbine blades are designed to generate turbulence on the upwind side of the blade above a given wind speed. This turbulence causes the turbine blades to stall instead of producing lift, so the rotation of the blades is slowed.

Another passive control system allows the turbine to turn out of the wind, either horizontally or vertically. Turning horizontally out of the wind is referred to as yaw. Turning vertically out of the wind is referred to as tilt.

Tip brakes employ weights that are placed on the tips of the turbine blades. When the rotational speed of the blades exceeds a certain threshold, the weights flare outwards due to the centrifugal force. When this happens, the shape of the tip brakes causes aerodynamic drag, which in turn slows the rotor.

Vertical-Axis Wind Turbines (VAWT)

Vertical axis wind turbines rotate about an axis perpendicular to the ground and are usually one of three designs: Darrieus, Giromill, and Savonius. Large-scale VAWTs usually take the form of a Darrieus design, often likened to an "eggbeater" because their long, C-shaped, blades bow out from the turbine's vertical axis. This type of turbine is usually ground-mounted, and the central tower is held upright by guyed wires. This VAWT design is not self-starting and usually requires an external power source to initiate rotation.

A more common design for small-scale VAWTs is referred to as a Giromill or H-bar model. Instead of the long, curved blades of the Darrieus design, the Giromill uses straight vertical blade sections, which are attached to the vertical axis with horizontal supports.

The third type of VAWT, Savonius, is based on drag and uses "scoops" to catch the wind. The Savonius is able to start by itself, unlike the Darrieus or Giromill, which must be started by an external source, such as a motor.

Vertical axis turbines will typically have many of the same components as the horizontal axis turbine: rotor, gearbox, and generator. Nevertheless, since they perform independently of the wind direction, they do not need a yawing mechanism or control system. VAWTs can be located near the ground or on a tower. For more information on the system components, please refer to the above section.

Vertical Axis

Advantages:

- The design is always aligned with the wind, so there is no need for a yaw mechanism.
- Several of the turbine's major components, including the gearbox and the generator, are ground-mounted, making them easily accessible for maintenance.
- VAWTs are often installed lower to the ground than HAWTs, so they can be installed in areas with height restrictions.

Disadvantages:

- Since VAWTs are located near the ground, they are exposed to lower wind speeds and higher turbulence.
- Some VAWT designs are not self-starting and need an initial boost to rotation.
- The weight of the turbine is supported by the ground-mounted components; this means that major repairs or the replacement of parts can require that the system be completely dismantled.
- VAWTs can be more difficult to control in high winds because they cannot be turned out of the wind.


Darrieus


Giromill


Savonius

Source: ecoPower, Mariah Power, WePOWER

Performance Metrics

Power Curve

Small wind turbine performance can be described using a manufacturer supplied power curve, which shows the turbine's output power versus hub height wind speed standardized to sea level air density (1.225 kg/m^3). The wind speeds are listed on the horizontal axis, in miles per hour (mph) or meters per second (m/s), and the turbine's power output is along the vertical axis in either watts or kilowatts (kW).

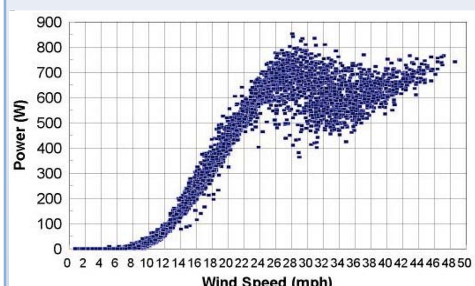
The power curves above have certain points that provide specific information regarding the turbines performance. The cut-in speed, at the lower end of the curve, is the threshold that the hub height wind speed must reach in order for the turbine to begin generating electricity. A turbine's nominal, or "rated" power, is the amount of electricity that the turbine will generate at a manufacturer specified wind speed; this value is often used to describe a turbine's generating capacity. The rated power is often confused with the turbine's peak power, located at the very top of the curve, which indicates the maximum amount of power the turbine can produce. The turbine's governing speed is the wind speed at which the turbine will protect itself from high wind speeds, since small wind turbines are subjected to large structural loads at high wind speeds.

Using either the rated power or the peak power as a basis of comparison between turbines can be misleading for two reasons. Wind turbine manufacturers don't all rate their turbines using the same wind speed, and the turbines are exposed to the wind speeds associated with rated or peak power only a small percentage of the time. It is more useful to compare turbine performance at the lower end of the curve, considering that the turbine will be operating at those wind speeds the majority of the time. Upcoming AWEA standards for small wind turbines will improve the ability to compare turbines by defining AWEA rated power at and 11 m/s wind speed and AWEA rated energy as the expected annual energy from a turbine at a location with an annual average wind speed of 5 m/s (11.2 mph).

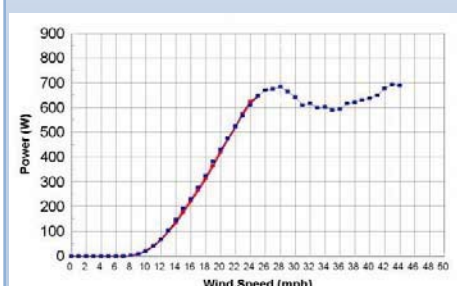
Details

A power curve is usually assembled from ten-minute averages of a turbine's power production at a given wind speed. A plot of a turbine's actual power production is much more scattered than the simple power curve that is provided by manufacturers. The plots in Figure 9 below compare observed power data with a power curve constructed from the average power production for each wind speed bin or increment.

Measured Power Data



Bin Averaged Power Data



Source: Paul Gipe (www.wind-works.org)

Figure 9. Comparison of measured and binned averaged power curves

Capacity Factor

To measure the productivity of a wind turbine, wind farm operators use a metric known as capacity factor. This variable compares the wind plant's actual production to its theoretical production that would result from the plant running at nominal capacity over a given amount of time. To calculate the capacity factor, the annual energy production is divided by the rated power multiplied by the number of hours in the year. This performance metric normalizes the data and allows easy comparison between different turbine technologies, sizes, and locations.

Most utility-scale wind farms operate between 65% and 90% of the time and are often not operating at their rated capacity. Therefore, a capacity factor of 25% to 40% is typical for these utility scale systems. Given that small-scale turbines use much less sophisticated technology, are installed in less windy sites, and are often subjected to more turbulent winds, their performance is often much less than that of a utility-scale wind plant. Based on a study of installed wind energy systems in Massachusetts, a capacity factor of 10% would be considered rather high for most small wind installations[2].

Equation

The capacity factor is calculated using the equation below:

$$CF = \frac{Actual\ Production\ (kWh)}{Ideal\ Production\ (kWh)}$$

To calculate the CF for a given year, divide the expected or actual annual production by the rated capacity multiplied by the number of hours in the year, as shown below.

$$CF = \frac{Annual\ Production\ (kWh)}{Rated\ Power\ (kW) \times 8760}$$

Availability

Availability refers to a measurement of a turbine's reliability. It is defined as the percentage of time that a turbine is able to generate electricity, that is, the time that the turbine is not down due to maintenance or repairs. Modern utility-scale wind turbines strive for an availability of more than 98%. Availability data for small-scale wind turbines is not currently available. The availability of a small wind turbine would be highly dependent upon the reliability of the system, the quality of the installation, the wind resource, and the level of system maintenance.

[2] Progress Report on Small Wind Energy Development Projects Receiving Funds from the Massachusetts Technology Collaborative (MTC), The Cadmus Group, Inc. (2008)

5 SITING ANALYSIS

While the wind resource may vary throughout the proposed installation site, the point with the highest wind speed may not offer the safest or most economical installation option. The positioning of a small wind turbine may be restricted due to many factors, including site access, performance, social, and legal considerations. It is important to take these other variables into account when determining the appropriate positioning of a turbine.

This chapter addresses small wind siting considerations that will help determine suitable installation sites. Proper turbine siting is essential for optimum energy production and a reasonable economic payback.

5.1 Site Access

The access of a potential installation site can restrict the ability to build upon the land. Access to sites can be obstructed by many different variables, including a lack of roadways, extreme terrain, or general remoteness. These factors may not completely restrict access to the site, but the cost of installation will increase dramatically with increased construction difficulty. Furthermore, the constructability of the land may be restricted due to environmental considerations, ground composition, or local regulations.

5.2 Performance

Obstructions

The wind resource must be quantified to begin the siting of a small wind system. Since the wind will fluctuate throughout the property and will vary with changes in the local terrain, the ideal turbine location will be positioned where the wind speed is the highest and least obstructed. The locations with the best available wind speed can be located with a wind map. However, small scale natural changes in the property's topography and local obstructions may not be accounted for in published wind resource estimates. Therefore, a site inspection and analysis is needed to adjust the wind resource estimates to a more likely range.

Careful consideration of the terrain is important when siting a wind turbine; a turbine positioned on the top or the windward side of a hill has better exposure to high velocity wind than if it is installed in a gully or on the leeward side of a hill. The prevailing wind direction is important to consider when positioning the turbine in close proximity to tall obstructions such as buildings,

> This chapter focuses on ground mounted installations only and does not consider building-mounted systems.
>
> The performance of wind turbines mounted on buildings is not well studied or documented and the wind around buildings can be very complex. The building itself can significantly disturb the airflow around the turbine, thereby adversely impacting a turbine's energy production and increasing wear and tear on the turbine. In addition, effects of the turbine on the building structure are not well understood.

trees, and geological formations. As wind flows around an obstacle, a wake forms immediately downstream. This region of turbulent airflow has a much lower velocity than the undisturbed wind above. Given that the available power in the wind is proportional to the cube of the wind's velocity, this reduction in wind speed significantly reduces the turbine's ability to generate electricity.

Turbulent winds not only adversely impact energy production, but also increase the fatigue loads that the turbine will experience, effectively shortening its operational life. Therefore, the recommended turbine siting is upwind of all major obstacles to ensure they are exposed to the least turbulent, highest velocity winds available.

Due to a small property size or an abundance of local obstacles, it may be difficult to locate the turbine away from the detrimental effect of obstacles. In these situations, the height of the turbine becomes increasingly important, since the effect of nearby obstacles can be decreased by increasing the height of the turbine. Raising the height of the system can move the turbine out of the turbulent airflow caused by an obstacle and will increase turbine performance.

The region of turbulent flow is approximately twice the obstacle height (H) and persists horizontally for roughly twenty obstacle heights (20H), as shown in Figure 10.

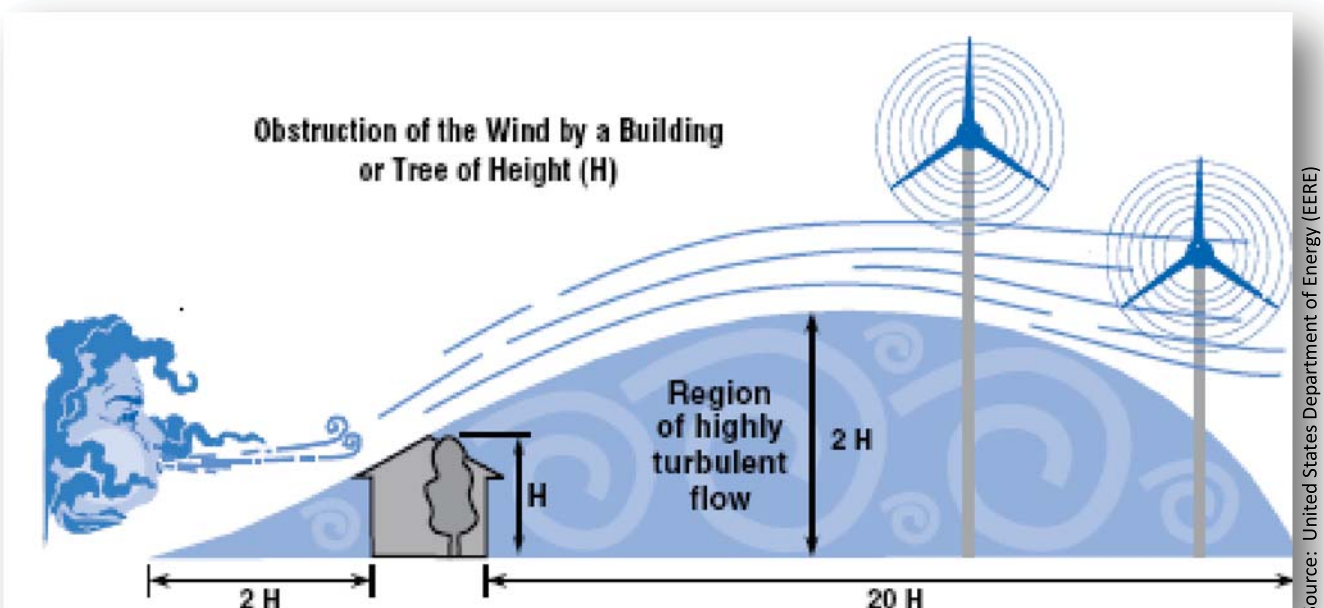


Figure 10. Approximate region of turbulent airflow

In addition to moving the turbine to higher quality wind, the turbine will experience increased wind speeds with increased heights, which will lead to much greater energy generation. While increased height can increase turbine performance, other considerations can ultimately restrict the height of the system, including the following:

- Additional space needed for raising/lowering the tower for maintenance
- Increased space needed for guy wires
- Increased construction cost
- Increased setbacks from nearby structures

Collection System

Increased distance between the turbine and the electrical connection point will influence the overall cost and efficiency of the system. A larger distance will result in increased wire lengths and will result in a higher cost that may not be recouped by the possible increase in available wind energy. Longer wire runs will result in higher electrical losses in the collection system and will reduce the electricity supplied to the grid.

If the turbine was certified by the Small Wind Certification Council (SWCC), the power curve includes the losses due to the collection system for a wire run length of at least eight rotor diameters from the base of the tower. There is no standard guideline, since the wire size can be increased to mitigate long wire run losses. Still, this should be a consideration during the siting and design process.

5.3 Safety

Since small wind systems can have relatively high tower heights and are located in windy conditions, the safety of the system is a major component of the siting process. Safety issues include, but are not limited to, possible tower failure and collapse, ice shedding, and electrical issues.

Wind turbines are typically setback from human occupied buildings to protect people if the tower were to fail. Setbacks are also used for property lines, power lines, and roads. A common distance for the turbine to be located away from property lines and power lines is at least the height of the turbine plus the length of the blades.

> In order to qualify under NYSERDA's incentive program (www.PowerNaturally.org), the turbine must have adequate set-backs from houses and other buildings.

Ice shedding results from accumulated ice on the turbine components shedding when temperatures increase and the ice melts. While this condition can be hazardous, it is not significantly different from ice shedding from other structures, such as power lines and transmission towers. Ice could theoretically be thrown from the blades as they rotate, but in practice ice typically sheds from the structure and falls near the base of the turbine. In the rare case that ice is actually thrown from a turbine, setbacks of at least the structure height will provide sufficient distance to protect against shedding ice. Customers can apply in writing for an exemption from the NYSERDA incentive setback requirements.

Wind turbines and inverters are professionally designed to be compliant with interconnection standards and safety requirements and rarely present major issues related to their interconnection to the grid. However, the turbine will be producing continuous power and the system must be treated with common safety practices. Furthermore, the installer of the system needs sufficient experience to safely design and install the system, reducing the risk of electrical shock or failure. For more information on interconnection standards and practices, please consult the National Electric Code (NEC).

5.4 Social

Aesthetics

Since wind turbines are located at the top of tall towers and are sited to be in open, unobstructed areas, they may be viewed from distances beyond the property boundaries. The visual impact of the turbine is affected by the turbine model, tower height, and local topography and obstructions. The turbine owner may enjoy the sight of the turbine, but neighbors and others in the community may have issues with being able to see the structure and may protest the turbine's installation. It is recommended that you discuss your plans to install a wind turbine with neighbors, early on. Communication is important to help gauge the response of neighbors and communities and get their feedback on any major issues. While the aesthetics of a turbine may not seem to be a major issue, they can prevent a small wind project from proceeding.

Furthermore, limitations on visual impact within the local community may be restricted through community or historical site regulation. For larger installations or instances with above average aesthetic concern, a visual impact analysis may be warranted to determine the visual implications of installing a wind turbine. Since the aesthetics of a small wind system are highly subjective and there are few laws or regulations specifically related to this issue, there are no concrete guidelines for the siting of a small wind system. The installer and property owner must be aware of the impact that the installation will have on the aesthetics of the property.

Acoustics

Small wind turbines produce audible noise, when operating, which can usually be heard by nearby observers. The sound generated by the system is created by both the mechanical components of the turbine and the aerodynamics of the rotating blades. The intensity of the sound is affected by many variables, including nearby surroundings, turbine model, hub height, and wind resource. Furthermore, the noise increases with increasing wind speeds and decreases at a rate proportional to the square of the distance from the turbine.

An additional consideration regarding on-site sound observations includes the increase in background noise that is observed with increasing wind speed, which will partly mask the increased aerodynamic noise of the turbine.

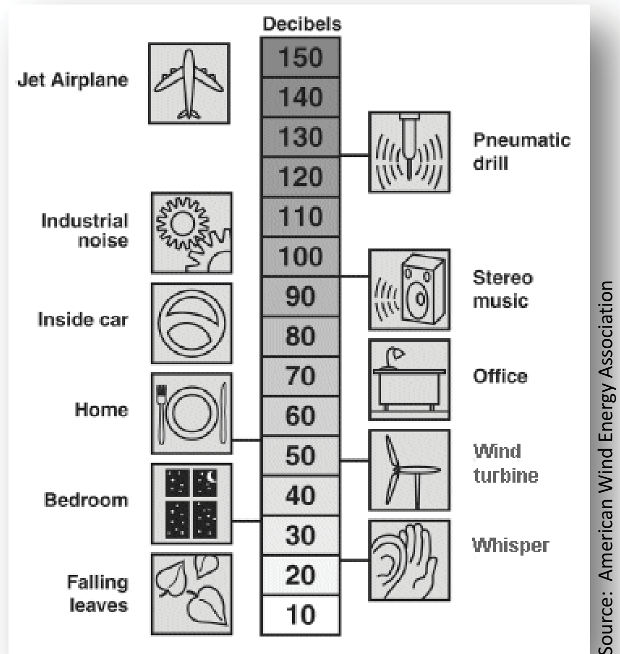
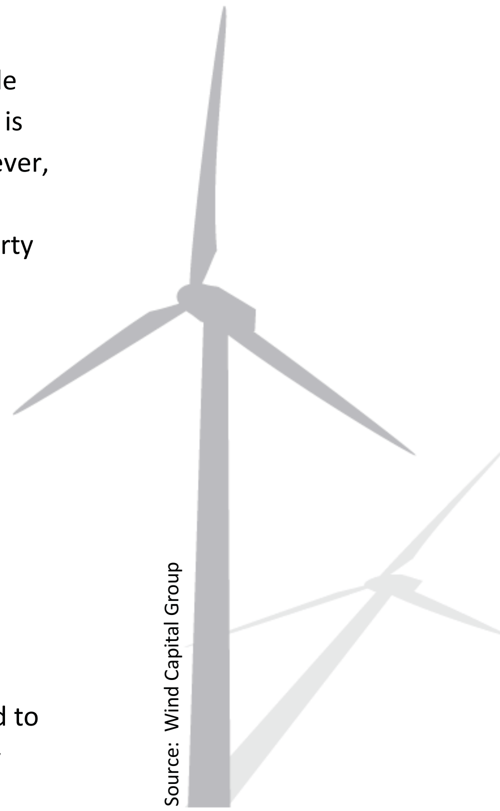


Figure 11. Turbine sound pressure levels

Since small wind turbines may be located in close proximity to people and residences, accurate acoustic data and a realistic expectation of the system's noise are important. The typical sound pressure levels for a small wind system at a distance of 100ft are shown in Figure 11, making a small turbine comparable to the noise level in a home or office environment. Therefore, the turbine acoustics are usually at a reasonable intensity and can be avoided with proper siting setbacks.

Shadow Flicker

Shadow flicker is caused by the rotating blades of the turbine and causes a repeating pattern of shadows on nearby land and structures. While this issue is typically associated with large, utility scale wind turbines, there is still an observed shadow flicker effect caused by small wind systems. However, the decreased rotor diameter and height of small wind systems drastically reduce the scale and negative implications of this phenomenon. The property owner or neighboring structures will experience shadow flicker when the turbine blades are directly in between the sun and observer's line of sight; however, due to setbacks from property lines and structures, the issue of shadow flicker is almost entirely eliminated. Furthermore, since the sun's position in the sky is constantly changing, an observer will only experience shadow flicker at certain times throughout the day or season, if at all.



Source: Wind Capital Group

5.5 Zoning and Permitting

As the interest in wind energy increases, more turbines are being installed in less remote locations where zoning and permitting policies need to be considered. Zoning regulations are complicated since they not only vary from state to state, but from one jurisdiction to the next. Due to the inconsistency of zoning policy, as well as the uncertainty surrounding local acceptance of wind energy projects, it is generally advisable to secure the required permits before purchasing the equipment. Additional material on the different types of zoning and permitting are included in the Appendix.

Resource

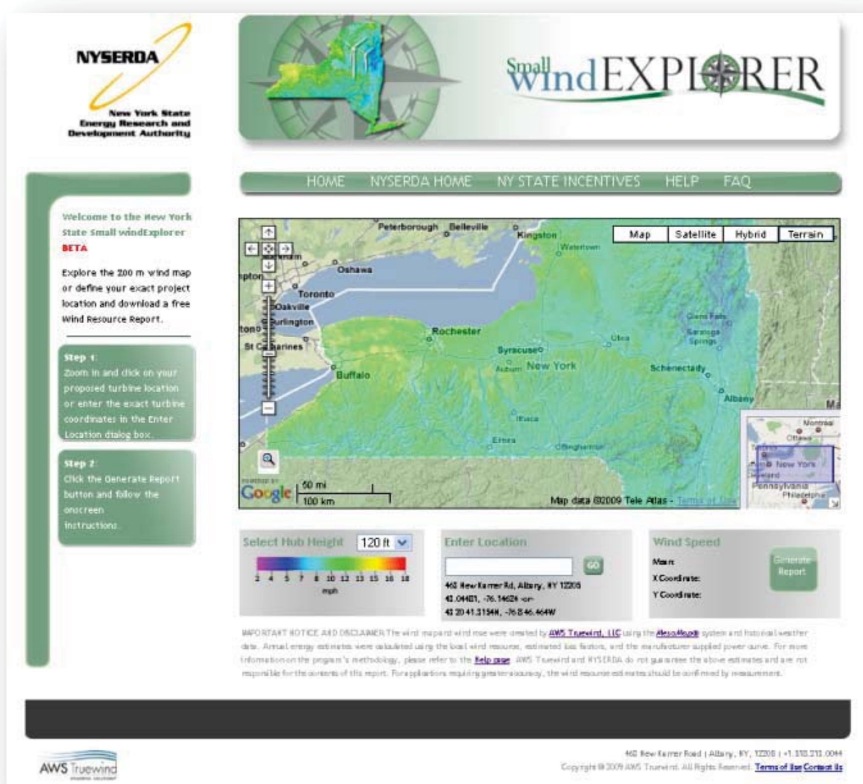
For additional information on zoning and permitting, please refer to the Appendix and the *AWEA Small Wind Permitting Handbook* at: http://www.awea.org/smallwind/documents/permitting.pdf.

6 ENERGY PREDICTION

An accurate estimate of the turbine's energy generating potential is essential for customer satisfaction and an honest depiction of performance and economic payback. The production capacity of the system depends on a variety of factors and can be estimated using the average annual wind speed, wind speed frequency distribution, turbine-specific power curve, adjustment for air density, and environmental and system losses. Wind resource and energy estimates can be obtained from a variety of sources, including on-site measurement, publicly available wind maps, turbine manufacturers, installers, and online tools and calculators. To make the process straightforward and to provide interested parties with accurate wind resource and energy production data, NYSERDA sponsors the Small windExplorer.

6.1 Small windExplorer

The Small windExplorer provides detailed wind resource and energy production estimation tools to help facilitate the development of wind energy projects located throughout New York State. The program offers these tools without the costly expenditure of measuring on-site data, making the process quick and economically feasible for small wind turbine installations.



Source: AWS Truewind

The program has a simple Web-based interface and allows the user to navigate to the specific turbine location to view and print wind resource and energy production reports. This detailed data helps potential turbine owners and installers accurately estimate the annual energy output from a specific turbine at a given hub height and project location. The wind resource information is based on the latest generations of validated wind maps developed by AWS Truewind.

To better meet the needs of the different users of the program, the program incorporates two separate printable reports that are tailored to the different needs of the users. After the user has selected the proposed turbine location, it will be presented with two report options, a basic and advanced wind resource report.

The basic wind resource report is intended for end-users that are interested in installing a small wind system. This report gives the information needed to determine the suitability of a small wind system on a property and will give the initial information needed for further consultation with an eligible installer. The report will present the basic information regarding the available wind resource, expected net energy output for various turbine rotor diameters, and a qualitative review of their site specific wind energy potential. Specifically, the wind resource will be described by a wind map for the site, a table displaying the annual average wind speed at three heights (80 ft, 100 ft, 120 ft), and an eight direction graphical wind rose.

The advanced wind resource report is intended for eligible installers and provides the tools necessary to perform a more detailed feasibility study for a small wind project. The advanced wind resource report incorporates much of the same information as the basic wind resource report, including a wind map, annual average wind speeds at three different heights, and an eight direction wind rose. Additionally, the advanced report allows the user to enter information on each directional sector to help describe upwind obstacles and calculate the losses due to turbulence.

6.2 Methodology

The steps involved in the Small windExplorer are shown in Figure 12 below. Each step represents an important part of the energy estimation process and is detailed further in the following sections. To perform an accurate energy estimate for a small wind turbine installation, the entire process must be followed. The Small windExplorer performs all the required steps and requires only minimal input from the user.

Also included in the flowchart are example wind resource and energy production requirements for a NYSERDA sponsored incentive (www.PowerNaturally.org). For instance, the average annual wind speed at hub height may be required to be greater than 10 mph and the annual energy consumption may not be allowed to exceed 110% of the property's consumption. For the most current NYSERDA incentive requirements, please visit the NYSERDA Web site.

Detailed instructions for using the Small windExplorer can be found in the Appendix.

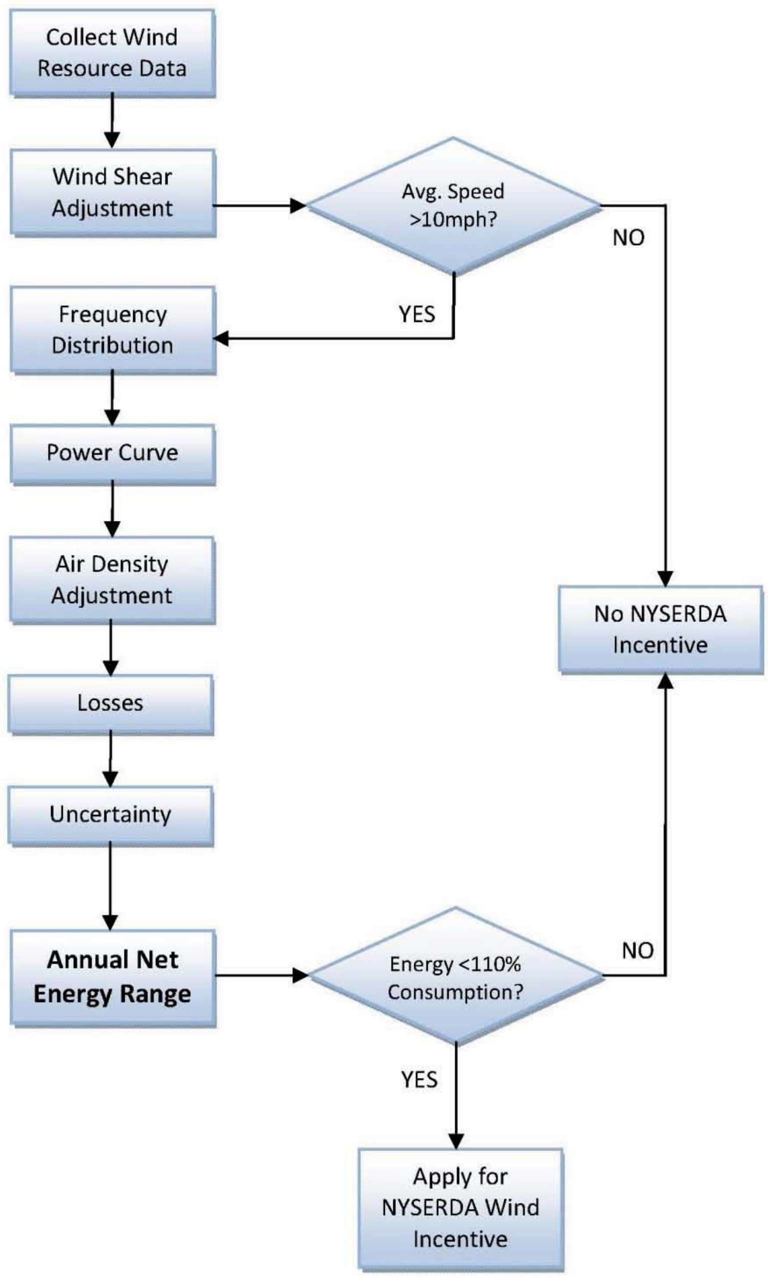


Figure 12. Methodology of the Small windExplorer

Wind Shear Adjustment

To begin the energy prediction process, the average annual hub height wind speed must be known for the turbine installation. Since the actual height of the turbine may differ from published wind resource estimates and maps, the average annual wind speed may need to be adjusted to account for wind shear, as discussed in Chapter 3. Therefore, the Small windExplorer models the vertical wind shear profile using the Power Law. The following example is provided to show the calculation performed in the program; the user only needs to enter the tower height.

Example

The wind speed at 110 ft can be estimated given the annual average wind speed at 120 ft and 100 ft, where U(120 ft) = 12.2 mph and U(100 ft) = 11.7 mph. The wind shear exponent is calculated using the two given heights and wind speeds.

$$\alpha = \frac{ln\left({}^{12.2}/_{11.7}\right)}{ln\left({}^{120}/_{100}\right)} = 0.230$$

The wind speed at 110ft can then be calculated using the wind shear exponent and the wind speed at 100ft.

$$V_3 = V_1\left(\frac{h_3}{h_1}\right)^{\alpha} = 11.7\left(\frac{110}{100}\right)^{0.230} = 12.0\ mph$$

Equation

The Power Law is described using the following equation:

$$\frac{V_2}{V_1} = \left(\frac{h_2}{h_1}\right)^{\alpha}$$

Where:
ρ = air density
A = swept area of blades
V = wind speed.

The wind shear exponent, α, is calculated using the following expression:

$$\alpha = \frac{ln\left({}^{V_2}/_{V_1}\right)}{ln\left({}^{h_2}/_{h_1}\right)}$$

Combining the above two expressions results in the following expression for V3 (extrapolated hub height wind speed at h3) as a function of known parameters:

$$V_3 = V_1\left(\frac{h_3}{h_1}\right)^{\left[\frac{ln\left({}^{V_2}/_{V_1}\right)}{ln\left({}^{h_2}/_{h_1}\right)}\right]}$$

Frequency Distribution

As discussed in Chapter 3, the frequency distribution of the wind is needed to accurately estimate the available power and is approximated using the Weibull distribution. The average hub height wind speed, $\bar{U}$, the Weibull shape factor, k, and the Weibull scale factor, A, are used to calculate the frequency distribution; these parameters are given as output in the Small windExplorer. The wind speeds are separated into regular increments, or bins, and the probability of a wind speed falling into a given bin is calculated using the Weibull expression.

While the bins can be sized to any wind speed range, the bins in the Small windExplorer are sized to 1 m/s increments. This bin width gives the needed accuracy for the calculations. Table 1 shows an example wind frequency distribution table with 1 m/s increment bins and the associated probability. If performing these functions outside of the Small windExplorer, a spreadsheet program will substantially decrease calculation time and the likelihood of error.

Wind Speed Bin	Wind Probability
0 m/s	0.00%
1 m/s	3.93%
2 m/s	8.47%
3 m/s	12.21%
4 m/s	14.40%
5 m/s	14.75%
6 m/s	13.46%
7 m/s	11.09%
8 m/s	8.30%
9 m/s	5.67%
10 m/s	3.54%
11 m/s	2.02%
12 m/s	1.06%
13 m/s	0.51%
14 m/s	0.22%
15 m/s	0.09%
16 m/s	0.03%
17 m/s	0.01%
18 m/s	0.00%
19 m/s	0.00%
20 m/s	0.00%

Table 1. Wind speed frequency distribution separated into 1 m/s bins

Equation

The Weibull distribution is modeled using the following equation within the Small windExplorer:

$$p(U) = \int_{U}^{U+1} \left(\frac{k}{A}\right)\left(\frac{u}{A}\right)^{k-1} exp\left[-\left(\frac{u}{A}\right)^{k}\right] du$$

Where:
p(U) = Probability wind speed will be between U and U+1 (in m/s)
k = Weibull scale factor
A = Weibull shape factor.

Power Curve

Once the wind speed frequency distribution is binned, the Small windExplorer uses the turbine's power curve to determine the gross energy production of the system. As discussed in Section 4.3, the power curve displays the turbine's power output for varying wind speeds using the same bin concept as above. The basic report uses a generic power curve weighted by swept area and the advanced report uses the manufacturer supplied power curve for the user selected turbine.

The Small windExplorer assumes that the turbine power curve was measured using the *AWEA Small Wind Turbine Performance and Safety Standard,* and certified by the Small Wind Certification Council (SWCC). As such, the power curve will be sea level normalized and will be measured at the connection to the load; therefore, the losses associated with the turbine, inverter, and wiring will be included in the performance testing. It is the responsibility of the installer to adjust the output estimates if the turbine has not been certified by the SWCC. More information on the SWCC and the AWEA Small Wind Standards can be found at www.smallwindcertification.org.

The power level for each of the binned wind speeds is imported into the frequency distribution table. Multiplying the power output at each wind speed by the probability of that wind speed gives the average power available in each bin. Adding the individual powers for all wind speed bins gives the total average power available from the system. Finally, to calculate the annual gross energy available from the system, the total average power is multiplied by the number of hours in the year, as shown in the following equation.

Example

As shown below, the gross power is equal to the wind probability multiplied by the applicable bin of the power curve. The sea level gross energy is then calculated by multiplying the gross power by the number of hours in the year.

Wind Speed Bin	Power Curve	Wind Probability	Gross Power
0 m/s	0.00 kW	3.93%	0.00 kW
1 m/s	0.00 kW	3.93%	0.00 kW
2 m/s	0.00 kW	8.47%	0.00 kW
3 m/s	0.03 kW	12.21%	0.00 kW
4 m/s	0.26 kW	14.40%	0.03 kW
5 m/s	0.56 kW	14.75%	0.06 kW
6 m/s	1.00 kW	13.46%	0.10 kW
7 m/s	1.62 kW	11.09%	0.14 kW
8 m/s	2.51 kW	8.30%	0.16 kW
9 m/s	3.49 kW	5.67%	0.15 kW
10 m/s	4.59 kW	3.54%	0.12 kW
11 m/s	6.00 kW	2.02%	0.09 kW
12 m/s	7.46 kW	1.06%	0.06 kW
13 m/s	8.78 kW	0.51%	0.03 kW
14 m/s	9.74 kW	0.22%	0.02 kW
15 m/s	10.20 kW	0.09%	0.01 kW
16 m/s	10.03 kW	0.03%	0.00 kW
17 m/s	9.83 kW	0.01%	0.00 kW
18 m/s	9.15 kW	0.00%	0.00 kW
19 m/s	8.70 kW	0.00%	0.00 kW
20 m/s	8.30 kW	0.00%	0.00 kW
	Total	**99.78%**	**0.98 kW**

$$Sea\ Level\ Gross\ Energy = 0.98\ kW \times 24\ hrs \times 365\ days = 8584.80\ kWh$$

Air Density Adjustment

The above energy estimate assumes that there are no additional loss factors in the system and that the turbine will perform exactly as stated on the power curve. However, the production of the system will depend on multiple variables and the energy estimate needs to be adjusted accordingly.

The power curves are given for standard sea level air density, so a density adjustment must be applied to give an accurate description of the available power at the turbine location. As discussed in Chapter 3, air density varies with changes in temperature and pressure and the amount of power in the wind is directly proportional to the density. The program estimates the temperature and elevation of each site and calculates the site specific air density, which is subsequently used to adjust the gross energy.

Equation

The site specific air density is calculated using the following equation:

$$\rho = \frac{P_o}{RT} e^{\left[-\frac{gz(1.0397-0.000025z)}{RT}\right]}$$

Where:
ρ = Air density (kg/m³)
P_0 = Standard sea-level atmospheric pressure in Pascals (101325 Pa)
R = Specific gas constant for dry air (287 J/Kg·K)
T = Air temperature (K), T(K)=T(°C) + 273.15
g = Acceleration due to gravity (9.8 m/sec2)
z = Elevation of temperature sensor (m).

Example

As an example, the air density adjustment at a site with an elevation of 357 m and mean annual temperature of 10°C is approximated below:

$$\rho = \frac{P_o}{RT} e^{\left[-\frac{gz(1.0397-0.000025z)}{RT}\right]}$$

$$\rho = \frac{101325}{287 \times (10 + 273.15)} \times e^{\left[-\frac{9.8\times357\times(1.0397-0.000025\times357)}{287\times(10+273.15)}\right]} = 1.192 \text{ kg/m}^3$$

$$Adjusted\ Gross\ Energy = 8584.8\ kWh \times \frac{1.192}{1.225} = 8356.1\ kWh$$

As shown above, the temperature and elevation of the site decreased the air density by 2.7%, resulting in an equivalent increase in the adjusted annual gross energy.

Losses

There are many losses in small wind systems that need to be taken into account in the energy estimate. The basic report assumes generic losses and the advanced report allows users to enter their own estimated losses.

Turbulence Losses

As discussed in Section 5.1, local obstructions and terrain can impact the available wind resource by decreasing the observed wind speed and increasing turbulence. Since these environmental factors may not be accounted for in available wind resource maps, they must be manually entered. The losses due to turbulence are approximately equal to the site's turbulence intensity. The basic report assumes a generic loss of 20% for turbulence intensity and the advanced report includes a data entry page to help estimate the losses caused by the local terrain.

The Small windExplorer estimates turbulence losses by calculating the estimated ambient turbulence intensity using the surface roughness and turbine hub height.

$$TI\ Loss\ (\%) = \frac{1}{\ln\left(\frac{hub\ height}{roughness}\right)} \times 100$$

Turbulence losses are weighted by the percentage of energy that is expected from each direction and then combined to compute a total turbulence loss for the site.

Other Losses

In addition to the losses associated with the surrounding environment, the turbine's performance will be affected by losses due to the collection system, inverter efficiency, and system availability. As noted earlier, the power curve will include inverter and collection system losses. Availability can be associated with the electrical grid downtime and any downtime due to maintenance or system failures. These losses depend on the model of turbine and inverter and the level of maintenance the system will experience. To account for the availability of the system, the Basic Report includes an Availability Loss factor of 2.0% and the Advanced Report allows the user to enter the expected Availability Loss.

If the inverter or wire specifications are different than those in the power curve performance test or if the system is expected to have additional environmental/system losses, the losses can be adjusted accordingly in the

Advanced Report using the Additional Known Losses field on the data entry page.

Uncertainty

There are many uncertainties in the energy prediction process, which lead to uncertainties in the annual energy estimate. The main sources of uncertainty include the estimation of the wind speed and loss factors. The basic report does not take these factors into account and instead gives a basic approximation for net energy. The advanced report uses approximated uncertainties for the different sources to create a range in energy production.

The wind speed estimates used in the Small windExplorer have an uncertainty of approximately 7.0%, which accounts for the inter-annual variability of the wind speed. Therefore, the upper and lower bounds of the gross energy estimate are calculated by increasing and decreasing the annual average wind speed by 7.0%, respectively. Adjusting the wind speed changes the frequency distribution, which has a direct effect on the total amount of energy available in the wind; therefore, the program runs three different scenarios for the varying wind speeds to calculate the range in energy production.

The uncertainty in estimating the losses is much harder to predict. Therefore, this uncertainty is estimated at 20% of the total loss, which is directly applied to the above energy range.

6.3 Economic Analysis

After the annual energy production of the system has been estimated, it is important to perform an economic analysis to determine if the wind energy system is worth installing.

An economic analysis should include the total system and itemized costs, applicable incentives, payment schedule, a quote for routine maintenance for a minimum of the first two years, and economic analysis. The routine maintenance quote must include information on scope, timing, and cost of routine maintenance items.

The analysis shall use the annual energy estimate range, along with the end-user's electricity cost, to produce a realistic economic payback. The economic payback will help the end-user understand the economics of the wind system and the amount of time needed to payback to initial investment.

Incentive

For systems that meet certain requirements, NYSERDA provides generous monetary incentives. For more information on the incentive levels, requirements, applications, and timing, refer to the NYSERDA Web site (http://www.powernaturally.org).

7 NYSERDA INCENTIVE

NYSERDA has sponsored incentives to encourage the development of a network of Eligible Installers who will install end-use wind energy systems for residential, commercial, institutional or government use. The incentives range in size and will be paid to Eligible Installers who install approved new grid-connected wind generation systems using qualified equipment. Eligibility requirements are described on NYSERDA's Web site (www.PowerNaturally.org).

Incentives are intended to benefit both the installer for business development, and the wind generation system owner, where generated power offsets the customer's utility power purchases. The Eligible Installer must pass incentives directly to their customers. Incentive levels depend on wind generator size, tower height, and customer type and are posted on NYSERDA's Web site (www.PowerNaturally.org).

Installer eligibility is determined and maintained for specific equipment, based on training and professional experience. Once deemed eligible, installers then apply for, and reserve on a first-come, first-served basis, NYSERDA incentive awards for approved, new, grid-connected, end-use wind generation systems.

Interested potential owners wishing to participate in this program are encouraged to contact several Eligible Installers for recommendations and quotes for a wind system. A list of Eligible Installers is posted on www.PowerNaturally.org.

Incentive

- Incentives are paid to eligible installers that have been approved to participate in the program.
- The entire incentive must be passed on to the owner of the wind system by the eligible installer.
- The prospective turbine owner should work with the installer to obtain all necessary pre-construction permits, approvals, certificates, etc. from all jurisdictions having authority prior to ordering equipment since NYSERDA will not process any payments without proof that all permits have been obtained.
- Incentives will not be paid for wind systems installed by contractors or individuals that are not on NYSERDA's list of eligible installers, which can be found at www.PowerNaturally.org.

8 OPERATIONS AND MAINTENANCE

8.1 Installation

Once the wind system has been determined to be economically feasible and after all permits and incentives have been approved, the wind system must be installed by an Eligible Installer. Depending on the type of turbine and foundation, the installation time can vary. The foundation will take two to three weeks to cure and the actual tower installation will take approximately 2-3 days.

A proper installation alone does not result in efficient operation and energy production; it is instead an important first step and should be followed by regular maintenance and inspections.

Incentive

To qualify for a NYSERDA incentive, the system must be installed by an Eligible Installer. Eligibility will be based on factors such as acceptance of all program terms and conditions, training, extent and type of installation experience, customer references, and meeting the insurance requirements of this program.

8.2 Maintenance

The amount of maintenance that a small wind system needs varies depending on the turbine manufacturer, installation method, and wind resource. Typical wind generator system maintenance includes regular oiling and greasing of turbine components and routine safety inspections. Bolts and electrical connections must be checked annually, along with the tower plumbing, guy wire tension, and all areas for corrosion. Blades must be checked for damage or decay and a blade's leading tape should be replaced to protect the turbine and ensure efficient operation.

Since most maintenance procedures require a technical background and knowledge of the turbine installation, all maintenance must be performed by the installer or other qualified individual. The end-user should pay close attention to the system's operation and production and contact the installer with any major changes in system production or safety concerns. The end-user should record the turbine energy production every month to track performance and should regularly visually inspect the installation. Keeping a close eye on the system will ensure greater availability and a longer lifetime for the system.

Installers must provide a five-year system warranty. The warranty must cover all components of the generating system against breakdown or degradation in electrical output of more than ten percent from their original rated electrical output. The warranty must cover the full costs, including labor, of repair or replacement of defective components or systems.

Installers must also provide instructions for maintenance and a quote for annual maintenance costs.

8.3 Follow-Up Inspections

Follow-up inspections performed by the installer are important to ensure proper turbine operation and safety standards. Inspection and maintenance schedules will vary between different types of systems and are usually detailed in the turbine and tower manufacturer user manuals. For guyed towers, the installer should inspect guy wire tension approximately 30 and 180 days after installation[3]. Following these initial inspections, the system should be checked on an annual basis or after severe weather. These will typically be at an extra cost and will be included in the installer's quote for regular system maintenance. Annual inspections will include, but are not limited to the following:

- Inspect each anchor point
- Check guy wire tension
- Check tower plumbing
- Turbine control system, if any
- Blade condition (cracks, leading edge, tip)
- Bolts, fasteners, bearings, wires
- Electrical connections, wire run, inverter

Once again, the specific inspection and maintenance needs should be addressed in the individual turbine and tower user manual and will vary between technologies and manufacturers.

If a NYSERDA incentive was awarded, NYSERDA reserves the right to make a reasonable number of visits to the customer site during and after installation of the wind generation system. The purpose of the site visit(s) is to provide NYSERDA with an opportunity to evaluate the installed wind generation system and make sure it was installed according to the information presented in the application.

[3] BWC EXCEL Installation Manual, Guyed Lattice Tower

9 CASE STUDIES

9.1 Alfred University / Alfred State College Farm

THE BACKGROUND

An on-site or small wind power energy system can provide consumers in windy locations with a cushion against electric power price increases. Wind energy systems not only help customers reduce their electricity purchases from utilities, they also help reduce U.S. dependence on fossil fuels, and they are nonpolluting. Cash incentives for installing wind energy are available in New York and vary between 15-70% depending on the installation.

THE STORY

In conjunction with the Center for Environmental and Energy Research (CEER) at Alfred University, the 10kW wind turbine was installed at the Alfred State College Farm Lab during a five-day installers workshop. The turbine produces power for the milking barn at the farm and provides the students and faculty with a renewable energy laboratory. Alfred U and Alfred State students monitor the performance of the wind turbine to determine how much power is produced and when it is available. "Small wind turbines can play an important role in supplying clean energy to rural areas," says Jim Adams, the project manager from AWS Scientific. The information will be used to determine the economic viability of other small wind energy installations. According to Dr. Chris Sinton, the former director of CEER, who arranged for installation of the turbine, "Alfred is in a region with both a large agricultural base and very good wind resources."

The purpose of the workshop was to train qualified wind installers. Fifteen people, some of whom had installed smaller wind systems, attended the workshop in order to gain hands-on training installing wind systems.

For more information on wind incentives log on to www.PowerNaturally.org or call 1-866-NYSERDA

THE TEAM

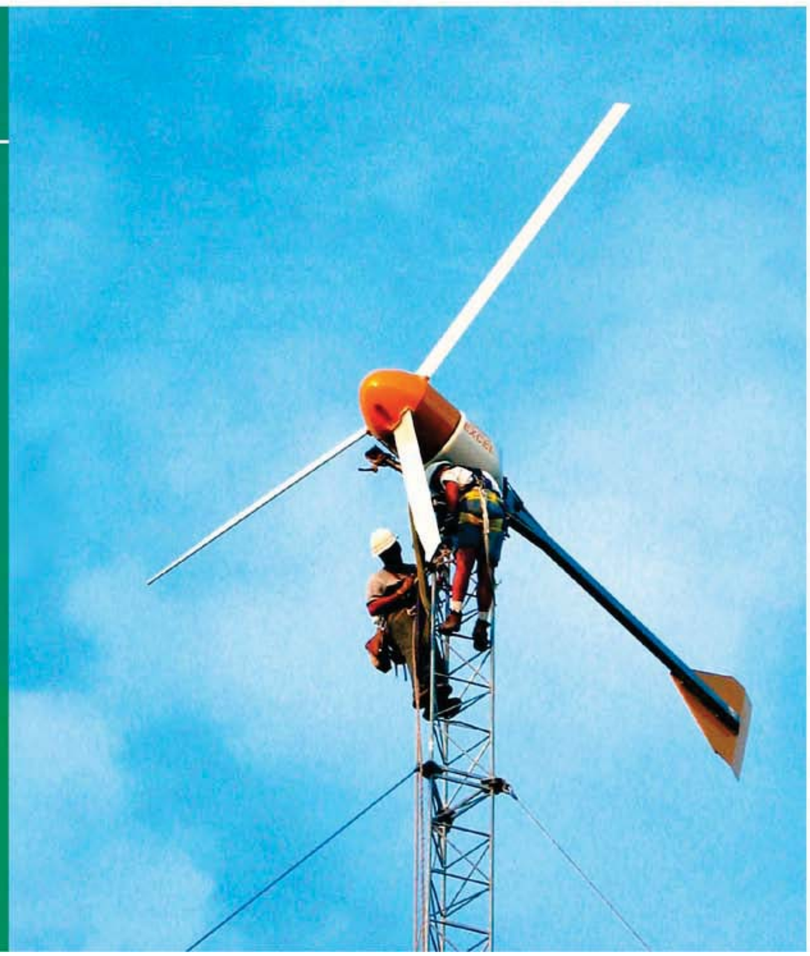
- NYSERDA: Funding and coordination of the On-Site Small Wind Incentive Program for New York State
- AWS Scientific: Coordinated the design, site assessment, installation and interconnection, hired the local subcontractors, and conducted the State Environmental Quality Review (SEQR). Working closely with NYSERDA, the team they led was able to complete the job within six months from the initial site visit to final approvals, installation, and interconnection.

THE SYSTEM

The wind turbine located on the Alfred State College Farm in Alfred, NY is a 10 kW Bergey Excel-S mounted on a 100 foot guyed lattice tower. The average annual wind resource at this site, as projected by the New York State Wind Map, is about 5.1 m/s (12 mph). The total installed cost of this system was approximately $55,000, and the NYSERDA incentive was $39,000.

THE SAVINGS

The estimated annual output of the Alfred University/Alfred State College Farm system is 11,000 kWh. A typical home in New York State uses about 6,000 kWh of electricity annually.



9.2 Apple Pond Farming Center

THE BACKGROUND

An on-site or small wind power energy system can provide consumers in windy locations with a cushion against electric power price increases. Wind energy systems not only help customers reduce their electricity purchases from utilities, they also help reduce U.S. dependence on fossil fuels, and they are nonpolluting. Cash incentives for installing wind energy are available in New York and vary between 15-70% depending on the installation.

THE STORY

Apple Pond Farming Center is a horse-powered, organic farm located in the Catskill Mountains of Sullivan County, New York. The farm offers family farm vacations, a comprehensive program of horse services and sales, and educational programs for schools, camps and families. Apple Pond Farming Center also offers seminars and workshops on the renewable energy systems that provide clean energy for its farm. "Installing a small-wind system on the farm was completely consistent with our philosophy and practices," said Dick Reisling, Apple Pond's owner.

The landowner assisted with the foundation work, and the electrical work was completed by students participating in a hands-on training workshop for small wind installation. The purpose of the workshop was to train qualified wind installers.

For more information on wind incentives log on to www.PowerNaturally.org or call 1-866-NYSERDA

THE TEAM

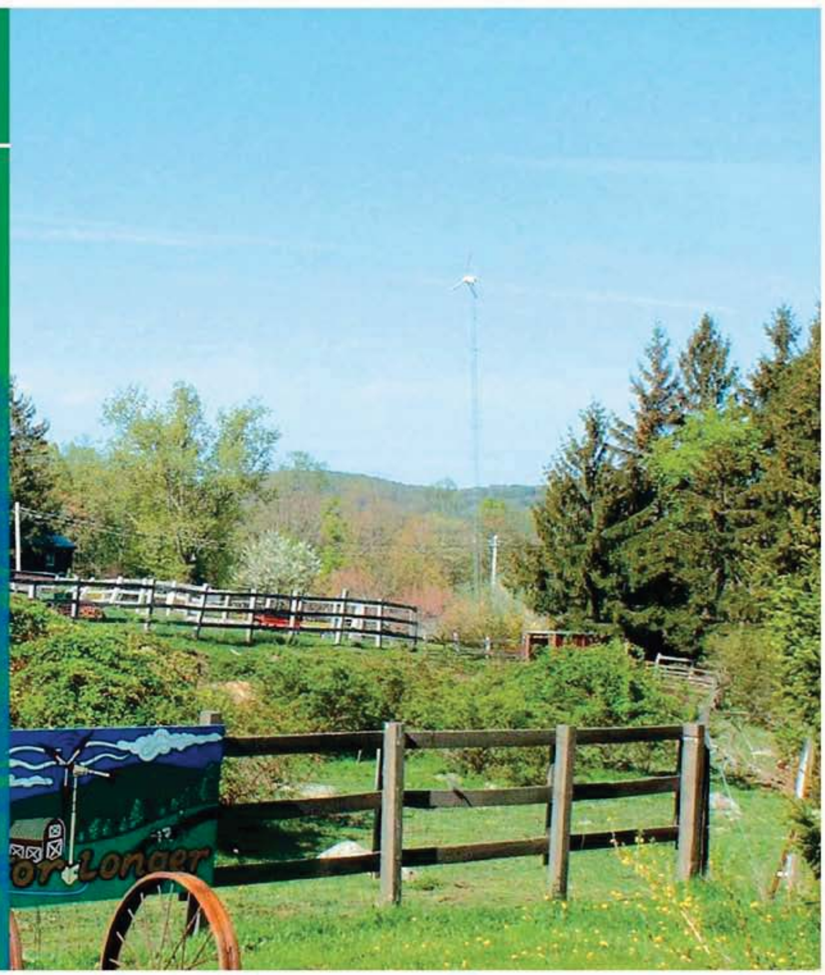
- NYSERDA: Funding and coordination of the On-Site Small Wind Incentive Program for New York State
- AWS Scientific: Coordinated the design, site assessment, installation and interconnection, hired the local subcontractors, and conducted the State Environmental Quality Review (SEQR). Working closely with NYSERDA, the team they led was able to complete the job within six months from the initial site visit to final approvals, installation, and interconnection.

THE SYSTEM

The Apple Pond Farm wind turbine, located in Sullivan County, NY is a 10 kW Bergey Excel-S mounted on a 120 foot guyed lattice tower. The average annual wind resource at this site, as projected by the New York State Wind Map, is about 4.4 m/s (10 mph). The installed cost of this system was approximately $50,000, and the NYSERDA incentive was $30,000.

THE SAVINGS

The estimated annual output of the Apple Pond Farming system is 11,500 kWh. A typical home in New York State uses about 6,000 kWh of electricity annually.



9.3 Olde Chautauqua Farm – Portland, NY

THE BACKGROUND

An on-site or small wind power energy system can provide consumers in windy locations with a cushion against electric power price increases. Wind energy systems not only help customers reduce their electricity purchases from utilities, they also help reduce U.S. dependence on fossil fuels, and they are nonpolluting. Cash incentives for installing wind energy are available in New York and vary between 15-70% depending on the installation.

THE STORY

Olde Chautauqua Farm, open to the general public for U-pick fruits or vegetables, is using wind power to generate electricity, with a newly installed 10kW wind turbine located in the middle of its lush grape vineyards. When NYSERDA issued a solicitation for small, on-site wind projects, Olde Chautauqua enthusiastically responded. After a site and resource assessment by AWS Scientific, Olde Chautauqua was selected to participate in NYSERDA's program.

"The turbine doesn't interfere with our agricultural operations," said Mike Jordan, Olde Chautauqua's owner. "In fact, we harvest grapes right up to the tower's base."

For more information on wind incentives log on to www.PowerNaturally.org or call 1-866-NYSERDA

THE TEAM

- NYSERDA: Funding and coordination of the On-Site Small Wind Incentive Program for New York State
- AWS Scientific: Coordinated the design, site assessment, installation and interconnection, hired the local subcontractors, and conducted the State Environmental Quality Review (SEQR). Working closely with NYSERDA, the team they led was able to complete the job within eight months from the initial site visit to final approvals, installation, and interconnection. Installation by Four Winds Renewable Energy and Offshore Services.

THE SYSTEM

The Olde Chautauqua Farm wind turbine, located in Portland, NY is a 10 kW Bergey Excel-S mounted on a 100 ft self-supporting lattice tower. The average annual wind resource at this site, as projected by the New York State Wind Map, is about 5.8 m/s (13 mph). The installed cost of this system was approximately $60,000, and the NYSERDA incentive was $36,000.

THE SAVINGS

The estimated annual output of the Olde Chautauqua Farm wind energy system is 14,500 kWh. A typical home in New York State uses about 6,000 kWh of electricity annually.

9.4 Weimann Farm – Locke, NY

THE BACKGROUND

An on-site or small wind power energy system can provide consumers in windy locations with a cushion against electric power price increases. Wind energy systems not only help customers reduce their electricity purchases from utilities, they also help reduce U.S. dependence on fossil fuels, and they are nonpolluting. Cash incentives for installing wind energy are available in New York and vary between 15-70% depending on the installation.

THE STORY

The Wiemann Farm, located in the Finger Lakes region of Upstate New York, is using wind power on its 134-acre property. Good planning, such as informing its neighbors of the upcoming project, smoothed the way for the Weimann's wind system to find a home on this working farm. "We learned some valuable lessons with this project," said Dave Wiemann. **"Providing as much information about the project as possible, including photographs and locations of currently installed small turbines, is helpful and gives the community a sense of what's happening elsewhere. It helps allay any fears or concerns they may have."** The installation for the Wiemann Farm turbine took about two and one-half days to complete, thanks to favorable weather and soil conditions.

For more information on wind incentives log on to www.PowerNaturally.org or call 1-866-NYSERDA

THE TEAM

- NYSERDA: Funding and coordination of the On-Site Small Wind Incentive Program for New York State.
- AWS Scientific: Coordinated the design, site assessment, installation and interconnection, hired the local subcontractors, and conducted the State Environmental Quality Review (SEQR). Working closely with NYSERDA, the team they led was able to complete the job within six months from the initial site visit to final approvals, installation, and interconnection.

THE SYSTEM

The Wiemann Farm wind turbine, located in Locke, NY, is a 10 kW Bergey Excel-S mounted on a 100 foot guyed lattice tower. The average annual wind resource at this site, as projected by the New York State Wind Map, is about 5.6 m/s (12.5 mph). The installed cost of this system was approximately $50,000, and the NYSERDA incentive was $30,000.

THE SAVINGS

The estimated annual output of the Wiemann Farm wind energy system is 12,000 kWh. A typical home in New York State uses about 6,000 kWh of electricity annually.

10 APPENDIX

A.1 Zoning and Permitting

As the interest in wind energy increases, more turbines are being installed in less remote locations where zoning and permitting policies need to be considered. In general, zoning policies designate acceptable uses of land within a given area; permits are required for uses that are not generally accepted or require additional regulation. Zoning regulations are complicated since they not only vary from state to state, but from one jurisdiction to the next. Due to the inconsistency of zoning policy, as well as the uncertainty surrounding local acceptance of wind energy projects, it is generally advisable to secure the required permits before purchasing the equipment.

Where to Start

It is important to research the local zoning restrictions that effect non-dwelling structures. There are three levels of local government that can influence zoning regulation: county, township, and municipality. Wind turbines are not always specifically addressed in the zoning codes as an allowed or permitted use. Non-listed uses are generally considered prohibited, and are only allowed through the use of a conditional use permit or a variance from the existing code. These permitting policies are explained in greater detail below, along with other review options that may be applicable depending upon the zoning policy in the region.

Permitted Use

Permitted uses are those that are allowed under all circumstances, as long as they meet applicable design standards. This approach is commonly applied to structures such as flagpoles, grain silos, and church steeples. For small-scale wind turbines, this type of permitting policy is more likely to be implemented in rural areas, where the impact of a small wind turbine installation on neighboring properties is expected to be minimal.

Special Use

A special or conditional use permit allows the installation of a small wind turbine if it meets the criteria outlined in the conditions of the permit. This type of regulation is employed when the use, in this case the installation of a small wind turbine, is regarded as generally appropriate for the zone, but not in every circumstance. Consequently, the use is subject to conditions to make certain that its impact on the surroundings is minimal. A public hearing and/or more detailed documentation of the project may be required in order to obtain a special use permit.

Variance

A variance is a modification or waiver to a particular zoning regulation. For small wind turbines, variances frequently deal with exceptions to required setback distances or structure height restrictions. The issuance of use variances serves as a method to handle unanticipated and appropriate exceptions to zoning ordinances. In obtaining a use variance, the burden of proof as to the appropriateness of the use rests with the applicant.

Accessory Use

An accessory use is one that is secondary to the principal use of the property. For small wind turbines, this accessory use is typically applied to agricultural, industrial or commercial settings, where the energy produced by the turbine is required to fulfill the property's principal purpose.

Overlay Zone

An overlay zone replaces the zoning regulations within a particular region. To shorten the permitting process, jurisdictions may create a specified zone that has been determined to be appropriate for small wind turbines, or wind energy development in general.

Site Plan Review

A site plan review is a process used to verify the installation is designed and constructed in an appropriate manner prior to the issuance of a building permit. The site plan review involves an evaluation of the proposed project by the local Planning Board, and may require a physical inspection of the project site and its surroundings prior to installation. This policy is typically used as a supplementary tool in the evaluation of proposed wind projects and is generally associated with an application for a special use permit.

Permits and Codes

Building Permit

As is the case with zoning regulations, the requirements for permits and codes vary with each locality. Typically, the construction of a small wind turbine will require a building permit. As part of the building permit application process, a plot plan may be requested, which outlines the details of the proposed wind project. A plot plan usually indicates the following:

- Property lines and physical dimensions of the property
- The location, dimensions and type of existing major structures on the property, including proposed location of the wind turbine
- The location of public roads, as well as any overhead utility lines
- The distances from the proposed turbine location to surrounding structures
- The specifications of the wind turbine, including manufacturer and model, rotor diameter, tower height, and tower type (freestanding or guyed)
- Blueprints or drawings of the tower and foundation are helpful

Note that these plot plan requirements will vary; it is best to consult the local ordinance to identify the requirements specific to your project. In some instances, zoning regulations may go to the extent of requiring an engineering analysis of the tower and foundation.

Electrical Permit

Some jurisdictions may require an electrical permit for the installation of a small wind turbine. If required, an electrical inspector will inspect the system to ensure that it complies with the standards outlined in the National Electric Code (NEC). The system may not be allowed to generate until it has been inspected and approved as compliant with the NEC.

If the wind turbine is interconnected with the electrical grid, the utility may require that an application be submitted describing the system and equipment. As part of the review process, the utility may want to inspect the system to verify that it complies with the NEC. The utility will often require that a one-line diagram of the system , which describes all of the electrical components, be submitted. Once the utility is satisfied that the system meets the necessary prerequisites, it will enter into an interconnection agreement with the turbine owner.

FAA

The Federal Aviation Administration (FAA) regulations need to be considered only if the total structure height is greater than 200 feet, or located within 3 ¾ miles of a commercial runway. The vast majority of small-scale wind turbines are below 200 feet in height. If the proposed turbine location is within the 3 ¾ mile radius, form 7460 must be submitted to the FAA so that it can determine if any restrictions need to be observed regarding the tower's height or location, or if obstruction lights are required.

State Environmental Quality Review Act

The State Environmental Quality Review Act (SEQRA) process was established to consider the potential impact on the environment when planning projects that are undertaken, funded, or approved by a State or local agency. Any NYSERDA funded project will require a SEQRA process to review for significant adverse environmental impacts.

There are three possible actions that can be pursued in a SEQRA, referred to as Type I, Type II, and Unlisted Actions. A Type II action is considered not to have any significant adverse impact on the environment; NYSERDA explicitly states that the installation of a wind turbine cannot be considered a Type II action or an Unlisted Action. Therefore, wind projects must be considered a Type I action by default, meaning that it is assumed to have a significant adverse impact to the environment.

Installer's Responsibilities

The requirements to fulfill the SEQRA process can vary depending upon the zoning regulation of the local government, as well as aspect of the project itself. The following guideline can be consulted to help determine the responsibility of the installer.

Does the local government have zoning?

YES – If the local government has zoning regulations regarding small wind turbines, then the following requirements need to be fulfilled.

- Appropriate Environmental Assessment Form (Full or Short)
- Visual Environmental Assessment Form Addendum
- Evidence that the local government has discretionary permitting authority (copy of zoning)
- Relevant SEQRA document:
  - Appropriate Environmental Assessment Form
  - Declaration and notice of coordinated review from lead agency
  - Resolution by the local government (if available)
  - Letters of project acceptance from neighbors within 300 feet of the proposed project installation site

NO – If the local government does not have zoning regulations, then the total height (tower + rotor) of the structure must be considered.

Is the total height 100 feet or greater?

YES – If there is no local zoning and the total structure height is 100 feet or greater, it is recommended that NYSERDA be contacted to determine how to proceed. NYSERDA will typically require the following:

- Full Environmental Assessment Form
- Visual Environmental Assessment Form Addendum
- Project Description Memo – details project and answers questions contained in Parts A, B, and C of the Full EAF or Part II of the Short EAF
- Letter from local government confirming that no zoning policies are applicable
- Letters of project acceptance from neighbors within 300 feet of the proposed project installation site

NO – If there is no local zoning, and the total structure height is less than 100 feet:

- Appropriate Environmental Assessment Form (typically the Full EAF)
- Visual Environmental Assessment Form Addendum
- Project Description Memo – details project and answers questions contained in Parts A, B, and C of the Full EAF or Part II of the Short EAF
- Letter from local government confirming that no zoning policies are applicable
- Contact information for the local government(s) and counsel

Letters of project acceptance from neighbors within 300 feet of the proposed project installation site

Environmental Assessment Forms (EAF)

There are three types of Environmental Assessment Forms (EAF) that the SEQRA process may require to evaluate the potential environmental impact of a small wind project.

Full Environmental Assessment Form (21 pages)

The Full EAF is required for any Type I action. The form is comprised of three parts, the first part requests information concerning the project, including a description of the proposed site and project, as well as applicable zoning regulations. The second part attempts to identify the potential adverse impacts that the proposed project may have on the environment. The third part gauges the significance of the impact.

- The front page is to be completed by the lead agency
- Part I (Sections A, B, & C) is to be completed by the Owner/Installer
- Parts II & III are to be completed by the Owner/Installer on behalf of NYSERDA

Short Environmental Assessment Form (2 pages)

The Short EAF is an abbreviated version of the Full EAF, and is only intended for Unlisted actions.

- Part I is to be completed by the Owner/Installer
- Parts II & III are to be completed by the lead agency

Visual Environmental Assessment Form Addendum (2 pages)

The Visual EAF is used to evaluate the potential visual impact that the proposed project could have. The Visual EAF is generally used in conjunction with a Full EAF, but may also be used with the Short EAF. This evaluation process focuses on the following: describing the existing visual environment, assessing the visual impact of the project, determining who will see the project and in what context, and identifying the visual compatibility of the project with the surroundings.

- Both pages should be completed by the Owner/Installer

Lead Agency

Any involved agency (government agency that has the authority to fund, approve or permit, or directly undertake the project) can become the lead agency. For the review of small wind projects, the Town is generally the lead agency.

Evaluation of EAF

After the EAFs have been submitted, the lead agency will assess the significance of the proposed project's environmental impact. If the project is determined not to have significant adverse environmental impacts, it will receive a negative declaration. If the project could have a potentially significant effect, but measures can be taken mitigate the project's environmental impact, a conditional negative declaration will be issued. Lastly, if the proposed project is determined to have a significant adverse impact to the environment, the project will not receive a positive declaration.

If a project receives a positive declaration, an Environmental Impact Statement (EIS) will be required to evaluate how to avoid or reduce the project's adverse environmental impact.

Additional Resources

SEQRA Information for small wind installers: http://www.powernaturally.org/Programs/Wind/InstallersInfo.asp?i=8
Department of Environmental Conservation: www.dec.ny.gov
Flow chart of the SEQRA process: http://www.dec.ny.gov/public/32521.html

A.3 Small windExplorer Instructions

How to Navigate the Application:

1. Zoom to a point of interest:
    a. Use your mouse to click anywhere on the map frame or,
    b. Explore the wind map by entering your location in the box provided. Accepted inputs include: latitude and longitude coordinates in decimal degrees or degrees, minutes, seconds, and street address.

    When you select a location, the application will automatically zoom to that spot. A push pin will appear and the coordinates will be displayed below.
2. Navigate the New York State wind map using standard Google Maps tools.

    a. Zoom in or out by dragging the line up or down the scale bar. You may also click on either the plus or minus signs to zoom in or out, respectively.
    b. Pan by clicking the up, down, left, right buttons or by holding down the cursor and dragging the mouse.
    c. Zoom to the full extent of valid data by clicking on the center button.
    d. Zoom in to an area using the custom zoom tool.

    Please note that the wind map will disappear when you zoom in beyond a certain extent.

3. Toggle the display using standard Google Map overlays:

   Click on Map, Satellite, Hybrid, or Terrain buttons to change the underlying base map.

4. Change the wind map's height level.

   Select from one of three map heights above ground level: 80, 100 and 120 feet by using the drop-down menu. This affects the both map display and the displayed wind speed underneath the Google Map frame.

5. View your wind speed for the selected location.

   The mean annual wind speed (in miles per hour) will be displayed in the informational box provided underneath the Google Map frame. This value is the mean annual wind speed at that location in miles per hour.

6. Generate a Wind Resource Report.

   Click the Generate Report button and follow the on-screen instructions.

How to Generate a Report:

After clicking the Generate Report button, the Data Entry Page will load. For the Basic Report, the user must enter his or her name and address to be included on the output report. For the Advanced Report, after logging in, the user must enter the following information:

- Name – of property owner where the turbine is to be installed (required)
- Address - where the turbine is to be installed (required)
- Turbine Model (required)
- Hub Height (required)
- Terrain description for each directional sector (assumed if not entered)
- Availability Loss (assumed if not entered)
- Additional Known Losses (assumed if not entered)

<u>Turbine Model</u>

Select a small wind turbine model to use in the analysis. Only NYSERDA qualified wind generators are included.

<u>Hub Height</u>

Enter the proposed tower height in feet.

<u>Terrain Description</u>

Select a terrain description that best matches each given direction, as seen from the tower. This description will help estimate the effects of upwind terrain and obstacles on energy production.

<u>Availability Loss</u>

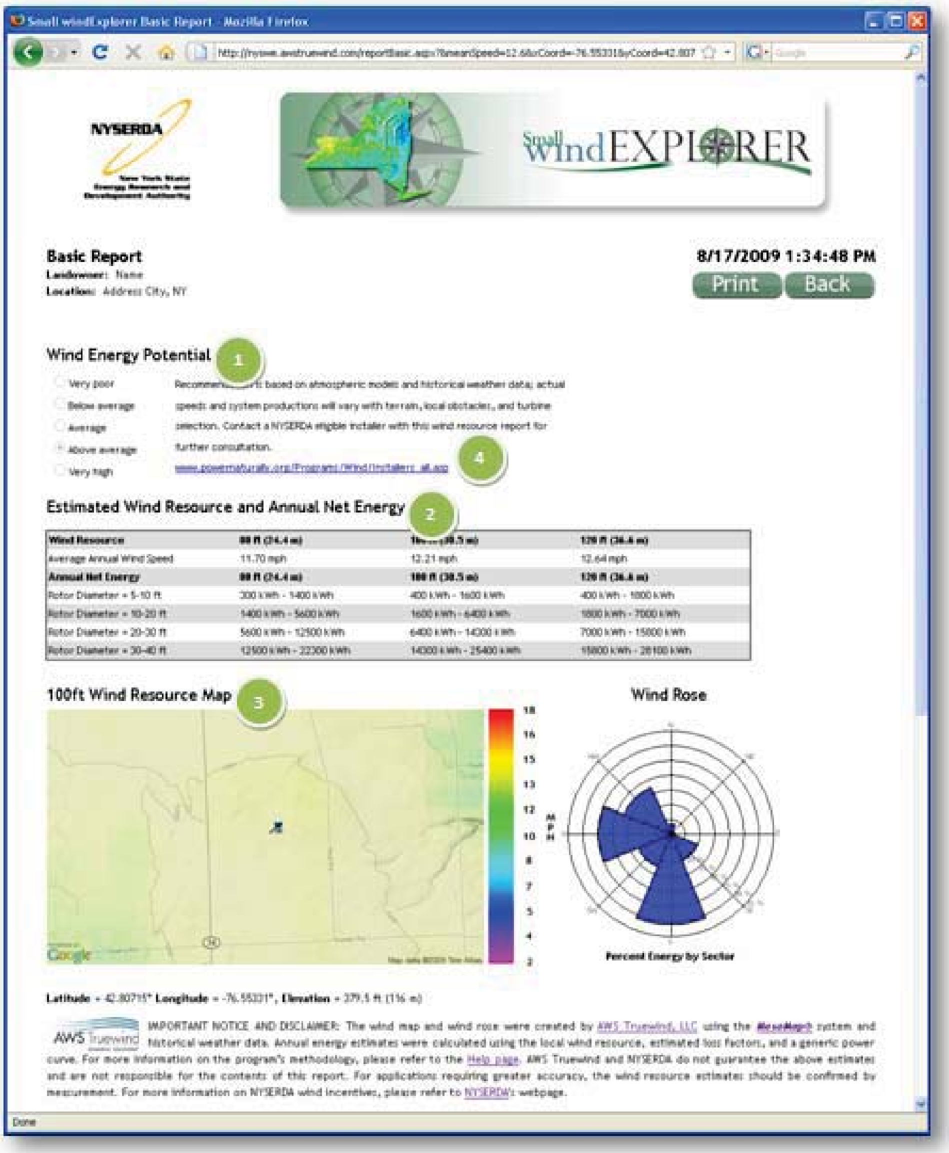
Enter the expected loss due to turbine availability.

<u>Additional Known Losses</u>

Enter additional environmental or system losses. As designed, the program assumes that all turbine power curves have been measured using the AWEA Small Wind Turbine Performance and Safety Standard; if the manufacturer supplied power curve was not created using this standard, an adjustment factor can be entered.

Once all fields are entered, click the Submit button to generate the applicable report.

How to Interpret the Basic Report:



1. Determine your site's Wind Energy Potential.

   This ranking will give you a qualitative assessment of the site's available wind resource.

2. Determine your site's estimated wind resource and annual net energy.

   The table presents data at three different heights (80, 100, 120 ft). If any of the heights have an estimated wind speed of less than 10 mph, a warning will appear for the user. The energy estimates provide information for various rotor diameters.

3. View your site's 200 m (656 ft) wind map and wind rose data.

   The site's wind resource map shows the average annual wind speed at 100 ft above ground level. The wind rose provides an estimate for the amount of energy located in each directional sector (N, NE, E, SE, S, SW, W, NW).

4. Contact a NYSERDA eligible wind installer with this wind resource report for further consultation.

How to Interpret the Advanced Report:

1. Determine the site's characteristics and available wind resource.

   The site's latitude, longitude, elevation, average annual wind speed at hub height, frequency distribution parameters, and surface roughness are displayed.

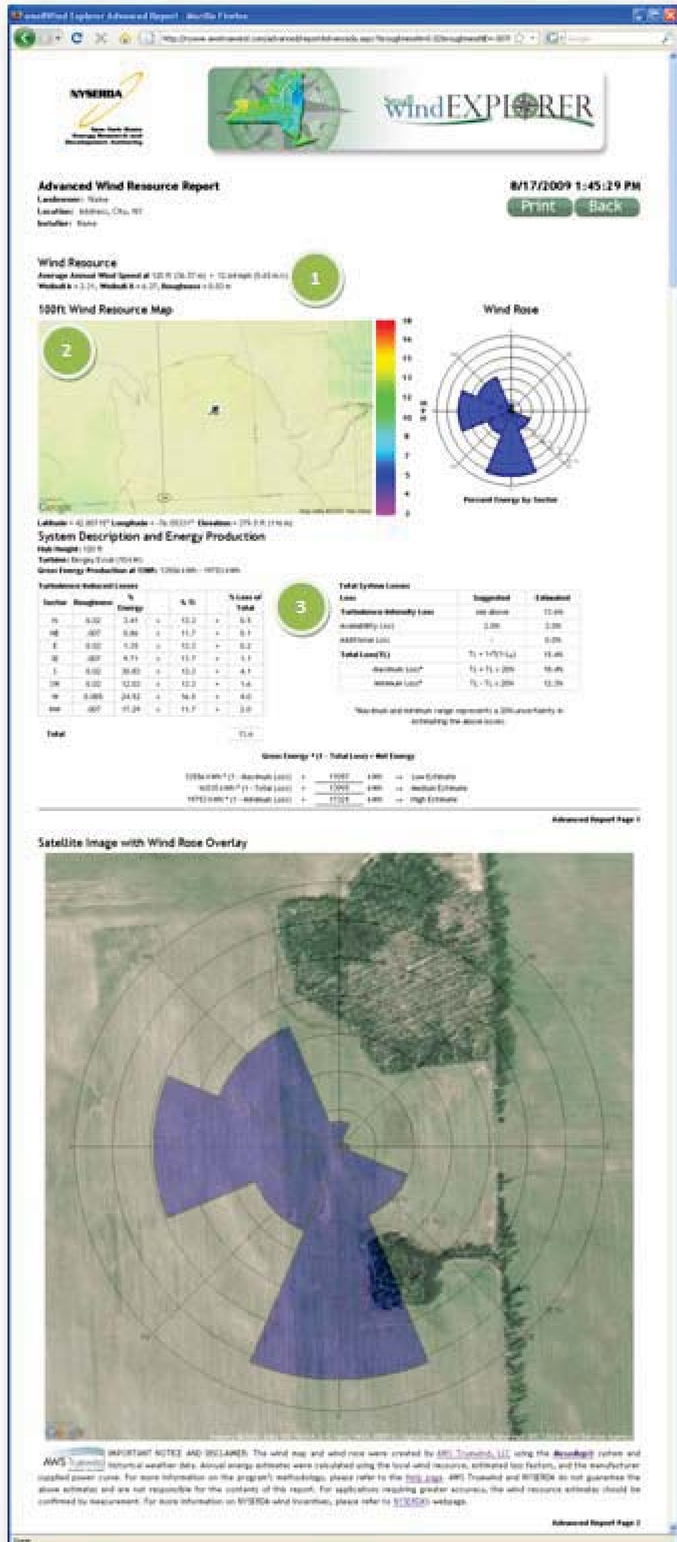
2. View the site's 200 m wind map and wind rose data.

   The site's wind resource map shows the average annual wind speed at 100ft above ground level. The wind rose provides an estimate for the amount of energy located in each directional sector (N, NE, E, SE, S, SW, W, NW).

3. Review the system losses and estimated annual energy production.

   Turbulence induced losses, availability losses, and additional known losses are summarized along with the estimated minimum and maximum total losses. The net energy summary displays the estimated range in annual energy production based on the chosen wind turbine, local wind resource, selected loss factors, and interannual variability in the wind.

   Review the satellite image with wind rose graphic to verify that the selected terrain roughness values match each direction.



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Customer Sited Wind Handbook

Final Report 10-08

CUSTOMER SITED WIND HANDBOOK NYSERDA Final Report 10-08