When it's essential...it's Weston&Sampson®
westonandsampson.com

Weston&Sampson®
environmental/infrastructure consultants

Five Centennial Drive, Peabody, MA 01960-7985
tel: 978-532-1900 fax: 978-977-0100

final report

Millbury Massachusetts

Wind Turbine Feasibility Study

October 2012

TABLE OF CONTENTS

LIST OF APPENDICIES

LIST OF FIGURES

EXECUTIVE SUMMARY

A feasibility study has been completed for the evaluation of a large scale wind turbine in the Town of Millbury, Massachusetts. The following report presents a comprehensive review of the critical factors and considerations analyzed as part of the study for installing a single wind turbine at the Butler Farm property located at 44 Singletary Road. This feasibility study incorporated thorough evaluation of virtual MET mast and existing published wind data; electrical usage, consumption and generation; economics; environmental, avian and noise impacts; engineering assessments and permitting issues towards development of a commercial-scale wind turbine.

The feasibility study addresses the technical and economic feasibility of construction of one 100 kW to 1.8 MW wind turbine at the Site. Conceptually, construction of a single large scale wind turbine could be used offset electrical consumption at multiple Town-owned facilities through virtual net metering. **Based on the results of this study, installation of a wind energy conversion facility is considered technically feasible, but not economically viable based on low predicated long term wind speed, the current cost of installation, and current value of energy.** Predicted long term wind speeds of 5.2 at a height of 80 meters was determined to be unfavorable for development of a commercial scale wind turbine at the Butler Farm Site. Aesthetic concerns, potential sound impacts and the degree of public support is also a potential limiting factor.

The cost for design, permitting, procurement and construction of a single 100 kW wind turbine is estimated to cost $1.03M; a single 600kW turbine is estimated to cost $1.87M; a single 1.5 MW turbine is estimated to cost $4.25M; and a single 1.8 MW turbine is estimated to cost $4.56M. The standard figures of merit, including: Net Present Value, Net Cash Flow, Benefit to Cost Ratio and Internal Rate of Return were all substantially negative, based on the low annual energy output from the low predicted wind speeds. Estimated capacity factors ranged from 4.7% to 10% are predicted long term average wind speeds of 5.2 m/s at a height of 80 meters. While commercially purchased wind modeling data suggested annual wind speeds of 6.5 m/s at 80 m, correlation of actual on-site measurements to nearby long term data sources yield a much lower annual wind speed of only 5.2 m/s. The average wind speed is considered poor for development of a wind turbine project.

Based upon the above, it is our opinion that development of a single large-scale wind turbine is technically feasible, but not economically viable. The next steps should include an internal assessment by the Town of Millbury to make a “Go” or “No Go” decision on the project. If there were consensus to continue with project development, then the Town would need to decide upon a procurement strategy, partnerships with interested third parties (such as MassCEC), and financing options. One of the first steps should be for the Town to obtain project entitlements for the land on which the proposed wind turbine will be located. If Millbury decides to develop the project under municipal ownership, then a draft Town Warrant article to authorize the debt incurred should be considered. Project permitting could also begin including obtaining a special permit or variance; filing with the USFWS, Natural Heritage, Massachusetts Historical Commission; and filing an electrical interconnection application.

List of Abbreviations

ABC	American Bird Conservancy
AGL	Above Ground Level
ASTM	American Society for Testing and Materials
BCC	Bird of Conservation Concern
CEC	Massachusetts Clean Energy Center
CMR	Code of Massachusetts Regulation
dB	decibel
dBA	A-weighted sound, in decibels
DMS	Decimal, Minute, Second
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FRP	Fiberglass Reinforced Plastic
ft	feet
GWh	Gigawatt hours
kV	kilovolts
kVA	kilovolt Amperes
kW	kilowatt
kWh	kilowatt-hours
m	meter
Mass DEP	Massachusetts Department of Environmental Protection
MASS GIS	Massachusetts Office of Geographic and Environmental Information System
MEPA	Massachusetts Environmental Policy Act
MHC	Massachusetts Historical Commission
MHD	Massachusetts Highway Department
MMA	Massachusetts Maritime Academy
mph	miles per hour
ms	meters per second
MTC	Massachusetts Technology Collaborative
MW	megawatt
NHESP	National Heritage and Endangered Species Program
NIMBY	Not In My Back Yard
PPA	Power Purchase Agreement
REPI	Renewable Energy Production Incentive
rpm	revolutions per minute
USDA	United State Department of Agriculture
USFWS	United State Fish and Wildlife Service
USGS	United States Geological Survey
V	Volt
WECS	Wind Energy Conversion System

1.0 INTRODUCTION AND BACKGROUND

A wind feasibility study has been completed for the Town of Millbury Massachusetts. The following report presents a review of the critical factors and considerations analyzed as part of the feasibility for installing a single large scale wind turbines at the Town-owned Butler Farm property. This feasibility study incorporated evaluation of wind resources, site characteristics, existing electrical infrastructure, electrical usage, environmental, avian and noise impacts; a regulatory review, and permitting plan. An estimate of wind turbine energy production and a financial analysis are also presented.

Photo 1 - Project location, Millbury, MA

Millbury is a town of approximately 13,000 people located at 42° 09' 48.8" North, 71° 47' 26.5" West. Millbury is the northernmost town in the Blackstone River Valley. Through this feasibility study, the Town is strengthening its belief in renewable energy and commitment, to evaluate one or more large-scale wind turbines on Town-owned property. In June 2009, a representative of the University of Massachusetts Wind Energy Center (WEC) in collaboration with Town staff, identified three potential wind turbine sites and completed a preliminary study on the siting considerations of a wind turbine in Millbury. The report (included in Appendix B) focused primarily on siting considerations for a meteorological (MET) tower and a fatal flaw analysis for a wind turbine. The overall conclusion of the study was that there were a number of factors favorable for a wind energy project in Millbury. This feasibility study evaluates a range of turbine sizes focusing on the Butler Farm Site.

Photo 2 – Butler Farm, Millbury, MA

The proposed wind turbine(s) would provide power for the Town to offset commercial electrical expenses and will be a showcase renewable energy project for surrounding towns located in the Blackstone River Valley. The location of the Town of Millbury is illustrated on a portion of a USGS topographic map as **Figure 1** in Appendix A. A Site Vicinity Map illustrating relevant landmarks within the Town of Millbury is provided as **Figure 2** in Appendix A.

2.0 WIND RESOURCES ASSESSMENT

There are many factors that affect the siting of a wind turbine, including topography, soils, setbacks, access, construction considerations, electrical interconnection, and wind speeds. The following section presents an assessment of the expected wind resources, based on the measured wind speeds at the Site, as well as other data sources used to estimate the long term average wind speeds at the site.

2.1 Methodology and Data Sources

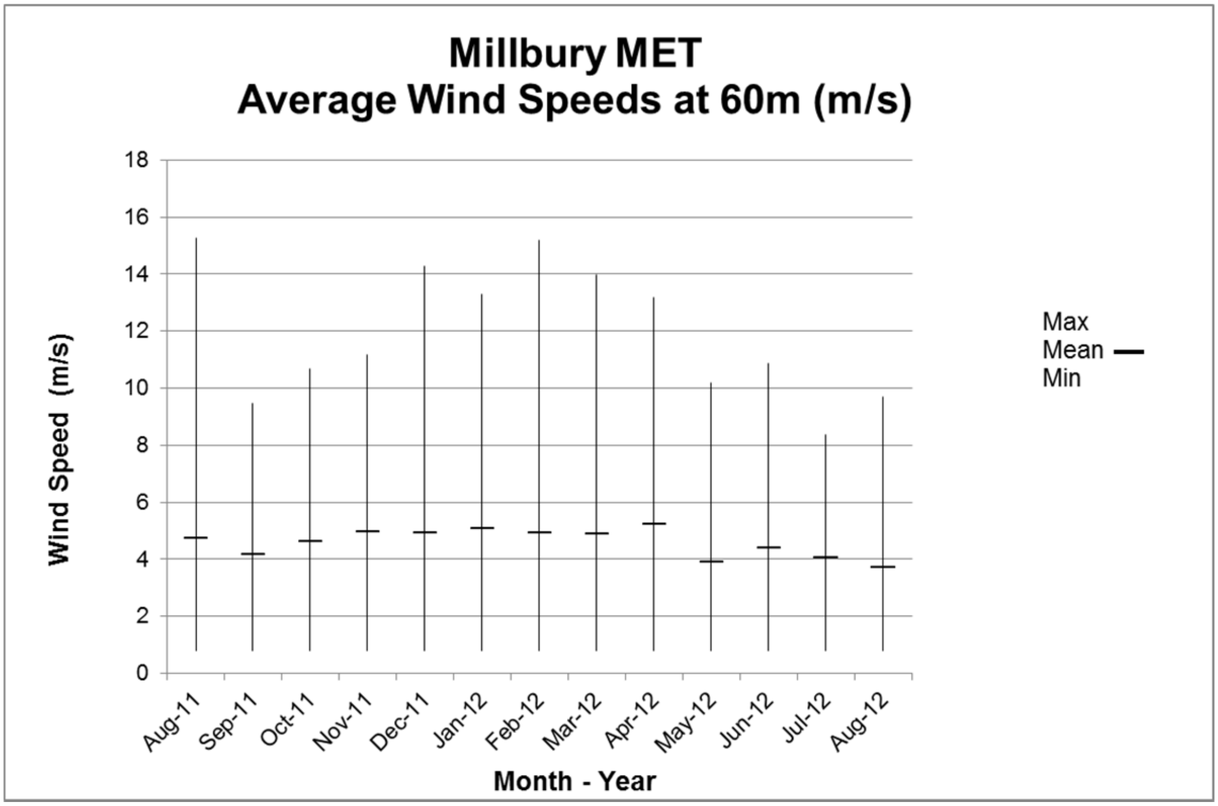
Weston & Sampson installed a MET tower at the site and collected wind data from August 26, 2011 through August 25, 2012. The MET tower is an NRG Systems 60-meter guyed tower with six anemometers to measure wind speed. Anemometers pairs were installed at heights of 60m, 50m and 40m. Single wind directional vanes were also installed at 40 and 60 meters. The tower was equipped with a grounding rod, temperature sensor and a barometer. Data collection was facilitated using an NRG Symphonie™ data logger. The measuring equipment, mast type and height were installed in general accordance with standard practices, including: adequate spacing between sensors and the supporting mast and boom structures; appropriate orientation of booms relative to prevailing wind direction; and wind data collection standards.

Photo 3 – MET Tower Installation

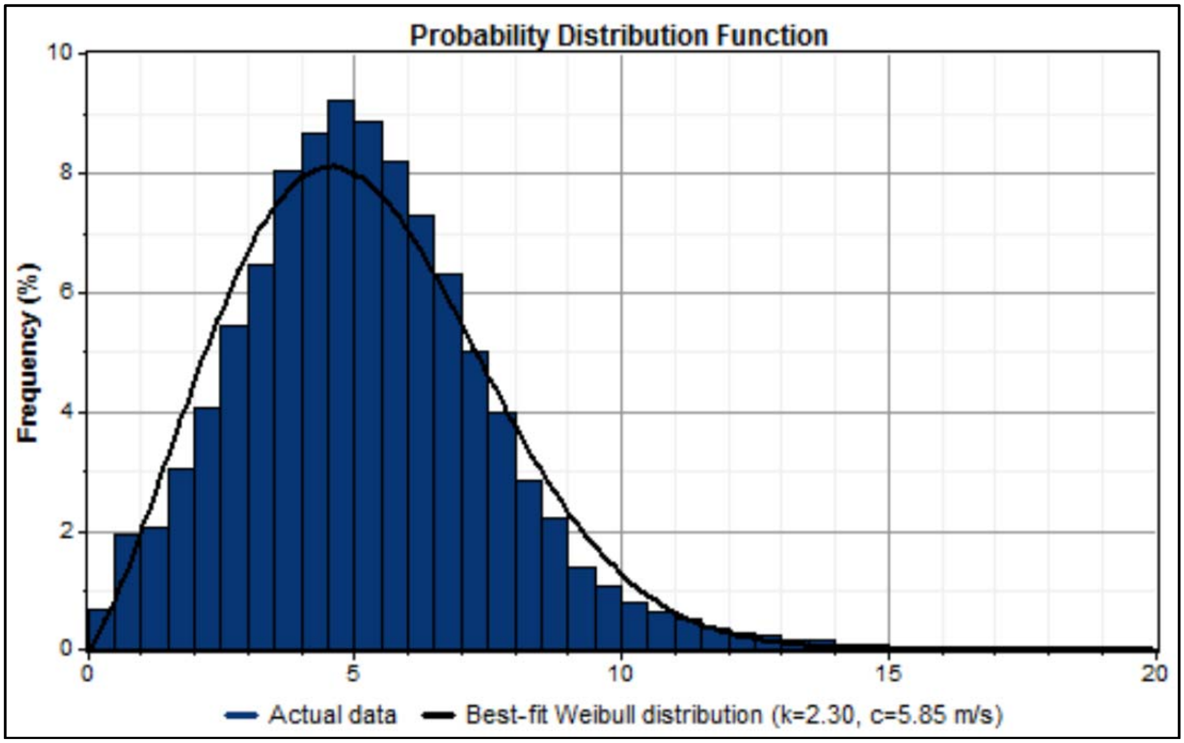
The data from the Symphonie logger is transmitted via cellular e-mail on a daily basis. The monitoring equipment samples wind speed and direction once every two seconds. These data points are then combined into 10-minute averages and, along with the standard deviation for those 10-minute periods, assembled into a binary file. The binary files are converted to ASCII text files using the NRG software BaseStation®. The text files are then imported into a database software program and subject to quality assurance (QA) tests prior to use. Based on the data logged, certain points are flagged and omitted during the analysis. Points are flagged if the data recorded was outside the limit of the instrument, icing occurred on the instrument, or if redundant measurements significantly differed.

The average wind speeds at the measured height of 40 meters, 50 meters, and 60 meters are provided in Table 1. The extrapolated wind speed at a height of 80 meters is also included in the table. Copies of the wind data summary reports and MET tower sensor data are included as Appendix C.

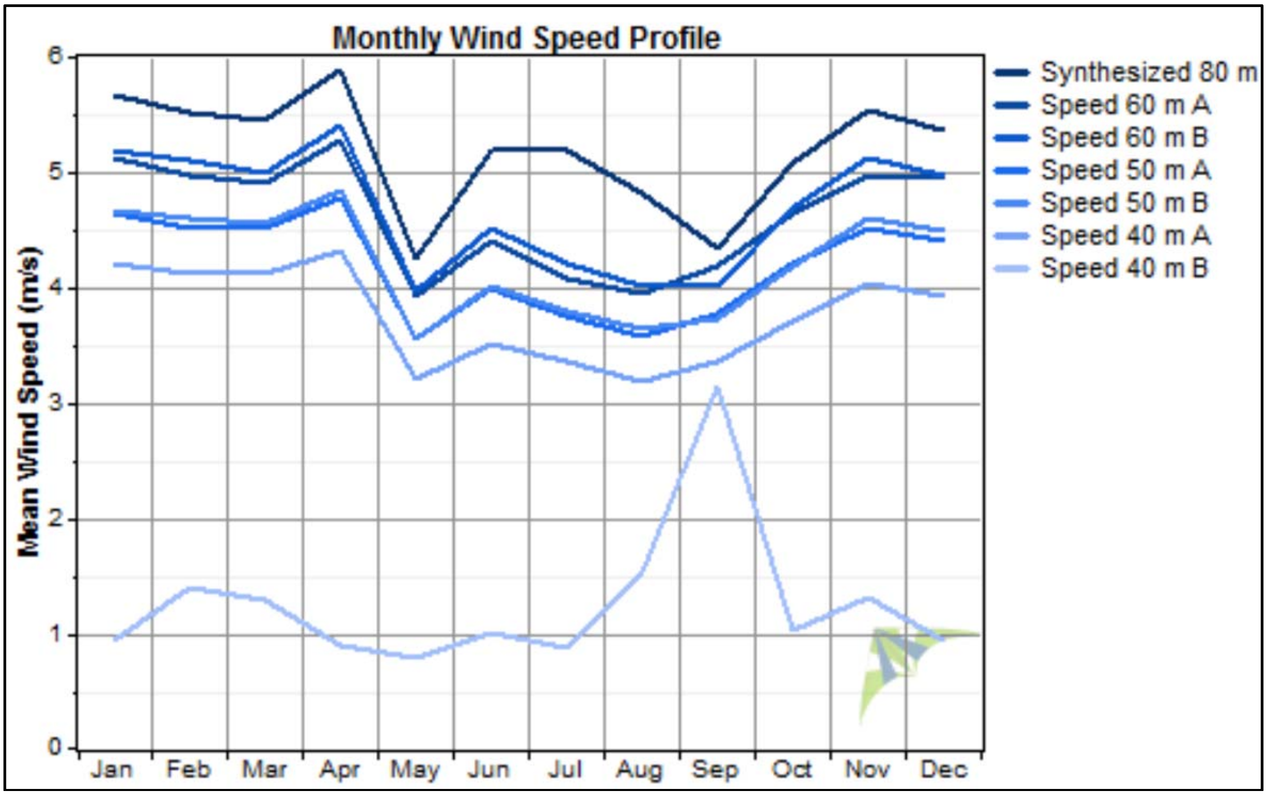
Table 1 - MET Tower Measured Wind Speeds	
Elevation	**Average Wind Speed (m/s)**
40 meters	3.7
50 meters	4.2
60 meters	4.6
80 meters (Extrapolated)	5.2



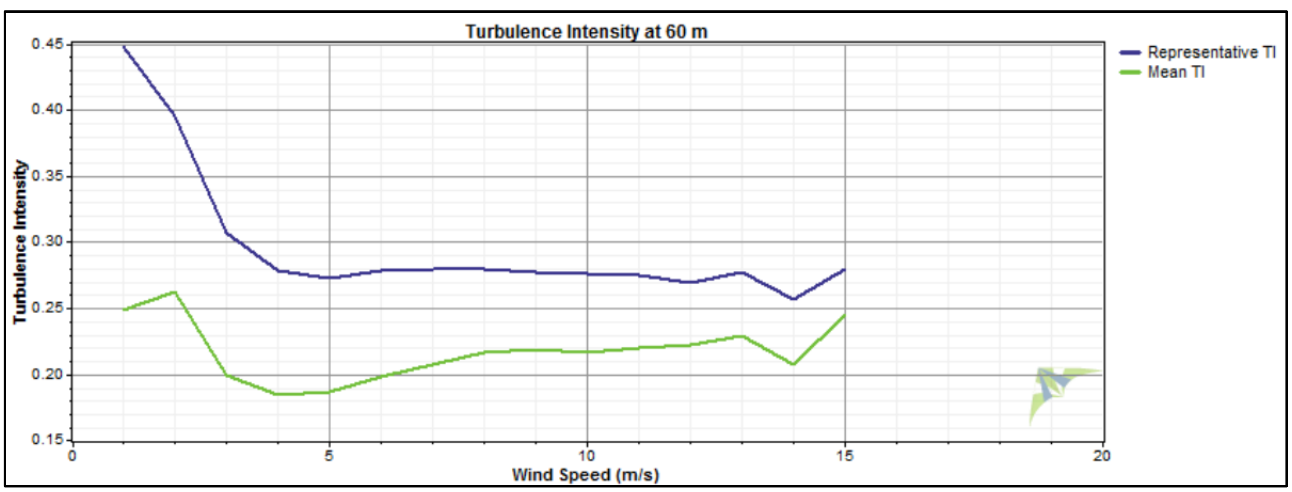
The measured data from the Butler Farm MET tower were evaluated using Windographer computer software to derive standard wind data statistics for the site. The graphical wind distribution frequency is given as follows:



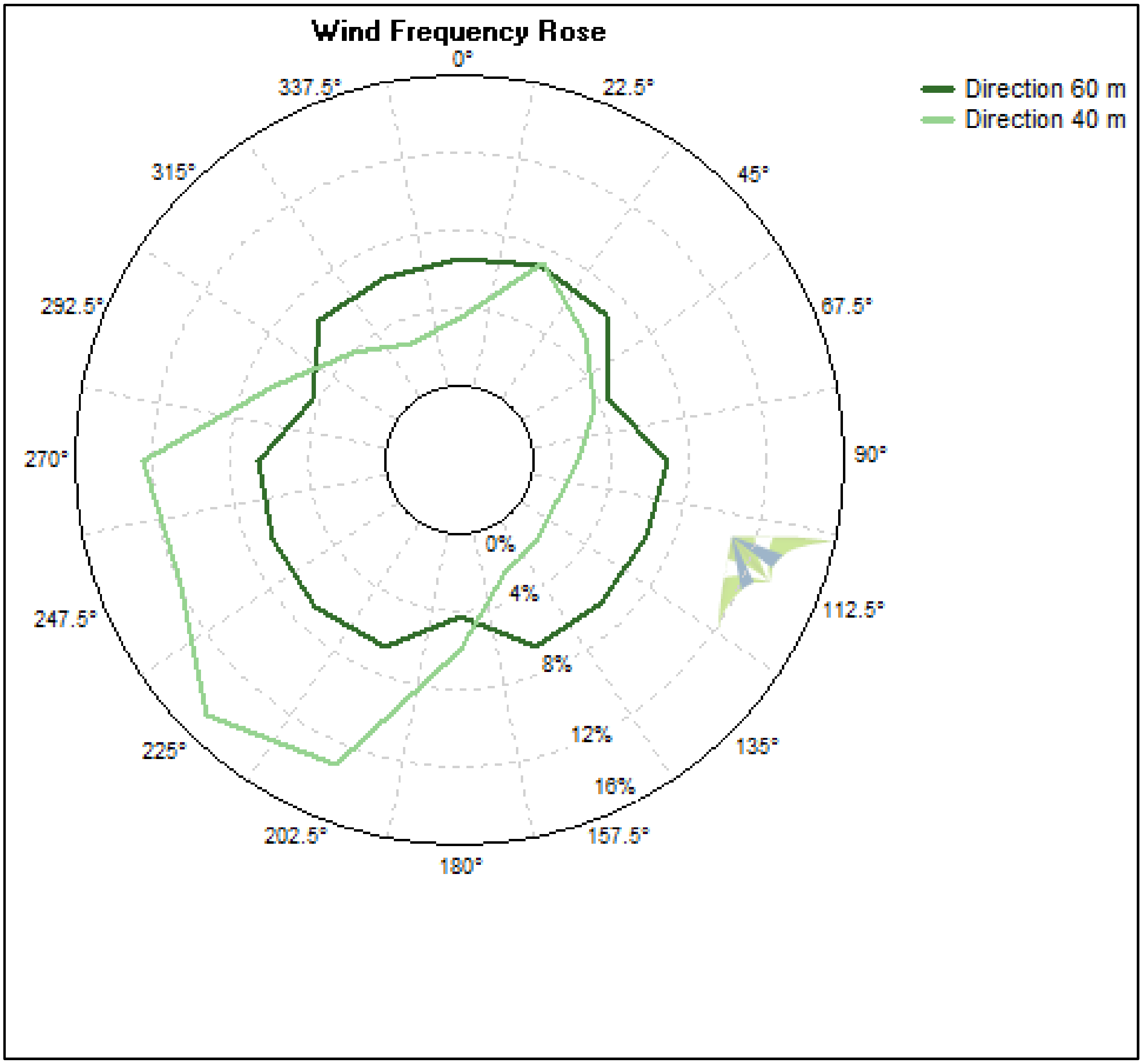
The monthly wind speed profile for each of the anemometers is given below. Please note, data collected from Sensor B at the 40 meter level was considered suspect (mechanical issues) and not used in the analysis.



The average turbulence intensity is 0.20, and is given below.



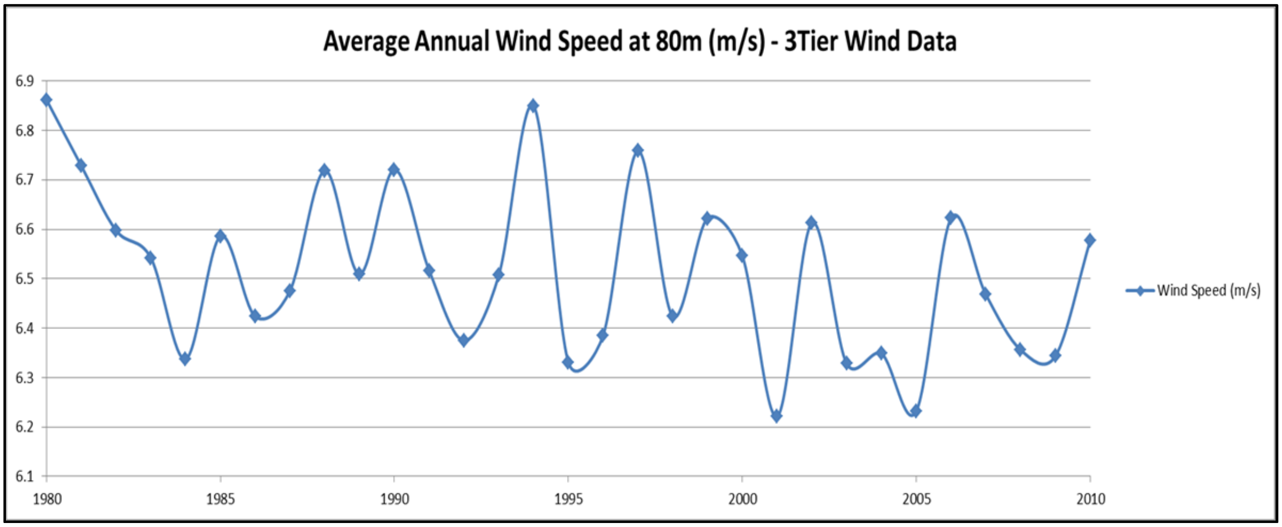
The predominant wind direction at the site is from the southwest. A graphical wind rose for the 40 meter and 60 meter directional vanes is provided below.



Weston & Sampson also reviewed the AWS TrueWind Map model of wind speeds for Millbury. The AWS TrueWind estimates are useful for site screening and while they do not replace the accuracy of site specific anemometry, they are considered reliable with a 94% factor of confidence. Table 2 represents the AWS true wind speeds for the Butler Farm Site at various heights.

Table 2 - AWS True Wind Map Predicted Wind Speeds	
Elevation	**Wind Speed (m/s)**
30 meters	5.07
50 meters	5.68
70 meters	6.10
100 meters	6.60

In addition a data set was also purchased from 3Tier which includes a set of long term virtual MET mast data for the Butler Farm Site. The data is a 30 year set with 10 minute averages from January 1, 1980 through August 3, 2010. This modeled data set suggests the long term average wind speed is expected to be 6.5 m/s at a height of 80 meters. In comparing the three data sets, the measured MET data contains lower wind speeds than the statistical long term wind speeds for the site. This suggests that the year measured was a below average year for wind speeds.



2.2 Obstructions and Their Impact on Wind Resources

The proposed wind turbine location at the Butler Farm Site is in a hilly terrain within a small +/- 2.0-acre meadow surrounded by trees. Other than the natural topography and trees on site, there are few obstructions at the site which would impact the wind resources. Ideally, the wind turbine would be placed on the highest available elevation at the site and trees would be cleared around the turbine sufficient to allow access and a clear area for construction; however, set back distances to property lines also have to be considered in turbine siting.

2.3 Correlation to Long Term Data

The 3Tier wind model predicted long-term annual average wind speeds 6.5 m/s at a height of 80 meters for the Site. The wind power class at the Butler Farm Site, based on measured data, was considered poor-marginal. Given the disparity between measured data and 3Tier model results, we reviewed other nearby data sets to better predict the long term average wind speed.

The on-site wind speed measurements spanned a full year. In general, a measuring period of one year is considered too short to make a reliable estimate of the long-term average wind speed. From year to year the average wind speed varies by approximately 4% (one standard deviation), which means that the 95% confidence interval for the long-term wind speed is ±8%. This estimate can be improved by correlating the wind speed measurements at the site with a reference meteorological station. In this way the short-term measurements can be correlated and adjusted based on a longer range of wind speed measurement.

For this correlation, wind speed data from the NOAA Station 94746, located at Worcester Regional Airport approximately 8.2 miles northwest of the Butler Farm Site was used. Publicly available wind measurement data from April 2005 to October 2012 were reviewed. The anemometer at NOAA Station 94746 is located at an elevation of approximately 1,000 feet, somewhat less than the Butler Farm site at an elevation 650 feet. Wind data for the 12-month period collected at the Butler Farm site was compared to NOAA Station 94746 data set. Data from the NOAA station were retrieved from the website: http://www.ncdc.noaa.gov/land-based-station-data.

Using the wind speed information from Butler Farm and the NOAA Station, a least-square linear regression analysis was performed to estimate long-term wind speed averages for Butler Farm. The data set for NOAA is considered acceptable for comparison with Butler Farm based on proximity to the Town and the direction of the prevailing wind being similar to for both locations, despite the difference in elevation, as monthly average wind speeds at Butler Farm correlated well to data from the NOAA Station, where the average monthly wind speeds follow a similar pattern. The long term average for the 7.5 year period at the NOAA station was 4.3 meters per second. The short term average for the period corresponding to the same period of time in which data was collected at the Butler Farm site (August 2011 through August 2012), was 4.0 meters per second; thus indicating a lower than average wind speed year.

The mean win speed at Butler Farm during the one year period was 4.6 meters per second at a height of 60 meters. Given the data collected at Butler Farm site was during a lower than average year for wind speeds, a long-term wind speed average of 5.0 meters per second is predicated at a height of 60 meters. Extrapolation of the data to different hub heights yields the following normalized long term average wind speeds at various hub heights:

Table 3 Normalized Long Term Wind Speeds, Millbury, MA

Height (meters)	Predicted Wind Speed (m/s)
40	4.02
50	4.52
60	5.00
80	5.19

Given the proximity, similarity in terrain and tree heights present at the Butler Farm and NOAA Station, the correlated long term predicated wind speeds at the Butler Farm of 5.2 m/s at 80 meters is used for estimating energy production potential for the various wind turbines evaluated.

Based on the wind resource assessment, the power density of the average wind speeds at the site is Poor-Marginal. The poor power density is expected to produce marginal economic returns based on development of a single large scale wind turbine. The average predicted long-term wind speeds should, however, meet the minimum criteria for grant eligibility under the Commonwealth Wind Program as having wind speeds of at least 6.0 m/s at 70 meters, and grant funding would improve the project economics if eligible for the maximum incentive. Standard wind power classes based on power density and wind speeds are given in Table 4.

Table 4 - Wind Power Classes			
Wind Power Class	Description	Power Density at 50m (W/m2)	Wind Speed at 50m (ms)
1	Poor	0-200	0 to 5.6
2	Marginal	200-300	5.6 – 6.4
3	Fair	300-400	6.4 – 7.0
4	Good	400-500	7.0 – 7.5
5	Excellent	500-600	7.5 – 8.0
6	Outstanding	600-800	8.0 – 8.8
7	Superb	800-2000	8.8 – 11.9

3.0 INSTALLATION SITE AND VICINITY

3.1 Evaluation of Site Vicinity

The Town owned Butler Farm is located at 44 Singletary Road, Millbury, MA. The surrounding neighborhoods are residential and rural. Certain areas of the property are within 300 meters of residences; however there are no homes near the 400 foot property line setback or proposed MET tower location, where it is expected that the turbine will be sited. The Site Survey completed by the University of Massachusetts' Wind Energy Center concluded that the Town should consider this parcel for one or more utility-scale or medium-scale turbines.

Height Restrictions and Proximity to Airports
Weston & Sampson retained the service of an aeronautical consultant, ASI, to provide an obstruction evaluation in accordance with 14 CFR, part 77 at a nearby location with coordinates:

71° 47' 26.5" West
42° 09' 48.8" North

This location is on the Butler Farm property in the general area of the proposed wind turbine. The results of the analysis indicate that a structure up to 500 feet AGL should receive routine approval from the FAA. There are no known AM radio stations located within three miles of the Site. The obstruction report also noted that further radar study should be completed due to potential impacts to Air Defense radar, Homeland Security radars, and WSR-88D weather radar operations. This recommendation is not considered a fatal flaw. The relevant correspondence is attached as Appendix D.

Proximity to airports is another important siting factor. The location of the Butler Farm property with respect to operating airports and air navigation facilities was evaluated. The Site is located 7.86 miles southeast of the nearest airport, which is the Worcester Regional Airport located in Worcester, MA. The next nearest airfield is the Southbridge Municipal Airport which is located 13.5 miles southeast of the Site. The proximity of the site with respect to these airfields is not considered a potential limiting factor.

3.2 Site Physical Characteristics

The Butler Farm Site is located off of Singletary Road in Millbury. It is a 50-acre site containing a meadow, abandoned orchard, forest, a single-family house that is used for office space and a meeting facility, a single vehicle, and a solar wireless facility for the fire department's monitoring/alarm equipment. It is located at a latitude and longitude of 42.1636° N and 71.7907° W; the elevation of the property is approximately 649 feet above sea level. Approximately 70% of the site is forested; the remainder of the property is meadow and other facilities (described above). The physical boundary of the property is depicted on **Figure 3** in Appendix A.

3.3 Wind Turbine Location

The location of the proposed wind turbine at the Butler Farm Site is on the northwest end of the meadow to the rear of the property. This location will require less clearing of trees. The northwest side of the meadow also has better wind resources than the surrounding areas. This location is not located in any flight paths for the surrounding airports. It is also considered to be located at a reasonable distance from nearby residences so as to minimize the visual and sound impact from the wind turbine. The coordinates (NAD83) for this location are as follows:

3.4 Site Access

Photo 4 – Butler Farm, Millbury, MA

Access to the proposed wind turbine location is available through existing paved highways, roads, driveways and parking lots. Turning radii and slopes of highway routes, as well as local roads are expected to be passable without any significant alterations or modifications. A detailed transportation study would need to be performed to better define the preferred access route and dimensional requirements, based on specific turbine weights and measurements.

Based on average expected weights and lengths of the components of a commercial scale wind turbine in 100 kW to 1.8 MW class, delivery of the major components and parts to the Butler Farm Site are considered feasible and not considered a fatal flaw. The proposed location at the Site is a meadow surrounded by trees. An access road on the property will need to be provided so the turbine can be delivered and erected at the selected location.

3.5 Site Geology and Soil Conditions

Based on review of the United Sates Geologic Survey Maps, the bedrock at the Butler Farm Site consists of Metamorphic Rocks. **Figure 4** in Appendix A depicts a portion of the Geologic Map illustrating the geological conditions in the area of Butler Farm.

Review of United State Department of Agriculture Soil Maps for Worcester County, Massachusetts, shows that the surficial soil at the Butler Farm Site consists of Woodbridge Fine Sandy Loam with 3 to 8 percent slopes. Refer to **Figure 5** in Appendix A for a portion of the referenced USDA Soil Map illustrating soil types at the Site.

Soil borings should be conducted in the location of any proposed wind turbine in accordance with ASTM D-1586. The borings should be drilled to a depth of 100 feet or until bedrock is encountered, whichever is less. Where bedrock is encountered, drilling should include coring at depth of 10 to 20 feet to confirm the competency of the existing of bedrock. The data from the test borings should be evaluated by a geotechnical engineer who would provide the structural engineer with design parameters such as bearing capacity, friction angles and other soil characteristics, including recommendations for a foundation type. A specific design could only be prepared once a specific turbine has been selected and specific loads are known.

3.6 Millbury Electricity Use

National Grid provides electricity for the Town of Millbury under multiple accounts. Review of the electrical data between July 1, 2008 and June 30, 2009 suggests that the Butler Farm property uses 2,045 kWh annually and the Town of Millbury, as a whole uses 3,627 MWh. Copies of selected electricity bills for the Town of Millbury are included in Appendix E.

3.7 Existing Electrical Infrastructure

National Grid provides electricity to the two story single family home on the old Butler Farm property. The property includes a detached single car garage powered from the home. Behind the garage is a pad mounted 10kw diesel powered generator that is not connected to the garage or to the home. The Town of Millbury uses the Butler Farm House as a part time conference/meeting room and to support several municipal antennas including the Fire Department Radio. The electrical billing and usage data provided for selected accounts in the Town of Millbury is included in Appendix E.

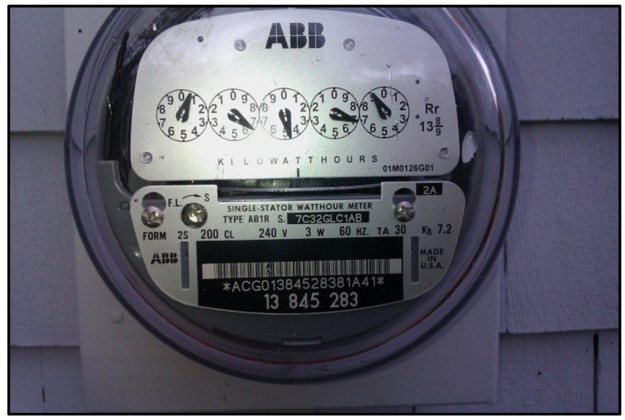


Photo 5 – Electricity Meter

The 240/120 volt single phase electrical service to the Farm House is provided from utility pole #19 along the Singletary Road. The electrical service to the farm is supported on two wooden poles located on the Butler Farm property. The utility poles along Singletary Road also support 3phase 13.8 kV distribution power that services the predominantly residential customers along Singletary Road and West Sutton Road.

3.8 Electrical Interconnection Plan

<u>Connection Point to the Utility Distribution System</u>

Due to the location of Butler Farm, there is only one connection point the wind turbine can tie into the existing electrical grid serviced by the utility. The point of common coupling (the PCC as the utility National Grid refers to it) at Singletary Road will require overhead medium voltage 3-phase cable carried on several wooden utility poles located on the Butler Farm property. Starting from the existing utility distribution cables at pole #19 the new turbine interconnect cable will cross Singletary Road to the series of poles terminating at the pad mounted fused disconnect switch near the turbine.

<u>Power Cables to the Turbine Location</u>

At pole #19 the utility will require the installation of a pole-mounted primary switch. A three-phase switch may is required by the National Grid with the ability to lock the switch in the open position and to provide a means of preventing the wind turbine from powering the electrical distribution system during a period of sustained utility outage. This device type, known as a group-operated air-break (GOAB) switch, would allow a utility lineman to verify the switch is in the open position from the ground.

Power Cables from the Utility Connection Point to the Turbine Disconnect Switch
The cables required to connect the utility power to the Turbine will be carried on wooden poles from utility pole #19 on Singletary Road to the disconnect switch located near the transformer. The distance between pole #19 and the disconnect switch is approximately 800 ft. The power cable run will require approximately seven poles. At the pole closed to the disconnect switch the cables will transition to an underground concrete-encased duct bank.

Transformer Disconnect Switch
The concrete-encased duct bank discussed above will continue from the last pole at the turbine end of the cable to under the pad mounted disconnect switch. The concrete encased duct bank will protect the cables from vehicle loading when the earth becomes soft in the spring. The disconnect switch is manually operated and is rated to open under full load turbine current and voltage operation. The line side of the disconnect switch connects to the step up transformer.

Transformers
The step-up transformer matches the utility distribution voltage to the turbine output voltage. The proposed interconnection would be to step-up the low-voltage 480V or 690V output of the turbine to a higher voltage for connection to the 13.8 kv National Grid distribution system. Turbines typically 600kW and larger generate at the European industrial voltage of 690V. The 690V to 13.8 kV transformer is a Wye-Wye configuration. The 100kw turbine generates at 480V. The 480V/13.8 kV transformer is a Delta-Wye configuration. New 15 kV class three-phase power cables are installed in an electrical duct bank to a new riser pole located near the turbine outside of the blade area and in an area that is protected from vehicle traffic.

Turbine Main Circuit Breaker
The main circuit breaker protects the turbine generator, power cables, transformer, disconnect switch and the utility distribution system from a ground fault or line to line fault. The Main Breaker is located within the turbine enclosure. This breaker does not protect the utility distribution system from over and under voltage or over and under frequency. The protective relaying system provides that function.

Protective Relaying
The protective relaying for the wind turbine generator will be selected by National Grid based on the results of their system impact study. Based on a review of the National Grid Electric Interconnection Requirements, it is anticipated that the protective relaying will include over and under frequency, over and under voltage and over current relay. When the protective relaying system detects conditions that are out of range a trip signal is sent to the main contactor to open disconnecting the wind turbine generator from the electrical distribution system. If power to the electrical distribution system is interrupted the turbine protective relaying system will sense the power loss and disconnect the wind turbine generator from the electrical distribution system.

Revenue Metering
The Revenue Metering will measure the energy produced by the wind turbine. The meter will measure the energy provided to the grid when the turbine is in operation producing Renewable Energy Credits (REC's). When the turbine is not turning fast enough to achieve the minimum output level or is off line the meter will measure the small energy required to power the turbine internal systems. This is known as bidirectional metering or Net Metering.

Wind Turbine Size
This feasibility study considers the installation of one of four different size wind turbines. The selected size depends on the capability of the local electrical distribution system to handle the

energy produced by the turbine. The turbines considered are a Northern Power System 100 kW wind turbine, the 600 kW Elecon Turbowinds T600-48, the 1,500kW GE 1.5 xle, and the 1800 kW Vestas V90. The remainder the electrical section will discuss the components required to interconnect the four sizes of wind turbines, as well as the electrical construction estimate for each.

3.9 Electrical Interconnection Details

National Grid has specific standards and requirements for the interconnection of distributed generation such as the proposed wind turbine project. The interconnection requirements address electrical system protection, revenue metering, operation, and the configuration of the primary interconnection equipment. National Grid will review and analyze the proposed design of the electrical interconnection of the facility to determine the impact on their electrical distribution system. Based on the results of the National Grid analysis, modifications may be required to the distribution system and/or to the wind turbine generator interconnection equipment.

The technical details of the major power system components associated with the electrical interconnection of the wind turbine generator are described below. Please refer to the one line electrical interconnection diagram E-1. The one line diagram shows a typical wind turbine interconnection. The transformer size, the disconnect switch and underground raceway will vary according to the wind turbine selected. The generator step-up transformer is described by specifying the transformer voltage rating (primary and secondary), power rating (kilovolt-amperes or kVA), winding configuration (primary and secondary), and construction type. All transformers shall be three phase, pad mount type, oil-filled, self-cooled transformers. The transformer oil shall be environmentally safe seed-based.

The primary voltage rating of the step-up transformer shall be sized to 13.8 kV three phase four wire 60Hz to match the nominal voltage of the National Grid distribution supply circuit. To allow for local voltage deviations that may exist on the distribution system, the transformer primary winding shall be equipped with fixed taps to change voltage level per National Grid requirements. For the generator step-up transformer, the secondary voltage rating will match the wind turbine generator voltage which is 480 volts for the 100kW Wind Turbine and 690 volts for the others.

<u>The 100 kW Wind Turbine</u>
The turbine’s 150Amp main breaker connects to the low voltage side of the 150 kVA transformer. The 600v rated power cables are installed in an underground duct bank. Each of the phase conductors consist of one #1AWG copper cable with type XHHW-2 insulation for a total of three. The duct bank consists of one 4” phase conduit, one 4” spare conduit and four 2” conduits for monitoring, control and communications respectively. Each phase conduit includes a #6 AWG copper grounding conductor. The PVC conduits are concrete encased and buried a minimum 30” below grade. The medium voltage 13.8 kV primary side of the transformer connects to the 15 kV rated fused safety disconnect switch. The disconnect switch includes a 15 kV lightning arrester with a pad lockable lever in the open position including clear visible indication for the open and closed positions. The switch is rated to open when the turbine is operating under full load.

<u>The 600kW Wind Turbine</u>
The turbine’s 700A main breaker connects to the low voltage side of the 750 kVA transformer. The 600v rated power cables are installed in an underground duct bank. Each phase conductor will consist of two 500kcmil copper cables with type XHHW-2 insulation for a total of eight. The duct bank consists of two 4” phase conduits, two 4” spare conduits and four 2” conduits for monitoring,

control and communications. Each phase conduit includes a #1 AWG copper grounding conductor. The PVC conduits are concrete encased and buried a minimum 30" below grade. The medium voltage 13.8 kV primary side of the transformer connects to the 15 kV rated fused safety disconnect switch. The disconnect switch includes a 15 kV lightning arrester with a pad lockable lever in the open position including clear visible indication for the open and closed positions. The switch is rated to open when the turbine is operating under full load.

1500 kW Wind Turbine
The electrical components are similar to the 1800kW turbine with the exception of the 1500 kVA transformer.

1800 kW Wind Turbine
The turbine's 2000A main breaker connects to the low voltage side of the 2000 kVA transformer. The power cables are installed in an underground duct bank rated 1000v. Each phase conductor and neutral conductor consists of six 500kcmil copper cables with type XHHW-2 insulation for a total of 18. The duct bank consists of six 4" phase conduits, three 4" spare conduits and four 2" conduits for monitoring, control and communications. Each phase conduit includes a 250kcmil copper grounding conductor. The PVC conduits are concrete encased and buried a minimum 30" below grade. The medium voltage 13.8kV primary side of the transformer connects to the 15kV rated fused safety disconnect switch. The disconnect switch includes a 15kV lightning arrester with a pad lockable lever in the open position and clear visible indication for the open and closed positions. The switch is rated to open when the turbine is operating under full load.

Power Cables to the National Grid Connection
The power from the wind turbine generator is converted from 480V or 690V to 13.8 kV using the transformer. The term "step-up transformer" is used for this equipment. The 13.8 kV power cables from the disconnect switch transition from underground up the wooden pole in a conduit riser at least 10 feet above grade. Upon exiting the riser the cables continues up the pole in free air along the series of seven poles to the National Grid point of common connection at pole #19 along Singletary Road. Additional communication, monitoring and 240/120v power cables are also supported by these poles.

The wind turbine generator interconnection uses 15 kV class power cables. The power cables are specified for 15 kV class insulation and consist of four, single conductor cables of either aluminum or copper. For the 1800 kW wind turbine generator the size of the power cables shall be a minimum of #1 AWG aluminum. This is typically the smallest size primary cable installed by the utilities. The #1 AWG aluminum cable has a capacity of 200 amps when run in free air. The full load current rating of the 100 kW, 600 kW, 1,500 kW and the 1,800 kW turbines are 7 Amps, 35 Amps, 70 amps and 95 amps respectively. So the 15kV #1 AWG aluminum cable is adequate for either turbine.

3.10 Electrical Interconnection Cost Estimate

The following cost estimate has been developed based on the conceptual design concept prior to completion of a formal interconnection application with National Grid. The planning phase cost estimate accuracy is generally expected to be within +/- 25%. The cost estimate is based on recent project experience and vendor quotes and may change based on the final design, construction conditions and changing material and labor costs.

The estimated cost for materials, equipment, and construction required to interconnect the 100 kW, 600 kW, 1,500 kW, and 1,800 kW wind turbines to the existing utility grid is $184,800, $221,700, $255,500 and $283,000 respectively. The tables included in Section 6.4 detail the major cost items for the four proposed interconnections. The balance of the interconnection system and miscellaneous high-voltage components including start-up testing are estimated at 20% of the total estimated installation cost. An additional cost for upgrades to the existing National Grid system if required could range from $100,000 - $150,000, however this cost would need to be confirmed by National Grid through an interconnection study after submittal of an application for interconnection.

The cost estimate is budgetary for planning purposes and does not include permitting, legal, financing and other costs beyond those listed above. The cost estimate does not include communication cables. The cost estimate is for interconnection only and does not include wind turbine itself. The cost estimate does not include utility-related upgrades and back charges for those upgrades.

The proposed interconnection is illustrated on the one-line diagram Drawing E-1 in Appendix A. The one- line diagram shows a typical wind turbine interconnection. The transformer size, the disconnect switch and underground raceway will vary based on the actual wind turbine selected.

4.0 ENVIRONMENTAL REVIEW AND PERMITTING PLAN

4.1 Environmental Review

The following section discusses the environmental and ecological characteristics at the Butler Farm Site. A review of various area receptors was conducted to determine what, if any, impact a wind turbine would have upon sensitive receptors at the site. **The result of this evaluation indicates that development of a single wind turbine is not expected to result in unacceptable negative impacts to wildlife or other sensitive receptors present at the Site.**

<u>Avian and Wildlife Impact Analysis</u>
The pertinent ecological and environmental factors associated with avian and wildlife impacts from the proposed construction of a single, commercial-scale wind turbine have been evaluated. The analysis consisted of a review of existing site conditions and available scientific databases. This information was correlated with available Mass GIS data layers including a review of aerial photographic imagery to make an initial determination of the potential ecological impacts of the proposed project. In addition, a determination of the likely avian impacts were formulated following the interim guideline developed by the United States Fish and Wildlife Service (USFWS), which include eight impact evaluation criteria for assessing avian impacts. Methodology used in making a determination about avian impacts was developed to incorporate three principal characteristics. These characteristics are environmental attributes, species composition, and ecological attractiveness of the area. Additional information regarding USFWS impact evaluation criteria can be found in Appendix F.

<u>Agency Consultation</u>
Federal and State agencies should be contacted to request information concerning endangered or threatened species and critical habitats within the project area. The Owner should contact the USFWS, New England Regional office, pursuant to Section 7 of the Endangered Species Act of 1973, to determine whether any federal listed species or habitats are present in the project area if construction of a wind turbine is planned. In addition, the Massachusetts Natural Heritage and Endangered Species Program (NHESP) should be consulted for information regarding any state listed species and habitats.

The initial correspondence would constitute the beginning of the “informal” or “simple” review process as outlined by Section 7 of the Federal Endangered Species Act and the Massachusetts Endangered Species Act (321 CMR 10.0000). If, at the conclusion of these consultations, it is determined that no federal or state listed rare species are present or in close proximity to the proposed project site, then the informal or simple review process may be considered complete. Should the conclusion of these consultations reveals that the project site will likely disturb one or more listed species, then a more detailed biological assessment or order of conditions may be required.

<u>Landscape Evaluation and Analysis</u>
Composition and spatial variation patterns for wildlife are strongly influenced by a multitude of biotic and abiotic landscape features. In lieu of comprehensive site surveys, Weston & Sampson gathered information regarding existing site conditions and habitats on the proposed site and analysis was conducted through review of site photographs, aerial photography, and scientific databases and literature.
The landscape evaluation focused on examining aerial photography of existing conditions to identify those biotic and abiotic features of significance. The Butler Farm Site is a 50-acre site

containing a meadow, abandoned orchard, forest, a single-family house that is used for office space and a meeting facility, and a garage for one vehicle. Surrounding the meadow are forested areas with trees approximately 30-40 ft high.

Examination of the proposed site reveals the presence of continuous corridors for wildlife movement. The site has few buffers to the natural communities and movement of wildlife between suitable habitats. The Site is bordered on the east, west, north, and south by contiguous plots of natural communities. Natural corridors exist in the region in the form undeveloped linear lands, streams, and wetland complexes that connect patches of preferred habitat. Man-made travel corridors include roads, utility corridors, and urban development.

Mass GIS Data Layers: Data regarding rare species and critical habitats is compiled by the Massachusetts Office of Geographic and Environmental Information (Mass GIS) and organized as a number of Geographic Information System (GIS) data layers. These layers are represented as number of polygons drawn in conjunction with existing landscape features, and can be utilized to determine the spatial relationships between areas of environmental significance (e.g. wetlands) and a proposed project site. A table of the GIS data layers used in avian impact screenings and subsequent analysis within this report has been summarized below:

Table 5 - Mass GIS Screening Data Layers

Data Layers	Authority	Date of Update
Estimated Habitats for Rare Wildlife	NHESP	September 2008
Priority Habitats for Rare Species	NHESP	September 2008
BioMap Core Habitat	NHESP	June 2002
BioMap Supporting Natural Landscape	NHESP	June 2002
Massachusetts Certified Vernal Pools	NHESP	January 2009
Potential Vernal Pools	NHESP	December 2000
Areas of Critical Environmental Concern	DCR	April 2009
DEP Wetlands (1:12,000)	MADEP	December 2004

Notes/Abbreviations:
NHESP: Natural Heritage and Endangered Species Program
MADEP: Massachusetts Department of Environmental Protection
DCR: Massachusetts Department of Conservation and Recreation

GIS screening of the area shows that no part of the Butler Farm Site is considered protected open space. No part of the Site is within an area of NHESP Estimated Habitats of Rare Wildlife or a NHESP Priority Habitats of Rare Species. The NHESP Estimated Habitats of Rare Wildlife data layer represents estimations of the habitats of state-protected rare wildlife (plants and animals) populations that occur in Massachusetts, while NHESP Priority Habitats data layer represents estimations of important state-listed rare species (animals only) habitats in Massachusetts. The NHESP habitat polygons are drawn by analyzing population records, species, habitat requirements, and available information about the landscape. The Site is not located within a DEP Approved Zone II area.

BioMap Core Habitat data layers present the most viable habitat for rare species and natural communities in Massachusetts. The BioMap Supporting Natural Landscape layers buffer and connect Core Habitat polygons and identifies large, naturally vegetated blocks that are relatively free from the impact of roads and other development. Based on previous development the site is not mapped as core wildlife habitat. **Figure 6** in Appendix A is a map presenting the results of the habitat GIS screening for Natural Communities, Estimated Habitats for Rare Wildlife and Areas of Critical Environmental Concern with respect to the location of the Site.

Species Listing and Habitat Considerations

Correctly identifying the species and associated habitats is critical to successfully assessing potential impacts of a wind turbine. National, regional and local references were reviewed to create a comprehensive species listing for the Town of Millbury. Compiling GIS screening information and visual examination of aerial imagery was performed to assess habitat constraints. These data were used to determine which species could reasonably be expected in the proposed study area. In addition, the surrounding areas were considered since regional and daily migratory effects can be substantial.

Determination of likely impacted avian species was the main objective of this analysis. Species listings were evaluated from a number of sources and were assembled to account for those species utilizing the Town of Millbury area during migratory stopover. Species listings were further refined to specifically address federally and state listed wildlife with endangered/threatened status or species of special concern. In total, there are five federal and state listed species present in the area near the Town of Millbury. Table 4-2 lists wildlife that are endangered, threatened or species of special concern status within the Town of Millbury, MA, as compiled by the Massachusetts NHESP. The table includes the state listing status, taxonomic group and most recent field observation.

Table 6 - List of Endangered or Threatened Wildlife in Millbury

Taxonomic Group	Scientific Name	Common Name	MESA Status	Federal Status	Most Recent Observation
Bird	Vermivora chrysoptera	Golden-winged Warbler	E	-	1970
Reptile	Terrapene carolina	Eastern Box Turtle	SC	-	1988
Vascular Plant	Cynoglossum virginianum var. boreale	Northern Wild Comfrey	E	-	1879
Vascular Plant	Ophioglossum pusillum	Adder's-tongue Fern	T	-	1933
Vascular Plant	Platanthera flava var. herbiola	Pale Green Orchis	T	-	1880

Special Considerations

The project site is located in the path of the North East Atlantic regional flyway, which can be identified as running along the east coast of North America. In a broad sense the flyway concept can be defined as the biological systems of migration routes that directly link sites in ecosystems in different geographical settings (Boere et al., 2006). Ecosystems primarily comprised of the suitable habitats of both breeding and non-breeding areas for birds. A flyway is in fact the totality of the ecological systems that are necessary to enable migratory birds to survive and fulfill their annual life cycles. **Figure 7** in Appendix A illustrates the four generalized North American regional migration flyways, with respect to the location of the Site. Development of a single large scale wind turbine is not expected to result in unacceptable negative impacts to wildlife or substantially degrade habitat.

Wetlands
The Town of Millbury Conservation Commission is an appointed body with authority to protect and preserve natural resources within the Town. The Conservation Commission's primary role is the administration of the Massachusetts Wetlands Protection Act (M.G.L. Chapter 131, Section 40) within the Town of Millbury. The Wetland Protection Act provides for the protection of several types of Resource Areas including Bordering Vegetated Wetlands (bordering on lakes, ponds, and streams), Banks, Land Under Water, Land Subject to Flooding, and Riverfront Areas (area within 200 feet of a river or perennial stream) and coastal resource areas. The Butler Farm Site is not classified as having any type of the protected resource areas at the proposed turbine location. Review of Mass GIS Wetland data layer indicates that no portions of the Butler Farm Site are protected open space and there are no wetlands on site. The area for the proposed wind turbine is upland area and greater than 100 feet from the nearest wetland, streams, ponds or surface water body. To confirm there is no potential for destruction or impacts to wetlands, written notification should be filed with the Town's Conservation Commission for a formal determination of no impacts by the proposed addition of a wind turbine at the Site. Based on review of the wetlands protection area maps and the expected footprint of a wind turbine, wetlands are not a concern for development.

4.2 Reduction in Air Pollution

Based on information from the MassCEC website, a single 1.0-MW turbine displaces 2,000 tons of carbon dioxide each year, which is equivalent to planting a square mile of forest, based on the current average U.S. utility fuel mix. To generate the same amount of electricity as a single 1- MW turbine using the average U.S. utility fuel mix would mean emissions of 10 tons of sulfur dioxide and 6 tons of nitrogen oxide each year. To generate the same amount of electricity as a single 1-MW wind turbine for 20 years would require burning 26,000 tons of coal (a line of 10- ton trucks 10 miles long) or 87,000 barrels of oil. To generate the same amount of electricity as today's U.S. wind turbine fleet (6,374 MW) would require burning 8.6 million tons of coal (a line of 10-ton trucks 4,321 miles long) or 28 million barrels of oil each year. 100,000 MW of wind energy will reduce carbon dioxide production by nearly 200 million tons annually.

Since 1993, ISO New England Inc. (ISO-NE) has analyzed the aggregate emission of SO2, NOX, and CO2 from fossil fuel-based electrical generating facilities. The *2006 DRAFT New England Marginal Emission Rate Analysis Report,* dated 2008, provides calculated estimates of marginal SO2, NOX, and CO2 air emissions for the calendar year 2006 in pounds per megawatt hour (lbs/MWh). Emission rates were estimated using the energy weighted average emission rates of generating units that typically would increase loading during higher energy demands.

Since the wind turbine uses air to generate electrons versus the predominately fossil-fuel based generation capacity of the NEPOOL's system, each electron generated by a renewable energy system can be viewed as displacing from the grid an electron that would otherwise be created by the existing system's fossil fueled marginal power plant. A 1.8 MW wind turbine is estimated to generate an output of approximately 4,097 MWh annually, based on a 26% capacity factor. Based on these statistics, the use of a 1.8 MW wind turbine would have the follow beneficial effect on air pollution:

Table 7 - Pollution Reduction Per Year by 1.8 MW Wind Turbine			
Pollutant	**Rate (From ISO-NE)**	**Energy from Turbine**	**Pollution Displaced**
SO_2	1.51 lbs/MWh	4,097 MWh	6,187 lbs/yr
NO_X	0.52 lbs/MWh	4,097 MWh	2,130 lbs/yr
CO_2	890 lbs/MWh	4,097 MWh	3,646,330 lbs/yr

4.3 Permitting Plan

A review of permitting requirements for Local, State and Federal jurisdictions was conducted as part of the project feasibility study. Below is a summary of the agencies potentially having jurisdiction, where review and approval should be obtained:

Local Agencies

- Town of Millbury Conservation Commission
- Town of Millbury Planning and Zoning Permit
- Town of Millbury Building Permit
- Utility Interconnection – National Grid

State Agencies

- Massachusetts Environmental Policy Act (MEPA)
- Massachusetts Highway Department (MHD)
- Massachusetts Historical Commission (MHC)
- Natural Heritage and Endangered Species Program (NHESP)
- Department of Environmental Protection (DEP)

Federal Agencies

- NPDES Permit Application with Environmental Protection Agency (EPA)
- Federal Aviation Administration (FAA)
- Federal Energy Regulatory Commission (FERC)

A summary of regulatory stakeholders, applicability to the scope of the proposed project, and possible administrative review requirements is summarized in below Table 6**.**

Table 8 - Permitting Matrix

	Agency	Permit or Approval	Project Relevance	Approval Process/Timeframe	Comments
Local	Conservation Commission	Notice of Intent (NOI)	Scope of work does not involve wetland or water resources	30 – 60 days	Subject site outside the 100 foot buffer zone of any wetland/water resource.
	Town of Millbury	Planning and Zoning	Requires Special Permit	60 -90 days	No Specific Bylaw for Wind Turbines
	Town of Millbury	Building and Electric	Required for utility structure and electrical work	30 – 60 days	None
Utility	National Grid	Interconnect to existing distribution system	Must be approved and notified when performing work, and if electricity generated is tied into existing distribution system.	Project application 55 days. Interconnection System Impact Study 12-18 month	Significant volume of recent interconnect applications delaying normal review time
State	MEPA	Environmental Notification Form (ENF)	Required for construction projects disturbing greater than 2 acres.	N/A	N/A
		Environmental Impact Report (EIR)	N/A	N/A	N/A
	NHESP	ENF/MESA Checklist	Project does not take part in Estimated Habitat	30 days from point of submission for simple review	Simple review pertains to those projects that will disturb less than 5 acres of estimated habitats

	Mass Turnpike Authority	Special Hauling Permit	Transportation of Turbine parts/accessories over state Highways	24 hours notice prior to transport	Project may not subject these requirements based on loads and dimensional characteristics of material
	Mass Highway Department	Permit to Move Overweight or Oversized Load	Transportation of Turbine parts/accessories via State highways	If regulated as oversize/dimension load, then same day processing. If regulated as "super load," then application must be filed in writing and requires full structural analysis and detailed transportation routing plan.	Super load requirements: >115 x 14 x 14 (length, width, height). All units in feet. Any transport of any oversized loads greater than 13'8" in height require a routing survey.
	Mass Historical Commission	Project Notification Form	All projects that require a permit, license or funding from any state agency must file a PNF	30 Days	
Federal	EPA	NPDES/CGP/ NOI	Applies to construction sites that disturb > 1 acre	Notification only, supported with SWPP plan.	Construction General Permit is applied for by the entity that has operational control over the job site, and the ability to enforce SWPP plan.
	FAA	Aircraft warning lighting	Required for all structures greater than 200 feet	Must obtain determination of no hazard and file Form 7460-2 within 10 days of achieving construction height	Obstruction analysis suggests height of 500 feet should be permitted
	FERC	Qualifying Facility Status	Required in order to enter power purchase agreement w/ electrical utility	Must file Form No. 556 with FERC	Dependent upon size of generating facility

	FWS	Informal Consultation Notice and/or Biological Assessment	Requires applicant request a list of all threatened, endangered, candidate species and critical habitats prior to beginning construction.	Notification only	If at the completion of informal consultation, further assessment is required a formal Biological Assessment must be prepared and reviewed by FWS. May require implementation of Habitat Conservation Plan (HCP)

Town of Millbury Zoning Bylaw

The Town of Millbury does not currently have a zoning bylaw regarding standards for large-scale wind turbines. The Town does have a bylaw regarding small scale wind turbines. The bylaw states that all WECFs shall require issuance of a special permit by the Planning Board, acting as the Special Permit Granting Authority. The base of any WECF shall be set back from any property line or road layout by at least 120% of the proposed height of the tower where the tower abuts residentially zoned properties; and set back 80% of the proposed tower height where the tower abuts non-residentially zoned properties. The bylaw also states that no WECF may exceed 100 feet in height unless approved by the SPGA. Therefore, a Special Permit must be obtained in order to construct a wind turbine greater than 100 feet in height.

Federal Aviation Administration

A Notice of Proposed Construction or Alteration is required by the Federal Aviation Administration, Chapter 14 CFR, Part 77 and form 7640-1 (Notice of Proposed Construction or Alteration) for all structures over 200 feet above ground-level, or within a few miles of an airport. Any wind turbine with a tip-height over 200 feet will also likely require hazard lighting. Form 7640-1 was filed for this location with the FAA for a determination if the proposed height of 500 feet above ground level would pose a hazard to navigation. The obstruction analysis indicates that a structure up to 500 feet AGL should receive routine approval from the FAA. Copies of the filing are included in Appendix D as relevant correspondence.

5.0 WIND PLANT CONFIGURATIONS

5.1 Foundation and Turbine Support

Wind turbine foundations vary depending upon the make, model and soil conditions at each site. Typical foundations include monolithic reinforced concrete slabs, pile supported mono slabs and deep piling or caissons. The foundation design depends on the tower design, which is most often a monopole tubular steel tower. The lattice towers are not used as frequently, which also minimizes the potential for nesting birds. Monopole designs are either straight or tapered poles. Standard tapered monopoles for a 600 to 1.5 MW wind turbine generally range in height from 50 to 80 meters, would have a base diameter of 10 to 18 feet and taper to four to eight feet at the hub height.

The foundation design will also depend upon the soil type, bearing capacity and tolerances of actual turbine and tower selected. Given the general soil characteristics of the region and area, a shallow, monolithic reinforced concrete slab could be used to support a tapered monopole. Foundations for similar projects have included octagonal-shaped reinforced monolithic slabs with a length and width of 40 to 50 feet and a thickness of six to eight feet. Deep foundation designs, which provide stability from overturning through the pressure created by the weight of the soil, is also likely to be a viable alternative for the Town of Millbury. Analysis of a specific foundation design is beyond the scope of this feasibility study, but should be developed in conjunction with a geotechnical exploration conducted during the design stage of the project, based on actual equipment specifications. The scope of a geotechnical study typically includes a series of standard penetration test borings, in accordance with ASTM D-1586, to depths of 50 to 100 feet or until bedrock is encountered and confirmed by coring.

5.2 Wind Turbine Alternatives

There are a number of commercially produced wind turbines on the market today. Generally, the most popular models are horizontal axis, three bladed, upwind models which are mounted atop of monopole towers. There are a variety of generator sizes, rotor blade lengths and tower heights which are commonly used, that affect the overall structure height. Table 5-1 provides a sample of the various manufacturers standard size wind turbine generators, rotor diameters, tower heights and overall height as measured from the tallest point of the blade in the 12 o'clock position.

Table 9 - Typical Wind Turbine Dimensions

Make/Model	Generator Size (kW)	Tower Height (meters)	Rotor Diameter (meters)	Overall Height (meters)	Overall Height (feet)
Vestas V-90	1,800	80	90	125	410
GE 1.5 XLE	1,500	80	82	121	396
GE 1.5 SLE	1,500	80	77	119	390
Elecon T600	600	50	48	74	243
Northern Power	100	40	29	55	180

Turbine Availability

The percent of time that a wind turbine is capable of producing power is known as the total availability. The factors and values used to compute turbine availability at the Site are tabulated in Table 5-2. The total annual availability of a turbine was computed from the product of the factors and equals approximately 93% of the year.

Table 10 - Factors Affecting the Availability of Turbines

Factor	Percent/yr
Grid connection efficiency	97%
Turbine availability	97%
Turbine icing and blade fouling	99%
Substation maintenance	99%
Utility downtime	99%
High wind speed hysteresis	100%
Total Availability	**93%**

The following assumptions were made for the factors affecting availability:

- **Grid connection efficiency**. The efficiency of the grid connection is estimated to be 97%. This includes the losses in the transformer and the transmission line. This should be confirmed by an electric loss calculation once the grid connection has been defined.

- **Turbine availability**. The technical availability of the turbine is assumed to be 97%. This figure is based on data from modern operational wind farms. Technical availability may be a part of the contract terms between the project owner and the wind turbine supplier. It is worth noting that manufacturers may not guarantee technical availability at the 97% level for small, one or two turbine projects. It is advisable to review this figure when the terms of the warranty are established.

- **Turbine icing and blade fouling**. Serious icing conditions can prevent a wind turbine from operating, as the turbine shuts down if there is imbalance of the blades. Undoubtedly there is the prospect for ice to collect on turbine blades located at the Butler Farm Site. Three days has been given as the likely total occurrence per year of icing events, which equates to an availability of 99.2%. Blade fouling is not expected to **occur, as this is primarily a problem** in very hot climates where severe insect fouling can affect the aerodynamics of the turbine blades.

- **Substation maintenance**. The connection to the grid may have to be temporarily shut down for maintenance. We have assumed that this might occur for a total of 16 hours per year.

- **Utility downtime**. Most wind turbines will fail to efficiently produce energy during lower wind conditions when the grid does not actively supply electricity for the machine's control systems due to a grid power outage. The will occur, on average, approximately 8 hours per year.

- **High wind speed hysteresis**. During very high wind conditions, a wind turbine will shut down to protect its electrical and mechanical components. The machine will only restart when wind conditions fall significantly below the cut-off wind speed. This factor is used to compensate for power loss during this restarting delay. Because Millbury rarely experiences winds above the typical wind turbine cut-out speeds (~25 m/s), high wind speed hysteresis is not expected to have any significant effect on power output.

5.3 Noise Assessment

Sound evaluations can become quite complicated due to the numerous factors affecting sound propagation, attenuation and absorption of sound, variable ambient conditions, and the characteristics of sound waves at different frequencies. The purpose of this sound evaluation is to qualitatively assess the likelihood of noise impacts from the proposed turbine.

Sound Basics

Sound is produced by pressure waves of a specific frequency or range of frequencies. The human ear registers sound by detecting very minute variations in sound pressure. The loudness of a sound as perceived by an individual can be quite subjective, but loudness is generally dependent on the sound pressure level. The sound pressure level is traditionally defined as a ratio of the sound pressure from a given source to a reference pressure. Loudness is represented by the unit decibel (dB) on a logarithmic scale, where 0 dB is undetectable to the human ear.

For reference, normal conversation is typically around 65 dB, a quiet evening in a rural setting is typically around 30 dB, and a lawn mower is typically around 95 dB from the perspective of the operator. To facilitate noise evaluations with respect to human receptors, the A-weighted sound level (dBA) is used. This convention accentuates or "weights" the sound pressure level within the frequency response of the human ear to better characterize the sound pressure level for a human receptor.

Aerodynamic sound generation is very sensitive to speed at the very tip of the blade. To limit the generation of aerodynamic sounds, large modern wind turbines may limit the rotor rotation speeds to reduce the tip speeds. Large variable speed wind turbines often rotate at slower speeds in low winds, increasing in higher winds until the limiting rotor speed is reached. This results in much quieter operation in low winds than a comparable constant speed wind turbine.

Sound Propagation

In order to predict the sound pressure level at a distance from source with a known power level, one must determine how the sound waves propagate. In general, as sound propagates without obstruction from a point source, the sound pressure level decreases. The initial energy in the sound is distributed over a larger and larger area as the distance from the source increases. Thus, assuming spherical propagation, the same energy that is distributed over a square meter at a distance of one meter from a source is distributed over 10,000 m^2 at a distance of 100 meters away from the source. With spherical propagation, the sound pressure level is reduced by 6 dB per doubling of distance. This simple model of spherical propagation must be modified in the presence of reflective surfaces and other disruptive effects. The development of an accurate sound propagation model generally must include the following factors:

- Source characteristics (e.g., directivity, height, etc.)
- Distance of the source from the observer
- Air absorption, which depends on frequency
- Ground effects (i.e., reflection and absorption of sound on the ground, dependent on source height, terrain cover, ground properties, frequency, etc.)
- Blocking of sound by obstructions and uneven terrain

- Weather effects (i.e., wind speed, change of wind speed or temperature with height). The prevailing wind direction can cause differences in sound pressure levels between upwind and downwind positions.
- Shape of the land; certain land forms can focus sound

Noise Evaluation Criteria

The proposed wind turbine project would be subject to Massachusetts's noise regulation (310 CMR 7.10). Massachusetts DEP Noise Guideline Document, dated March 2006, stipulates no increase of ambient sound levels at the property line, and at the nearest inhabited building, by more than 10 dB(A) above ambient conditions with no pure tone conditions.

Wind Turbine Sound Production

Wind turbines in operation produce sound. The sound is produced by the rotating blades passing through the air, and by the mechanical noise associated with the components in the turbine hub. Review of manufacture specifications for a Vestas V90 indicates the maximum noise level produced at the hub is approximately 103.5 dB(A) at wind speed of 7.0 meters per second and above.

Predicted Noise Levels

Accurately predicting noise levels from a given source at different locations is a complex task, and involves the identification and quantification of a number of factors including the relative reflectivity of surrounding surfaces, atmospheric conditions, ambient sound conditions, wind speed and direction, obstacles, the frequency distribution and intensity of the source, and a number of other factors. A noise study was completed for the Butler Farm Site in November 2010 by Harris Miller Miller & Hanson Inc. (HMMH). As part of the study, HMMH reviewed applicable noise standards and criteria, presented the data collection program associated with the ambient noise environment, described the modeling used to project noise emissions from the selected wind turbine, and analyzed all of this information to assess potential noise impacts from the project.

In order to estimate the increase in ambient noise conditions caused by the turbine, the ambient conditions must be known. Noise measurements were performed at a total of six measurement locations in the project study area. Long-term monitoring was conducted at one location continuously from November 18 through November 22, 2010. Short-term monitoring was performed at five measurement sites on November 18 and November 21, 2010, for durations of 20 to 30 minutes at each site .During the short-term measurements, the average (Leq) daytime noise levels ranged from approximately 45 to 60 dBA in the study area and from 37 to 53 dBA in late night hours. Background L90 noise levels ranged from 36 to 40 dBA during the day and from 29 to 33 dBA at night. The primary contributions to the ambient noise level in the project area observed during the attended short-term measurement periods were from local traffic, aircraft flyovers, and wind in foliage. Nighttime measurements were conducted between 11:30 p.m. and 3 a.m. because the data from the long-term site showed those time periods to be the quietest times of the night.

Computer software was also to predict sound impacts. WindPRO™ DECIBEL module was also utilized for this assessment. The WindPRO module DECIBEL for Noise Impact Calculation makes noise calculations a relatively simple task. The software uses a database of sound measurements from various manufactures of wind turbines. It is possible to define Noise Sensitive Positions (spots) as well as areas described by polygons. These polygons can be drawn directly on the background maps of the Site. The program calculates based on the noise emission data (Lwa or octave data) the point on the polygon line with the highest noise impact and prints the coordinates and noise level for the point in an output report. Differences in elevations between wind turbines and neighbors are included in the calculations since the coordinates for the wind turbines and the noise sensitive areas/positions all are given in 3D.

The program automatically calculates these elevations where digital maps are used. For each polygon/position, the maximum allowable noise level can be entered. In this way, it is possible to simultaneously carry out, for example, calculations relative to the nearest neighbor based on a 45 dB level and a nearby urban area at another distance based on a 40 dB level. Also it is possible to enter the initial background noise level without turbines if this is known and then calculate the additional noise produced by the proposed wind turbine. It is also possible to link a DECIBEL calculation to a project layout so a noise isoline map is automatically updated in the project window when changes are made. This makes it easier to find the optimal layout with regards to noise impact.

Predicted Compliance with Criteria

HMMH conducted a background noise study and modeling for a conceptual wind turbine project. The study reviewed applicable noise standards in effect at the time of the assessment and criteria, presented the data collection program associated with the ambient noise environment, described the modeling used to project noise emissions from the selected wind turbine, and analyzed all of this information to assess potential noise impacts from the project. Based on this study, we conclude the following:

- Under most turbine operating conditions, increases in existing ambient noise caused by the turbine will be well below the Massachusetts Department of Environmental Protection (DEP) noise guideline of 10 dBA increases in broadband noise levels.
- During the quietest nighttime hours with hub-height wind speeds of approximately 7 m/s, the proposed Millbury Wind project is predicted to exceed the 10 dBA MassDEP guideline at the nearby occupied structure on the Butler Farm property east of the proposed turbine site.
- No residential properties will be exposed to increases in existing noise levels greater than 10 dBA, but projected worst-case increases equal 10 dBA at the nearest homes during the quietest nighttime hours when hub wind speeds are approximately 7 m/s. However, at hub wind speeds less or greater than 7 m/s, the sound-level increases will be less, because of decreasing turbine noise emissions at lower speeds and increasing background noise at higher speeds.
- The Project is in compliance with the MassDEP noise guideline for a pure tone condition.
- The Town of Millbury noise limits will not be exceeded in any of the nearby noise-sensitive areas.

During quiet nighttime periods when winds are low near the ground but sufficient for the turbine to operate, sound from the turbine will be audible and noticeable to some in the nearest surrounding residential areas. The increase in background sound levels at the nearest adjacent residential structures is expected to be 10 dBA. The maximum increase in sound levels at the Farm House building on the Butler Farm property is expected to be 12 dBA, and the increase in sound levels at the property boundaries is expected to be a maximum increase of 13 dBA. The predicted sound levels could be problematic and further study would be needed if an alternate turbine, hub height or location is selected. A copy of the HMMH sound study report is included in Appendix K. It should be noted that the guidelines for background sound studies have been modified since the HMMH sound measurement program was implemented in 2010, where primarily the duration of studies today are being conducted for 14 days instead of seven.

5.4 Visibility Assessment

WindPRO visual was used to produce photo simulations to represent the visual impact of a conceptual wind turbine project at the Butler Farm site. The visibility study was conducted to assess how the proposed wind turbine would impact the look of the site and from representative areas beyond the site. The wind turbine used in the simulations was a 1.8 MW Vestas V90. This wind turbine is representative of the largest turbine currently considered for the Butler Farm Site. This size configuration, modeled in the visual simulations included in Appendix G, has a hub height of 80 meters (262.4 feet) above ground level (AGL) and a rotor diameter of 90 meters (295.2 ft.). The structure would have an overall height of approximately 125 meters (410 feet). The tower was assumed to be a tubular steel monopole with a three rotor blades.

Viewpoint Locations

As one moves away from the proposed turbine location, intervening structures, topography, trees and vegetation quickly block and obscure views of the turbine. Some of the views of the wind turbine will, therefore, always be partially or completely blocked. Open views of a proposed turbine at the Butler Farm Site are represented from the several different locations. Visually sensitive areas in the vicinity of the proposed project were identified based upon a review of maps of the area and field reconnaissance. Locations were selected to provide representative vantage points where the turbine may be visible to simulate the view shed if a wind turbine was erected as proposed. These include locations that may experience visibility of the proposed turbine.

The locations, which were visited during the area reconnaissance to assess potential visibility, included the surrounding residential areas and nearby roadways. Multiple locations, termed viewpoints, were used to simulate the visibility of the proposed turbine. The viewpoints were selected for simulation purposes to provide a range of distances and directions from the site where the turbine may be visible. The images were produced using images of a 1.8 MW Vestas V90 wind turbine on an 80 meter tall tower. Refer to Appendix G for a series of photographic simulations, including a key map depicting the vantage point for each of the simulations. Manufacture details which describe representative wind turbines in this size range are also provided in Appendix H for reference.

5.5 Shadow Flicker

Shadow flicker is a phenomenon caused by periodic obstruction of light caused by the rotating blades of the turbine. Modern commercial-scale turbines are typically three-bladed and rotate at approximately 20 rpm, which means that shadow flicker, when present, would occur at a frequency of 60 shadows per minute, or 1.0 Hz. Shadow flicker at this frequency is normally considered a nuisance issue, but there are no established health and safety regulations or exposure standards to date in the United States. Shadow flicker is an intermittent nuisance and is generally a concern only under the following conditions:

- The sun is shining and has a clear unobstructed path to the turbine;
- The turbine is between the viewer(s) and the sun, and within approximately ½ mile of the viewer(s);
- The turbine is in operation; and
- There are no obstacles between the turbine and the viewer(s).

As is evident from the list of conditions above, an evaluation of the significance of shadow flicker for a particular site is dependent on a number of factors, including site geometry, the locations of potential viewers, blade finish on the turbine's rotors, the relative "sunniness" of the location and the operational status of the turbine at a given time on a daily basis.

As part of this feasibility study, we have attempted to describe the likely extent of shadow flicker in reference to the proposed turbine location and known receptors, and to qualitatively evaluate the impacts associated with shadow flicker in the areas of concern. Shadow flicker was modeled using WindPRO SHADOW module software, and used to produce a map of the area that would be subjected to shadow flicker. The model computes flicker density contours representing the range of potential show-flicker hours for the areas near the wind turbine. This distribution was based on a single Vestas V90 wind turbine on an 80-meter tall tower. Development of a single Vestas V90 wind turbine on an 80-meter tall tower is expected to result in a low to medium number of shadow flicker hours for the surrounding residential areas. In general, locations greater than 1,000 ft. from the proposed turbine location will fall into the low range. Refer to **Figure 9**, included in Appendix A, for a Shadow Flicker Map representing the distribution of shadow flicker produced from a turbine at the proposed location. Under a worst-case scenario, the nearest residences located along W. Sutton Road and Crest View Lane would experience shadow flicker effects for a total of approximately 30 to 40 hours per year or 4.9 to 6.6 minutes per day. However, much of the area surrounding the site is wooded, and therefore there will be existing visual barriers to shadow flicker. Model input and output data are also included in **Appendix I**.

6.0 ENERGY PRODUCTION AND FINANCIAL ANALYSIS

6.1 Project Economics

This section provides an analysis of the various direct costs and revenue factors associated with the typical behind the meter large scale wind turbine project, as well as estimates of indirect costs and benefits. Several financial scenarios are evaluated based upon different turbines, funding sources, etc. The merits of a net metered wind turbine project are often evaluated on a pre-tax, equity financed scenario, where simple payback and internal rate of return are easily calculated. A number of economic risk factors are also identified and discussed in this section.

For a given project, a general rule is the larger the turbine, the higher the output and the lower the cost per unit of energy produced. The project is also depended upon three significant factors: wind resource, the value of the energy created and the cost to develop the project. It should be noted, that market demand for wind turbines over the last several years has increased and fluctuated dramatically, resulting in increased pricing and decreased availability of equipment, and longer lead time for delivery of turbines and related equipment. In today's rapidly evolving wind turbine market, many utility scale turbine manufactures are not willing to support a single turbine project and require minimum orders ranging from 20 to 50 megawatts.

6.2 Estimated Energy Production

Based on the predicted wind speed and the wind resource modeling, the wind speed and direction distribution were derived at the selected wind turbine height. The wind speed distribution gives the number of hours that a particular wind speed blows per year. Using Windographer software, this wind speed distribution was then combined with the power curve of five different wind turbines to obtain an estimate of the annual wind energy production. The output is corrected for estimated availability and electrical grid efficiency to obtain an estimate for the net annual wind energy production.

Based on the wind resource at the Butler Farm Site, four different sized wind turbines were considered for this assessment. The turbines considered are all within the recommended size class that would meet the estimated FAA height limit of 500 feet. The FAA structure height restrictions could limit some turbines from further consideration and should be confirmed prior to development. The power curve for the various wind turbine generators was obtained from the modeling software data sources or input from manufactures specifications for modeling purposes. Copies of specification from the various wind turbines selected are included within **Appendix H**.

<u>Calculation of Net Energy Production</u>
The energy production calculations and capacity factors for the selected turbines are summarized in Table 9. In this analysis we used a wind resource probability of 90% (P90). The long term average wind speeds are estimated to be 5.2 m/s at a height of 80 meters at least 90% of the time. It should be noted that a lower probability, P50 for example, would result in a higher expected wind speed average, and thus higher expected turbine output. Net output of the turbines has taken into account a 90% availability factor for the typical losses discussed above. The P90 value has been evaluated for all four turbines. Modeling output report is included in **Appendix I.**

Table 11 –Energy Production Estimates					
Characteristic	Northern Power	RRB-PS600	GE 1.5 SLE*	GE 1.5 XLE	Vestas V-90
Nameplate Rating (kW)	100	600	1,500	1,500	1,800
Hub Height (meters)	37	63	80	80	80
Rotor Diameter (meters)	21	47	77	82.5	90
Structure Height (meters)	125	121	119	74	55
Average Wind Speed at Hub Height (m/s)	4.4	4.9	5.2	5.2	5.2
Turbulence Intensity	0.24	0.21	0.20	0.20	0.20
Capacity Factor %					
Annual Energy (MWh)					

6.3 Project Costs

The project costs evaluated included estimated soft costs for the required studies, permitting, design and other related efforts (legal and public relations excluded); capital costs for the procurement and installation of the turbine; construction of foundation, electrical interconnection, and erection of the turbine, commissioning, startup costs. Other long term project cost include the principal and interest payments for financing of the project, as well as ongoing annual operation, maintenance and insurance costs. Only equity financed scenarios were evaluated.

6.4 Electrical Interconnection Cost Estimate

A planning level cost estimate has been developed based on the conceptual design concept prior to completion of formal interconnection of a nominal 100 kW, 600 kW, 1.5 MW, and 1.8 MW wind turbine application with National Grid. The planning accuracy cost estimate is generally expected to be within an accuracy of +/-25%. The cost estimate is based on recent project experience and vendor quotes and could change based on the final design and construction conditions. Table 6-2 through 6-5 details the major cost items for the proposed interconnection:

Table 12 – Electrical Interconnection Cost Estimate – 100 kW Wind Turbine				
Item Description	**Quantity**	**Units**	**Unit Cost**	**Item Total**
GOAB Disconnect Switch	1	Each	$4,500	$4,500
Utility Poles w/ #1 AWG Al Cond. 3 Phase 4 Wire 13.8 kV	700	Feet	$51	$35,700
Communication Cables (Verizon) including High Speed Transfer Trip	800	Feet	$12	$9,600
Excavation, Backfill & Compaction Trench 4' x 6' deep x 100' from Turbine Pad, Transformer Pad, and Disconnect Switch	33	Cubic Yard	$37	$1,221
Concrete w/ Rebar for Transformer Pad, Disc. Switch Pad (cast in place)	2	Each	$1,650	$3,300
Primary Underground Conduits from Riser Pole to Disc. Switch and Transformer. (2' x 5" Power Conduits and 4 x 2" for Communication Conduits)	50	Feet	$32	$1,600
Grounding System for Transformer and Disc. Switch Pad	1	Each	$2,500	$2,500
Fused Disconnect Switch 15 kV	1	Each	$15,000	$15,000
Transformer Seed Oil Filled 150kVA 480v/13.8kV Delta-Wye Windings.	1	Each	$15,000	$15,000
Primary Cable 4 wire #1 AWG Copper from Riser Pole to Disc. Switch and to Transformer Primary	1	Each	$2,500	$2,500
Secondary Underground Conduits from Transformer to the Turbine. (2 x 5" Power Conduits and 4 x 2" Communication Conduits)	50	Feet	$50	$2,500
Secondary Cable from Transformer to Turbine (1 set of 4 wire #1 AWG Copper Cables)	70	Feet	$13	$938
Concrete for Underground Duct Bank from Riser Pole to Turbine (100 ft.)	11	Cubic Yard	$350	$3,850
Redundant Electrical Power System Protective Relaying	1	Each	$25,000	$25,000
All Items Above Indicate Installed Costs				
Subtotal – Construction				$123,209
Contractor Markup including Insurance and Permitting		20% of Subtotal		$24,642
Electrical Testing Startup and Commissioning		20% of Subtotal		$24,642
Contingency		10% of Subtotal		$12,321
Total Electrical Cost Estimate				**$184,814**

NOTES:

1. Cost estimate is for planning purposes only and only includes the items listed above
2. Cost estimate does not include the wind turbine
3. Cost estimate does not include utility related upgrade fees

Table 13 – Electrical Interconnection Cost Estimate – 600 kW Wind Turbine				
Item Description	**Quantity**	**Units**	**Unit Cost**	**Item Total**
GOAB Disconnect Switch	1	Each	$4,500	$4,500
Utility Poles w/ #1 AWG Al Cond. 3 Phase 4 Wire 13.8 kV	700	Feet	$51	$35,700
Communication Cables (Verizon) including High Speed Transfer Trip	800	Feet	$12	$9,600
Excavation, Backfill & Compaction Trench 4' x 6' deep x 100' from Turbine Pad, Transformer Pad, and Disconnect Switch	33	Cubic Yard	$37	$1,221
Concrete w/ Rebar for Transformer Pad, Disc. Switch Pad (cast in place)	2	Each	$1,650	$3,300
Primary Underground Conduits from Riser Pole to Disc. Switch and Transformer. (2' x 5" Power Conduits and 4 x 2" for Communication Conduits)	50	Feet	$32	$1,600
Grounding System for Transformer and Disc. Switch Pad	1	Each	$2,500	$2,500
Fused Disconnect Switch 15 kV	1	Each	$15,000	$15,000
Transformer Seed Oil Filled 750kVA 600v/13.8kV Wye-Wye Windings.	1	Each	$35,000	$35,000
Primary Cable 4 wire #1 AWG Copper from Riser Pole to Disc. Switch and to Transformer Primary	1	Each	$2,500	$2,500
Secondary Underground Conduits from Transformer to the Turbine. (3 x 5" Power Conduits and 4 x 2" Communication Conduits)	50	Feet	$60	$3,000
Secondary Cable from Transformer to Turbine (2 sets of 4 wire 500kcmil Copper Cables)	70	Feet	$72	$5,040
Concrete for Underground Duct Bank from Riser Pole to Turbine	11	Cubic Yard	$350	$3,850
Redundant Electrical Power System Protective Relaying	1	Each	$25,000	$25,000
All Items Above Indicate Installed Costs				
Subtotal – Construction				$147,811
Contractor Markup including Insurance and Permitting		20% of Subtotal		$29,562
Electrical Testing Startup and Commissioning		20% of Subtotal		$29,562
Contingency		10% of Subtotal		$14,781
Total Electrical Cost Estimate				**$221,717**

NOTES:
1. Cost estimate is for planning purposes only and only includes the items listed above
2. Cost estimate does not include the wind turbine
3. Cost estimate does not include utility related upgrade fees

Table 14 Electrical Interconnection Cost Estimate – 1,500 kW Wind Turbine				
Item Description	**Quantity**	**Units**	**Unit Cost**	**Item Total**
GOAB Disconnect Switch	1	Each	$4,500	$4,500
Utility Poles w/ #1 AWG Al Cond. 3 Phase 4 Wire 13.8 kV	700	Feet	$51	$35,700
Communication Cables (Verizon) including High Speed Transfer Trip	800	Feet	$12	$9,600
Excavation, Backfill & Compaction Trench 4' x 6' deep x 100' from Turbine Pad, Transformer Pad, Disconnect Switch and Riser Pole	33	Cubic Yard	$37	$1,221
Concrete w/ Rebar for Transformer Pad, Disc. Switch Pad (cast in place)	2	Each	$1,650	$3,300
Primary Underground Conduits from Riser Pole to Disc. Switch and Transformer. (2' x 5" Power Conduits and 4 x 2" for Communication Conduits)	50	Feet	$32	$1,600
Grounding System for Transformer and Disc. Switch Pad	1	Each	$2,500	$2,500
Fused Disconnect Switch 15 kV	1	Each	$15,000	$15,000
Transformer Seed Oil Filled 1,500kVA 690v/13.8kV Wye-Wye Windings.	1	Each	$50,000	$50,000
Primary Cable 4 wire #1 AWG Copper from Riser Pole to Disc. Switch and to Transformer Primary	1	Each	$2,500	$2,500
Secondary Underground Conduits from Transformer to the Turbine. (5 x 5" Power Conduits and 4 x 2" Communication Conduits)	50	Feet	$65	$3,250
Secondary Cable from Transformer to Turbine (4 sets of 4 wire 500kcmil Copper Cables)	70	Feet	$176	$12,320
Concrete for Underground Duct Bank from Riser Pole to Turbine	11	Cubic Yard	$350	$3,850
Redundant Electrical Power System Protective Relaying	1	Each	$25,000	$25,000
All Items Above Indicate Installed Costs				
Subtotal – Construction				$170,341
Contractor Markup including Insurance and Permitting		20% of Subtotal		$34,068
Electrical Testing Startup and Commissioning		20% of Subtotal		$34,068
Contingency		10% of Subtotal		$17,034
Total Electrical Cost Estimate				**$255,511**

NOTES:

1. Cost estimate is for planning purposes only and only includes the items listed above
2. Cost estimate does not include the wind turbine
3. Cost estimate does not include utility related upgrade fees

Table 15 Electrical Interconnection Cost Estimate – 1,800 kW Wind Turbine				
Item Description	**Quantity**	**Units**	**Unit Cost**	**Item Total**
GOAB Disconnect Switch	1	Each	$4,500	$4,500
Utility Poles w/ #1 AWG Al Cond. 3 Phase 4 Wire 13.8 kV	700	Feet	$51	$35,700
Communication Cables (Verizon) including High Speed Transfer Trip	800	Feet	$12	$9,600
Excavation, Backfill & Compaction Trench 4' x 6' deep x 100' from Turbine Pad, Transformer Pad, Disconnect Switch and Riser Pole	33	Cubic Yard	$37	$1,221
Concrete w/ Rebar for Transformer Pad, Disc. Switch Pad (cast in place)	2	Each	$1,650	$3,300
Primary Underground Conduits from Riser Pole to Disc. Switch and Transformer. (2' x 5" Power Conduits and 4 x 2" for Communication Conduits)	50	Feet	$32	$1,600
Grounding System for Transformer and Disc. Switch Pad	1	Each	$2,500	$2,500
Fused Disconnect Switch 15 kV	1	Each	$15,000	$15,000
Transformer Seed Oil Filled 2,000kVA 690v/13.8kV Wye-Wye Windings.	1	Each	$65,000	$65,000
Primary Cable 4 wire #1 AWG Copper from Riser Pole to Disc. Switch and to Transformer Primary	1	Each	$2,500	$2,500
Secondary Underground Conduits from Transformer to the Turbine. (6 x 5" Power Conduits and 4 x 2" Communication Conduits)	50	Feet	$70	$3,500
Secondary Cable from Transformer to Turbine (5 sets of 4 wire 500kcmil Copper Cables)	70	Feet	$220	$15,400
Concrete for Underground Duct Bank from Riser Pole to Turbine	11	Cubic Yard	$350	$3,850
Redundant Electrical Power System Protective Relaying	1	Each	$25,000	$25,000
All Items Above Indicate Installed Costs				
Subtotal – Construction				$188,671
Contractor Markup including Insurance and Permitting		20% of Subtotal		$37,734
Electrical Testing Startup and Commissioning		20% of Subtotal		$37,734
Contingency		10% of Subtotal		$18,867
Total Electrical Cost Estimate				**$283,006**

NOTES:

1. Cost estimate is for planning purposes only and only includes the items listed above
2. Cost estimate does not include the wind turbine
3. Cost estimate does not include utility related upgrade fees

For most single turbine behind the meter applications, the capital cost of the wind turbine is the single largest expense of the project. For this project, we evaluated four different wind turbines sizes in the 100 to 1,800 kW range. The capital expense of a wind turbine in the 100 to 1,800 kW size class is $2,700 to $4,500 per kW. Another of the larger cost items is the foundation system, which can vary, depending upon final design, soil conditions, and other factors.

The total estimated cost of developing a project of this size ranged is $1.0M to $4.5M. The maximum possible MassCEC grant funding, based on the most recent program criteria, is $400,000. The unit cost ranged from $2,700 to $4,500 per installed kW, without grant incentives and from $2,500 to $3,800 per kW with maximum grant incentives. A summary of the project costs are presented in Table 6 below:

Table 16 - Project Cost Estimate Summary

Turbine Size	100 kW	600 kW	1,500 kW	1,800 kW
Design and Permitting	$75,000	$100,000	$200,000	$250,000
Capital Equipment	$557,500	$1,100,000	$3,000,000	$3,150,000
General Construction	$50,000	$50,000	$100,000	$150,000
Foundation installation	$100,000	$300,000	$500,000	$525,000
Electrical interconnection	$184,814	$221,717	$255,511	$283,006
Installation (crane)	$40,000	$50,000	$100,000	$100,000
Commissioning/Startup	$25,000	$50,000	$100,000	$100,000
Sub Total	$1,032,300	$1,871,717	$4,255,511	$4,558,006
Possible CEC Grant	$165,000	$320,500	$400,000	$400,000
Net Project Cost	$867,314	$1,511,217	$3,855,511	$4,158,006

6.5 Economic Analysis

For a wind energy project of this nature, the viability is generally based on the wind resource, the value of the energy created (or displaced) and the capital cost of the project. In this analysis we used a wind resource probability of 90% (P_{90}). That is, the average wind speed will be 6.4 m/s at an 80 meter hub height at least 90% of the time. It should be noted that a lower probability, P_{50} for example, would result in a higher expected wind speed average, and thus higher expected turbine output, and higher rate of return on the investment. Specific risk tolerances should be considered as part of the next steps in the development of the project.

In order to perform an economic analysis for the alternatives presented, the benefits and costs of the project were evaluated. The project costs include costs for design and permitting, installation and interconnection, operation and maintenance, and insurance. The benefits of the project include the value of offset retail energy purchases. The value of the avoided cost was calculated based on the sum of the estimated value of default service, distribution, transmission and transition kilowatt-hour charges. The value of the sale of Renewable Energy Certificates (REC) was estimated in the short term at $25 per MWh. The cost and benefits are estimated over the useful life of the project and are then factored into a simple economic model (discounted cash flows) which estimates the Net Present Value and other financial metrics of each alternative. For this study, we have modeled the cost and benefits of four single wind turbine sizes, assuming a project paid with cash with and without the maximum available grant incentives, a loan term of 20 years at 4%, also both with and without a grant. The table below provides a summary of the economic model assumptions:

Table 17 - Economic Model Variable Input	
Project Term	20 years
Value of Net Metering Credit	$128 MWh
Value of Renewable Energy Certificates	$15-25 MWh
Discount/Loan Rate	4.0%
Interest Rate on Principal Debt, if applicable	4.0%
Term of Debt	20 years
Operation and Maintenance	$40 kW
Energy Escalation Rate	2.0%
Inflation Escalation Rate	2.0%

An industry-standard economic metric for a wind turbine project is the net present value (NPV). The NPV can be defined as the present value of the initial investment, plus all future cash flows. For a wind turbine, cash flows are evaluated over the useful life of the equipment, usually 20 years, but sometimes 25 to 30 years, depending upon the manufacturer and care taken during the maintenance of the equipment.

Another useful measure is a time-adjusted benefit-cost ratio (BCR). The BCR is the present value of cash inflows divided by the present value of cash outflow. An investment which has BCR which is greater than 1.00 predicates a positive return on the investment and anything less than 1.00 costs more than the benefit of the investment. A project with a BCR of 1.00 is considered breakeven.

The Internal Rate of Return (IRR) is also used to judge the economic merits of an investment. If the IRR exceeds the opportunity cost of capital, the investment is attractive. If the IRR equals the cost of capital, the investment is marginal. The IRR is a capital budgeting metric typically used by private firms to decide whether they should make investments. It is an indicator of the efficiency or quality of an investment, as opposed to net present value (NPV), which indicates value or magnitude. The IRR is the annualized effective compounded return rate which can be earned on the invested capital, i.e., the yield on the investment. A project is a good investment proposition if its IRR is greater than the rate of return that could be earned by alternate investments of equal risk (investing in other projects, buying bonds, even putting the money in a bank account). In general, if the IRR is greater than the project's cost of capital, or hurdle rate, the project would add value for the Town. Formally, the IRR of an investment is equal the discount rate at which the investment's NPV equals zero (Higgins, 1998).

Project cash flow is based upon the amount of retail power which can be off-set by the turbine, sale of any excess energy which may be produced and the sale of renewable energy certificates (REC) which have a marketable value. The amount of retail power which can be off-set is also a function of coincidence factor. The coincidence factor, a measure of the percentage of time power is being created and used on the site at the same time, in that the value of electricity is instantaneous. If energy is not being used when it is produced, it is typically sold back to the grid. Since the changes in net metering allow all of the energy produced from a renewable source with a nameplate rating of up to 2.0 MW, a 100% coincidence factor is used in this analysis.

The economic performance of each scenario improves when factoring in grant funding from CEC under the Commonwealth Wind program, which can provide, if eligible, up to $400,000 per project for a public entity for design and construction for 1,500kW and larger turbines. Grant funding is a significant factor on the NPV, BCR and IRR, particularly for smaller capital projects. Other economic factors which impact the project economics are the discount rate (cost of capital) and inflation factors (both general and fuel-related energy costs). The economic performance erodes as the discount rate and general inflation rise. The economic modeling herein assumes that the project will be paid for with equity (cash) or debt (loan). Simple payback estimates, as the name implies, does not consider inflation and is based on the first full year of net revenue divided by the project cost. The cost estimates do not include the cost of decommissioning, nor do they include the residual value of the installation. In this case, these figures are assumed to be of equal value and therefore would have a net zero impact on the analysis.

We also included the cost of a 1.5 MW GE turbine for which we obtained a price quote, where the equipment is unused, but being sold by a third party and no manufacture warranty is available. After market turbines from other developers are often available where purchased, but not used on other project for one reason or another. Where there is obvious upside to a project with discounted equipment costs, the price certainty and availability of an aftermarket turbine can be unpredictable and project proponents must be willing and able to act quickly without OEM warranties. Below is a summary of the economic analyses for each scenario, both with and without MassCEC grant funding:

Table18 – Economic Summary (Equity Financed, No Grant)

Turbine Make, Model	Northern Power	RRB-PS600	GE 1.5 SLE*	GE 1.5 XLE	Vestas V-90
Nameplate Rating (kW)	100	600	1500	1500	1800
Hub Height (meters)	37	63	80	80	80
Installed Cost	$1,032,314	$1,871,717	$2,605,511	$4,255,511	$4,558,006
Installed cost per kW	$10,323	$3,120	$1,737	$2,837	$2,532
Capacity Factor, %	4.7%	7.6%	8.6%	6.8%	10.8%
Annual Energy (kWh)	37,055	359,510	804,168	1,017,036	1,532,650
NPV (4% Discount Rate)	($880,700)	($1,371,375)	($1,843,471)	($3,042,014)	($2,613,307)
Cash Flow, 20 Years	($784,183)	($1,083,352)	($1,415,194)	($2,475,357)	($1,687,001)
Benefit to Cost Ratio	0.17	0.39	0.49	0.41	0.54
Internal Rate of Return	-7.2%	-5.3%	-4.9%	-5.9%	-3.6%
Simple Payback, years	22726.9	100.9	77.1	68.48	39.2
Cost/kWh, 20 Years	$1.54	$0.35	$0.27	$0.29	$0.21

Net Cash Flow is over 20 year term
IRR and Payback are Not Applicable to a Debt Financed Project.
* Price for GE 1.5 SLE excluding OEM warranty (new, after market turbine)

Based on the above, development of a large-scale wind turbine does not appear economically viable. The alternatives become better economically with increased turbine size, as one would expect; however, none of the turbines modeled have a positive Net Present Value or Benefit to Cost Ration greater than 1.0. The smaller (100 kW and 600 kW) wind turbines have predicted capacity factors in the single digits, and the longest payback periods. The greater negative values over the 20 year project term, suggesting all of the scenarios modeled would cost more money to operate than the monetary benefits they would return. While all of the financial figures of merit improve where grant funding is added, none of them are economically attractive. The economic summary if grant funding is available is provided in Table 19 below.

Table 19 – Economic Summary (Equity Financed, With Grant Funding)					
Turbine Make, Model	Northern Power	RRB-PS600	GE 1.5 SLE*	GE 1.5 XLE	Vestas V-90
Nameplate Rating (kW)	100	600	1500	1500	1800
Hub Height (meters)	37	63	80	80	80
Installed Cost	$867,314	$1,551,217	$2,205,511	$3,855,511	$4,158,006
Installed cost per kW	$8,673	$2,585	$1,470	$2,570	$2,310
Capacity Factor, %	4.7%	7.6%	8.6%	6.8%	10.8%
Annual Energy (kWh)	37,055	359,510	804,168	1,017,036	1,532,650
NPV (4% Discount Rate)	($722,046)	($1,063,202)	($1,458,855)	($2,657,399)	($2,228,692)
Cash Flow, 20 Years	($619,183)	($762,852)	($1,015,194)	($2,075,357)	($1,287,001)
Benefit to Cost Ratio	0.20	0.45	0.55	0.45	0.58
Internal Rate of Return	-6.3%	-4.2%	-3.9%	-5.3%	-2.9%
Simple Payback, years	19094.3	83.6	65.3	62.0	35.8
Cost/kWh, 20 Years	$1.32	$0.31	$0.24	$0.27	$0.20

Net Cash Flow is over 20 year term
IRR and Payback are Not Applicable to a Debt Financed Project.
* Price for GE 1.5 SLE excluding OEM warranty (new, after market turbine)

Grant funding reduces initial capital costs, as indicated by the higher Net Present Value for each of the project scenarios, when using the same values for discount rate and inflation factors. The NPV, Net Cash Flow and benefit to cost ratio are all negative, even for a discounted after-market turbine, which are considerably cheaper than a comparable new turbine from the original equipment manufacturer. One additional scenario was included in the analyses, which looked at annual cash flows for a turbine which was financed at a rate of 2% for 20 years, which was also financially unattractive. Depending upon ownership structure, tax incentives could also be factored into the economic evaluation; however, the low wind resource is not likely to attract offers for private development. It should be noted that all of the scenarios are sensitive to the discount rate (4.0%), rate of general inflation (2%) and energy inflation rate (2.0%), which have been used in this analysis. Grant funding helps reduce the initial capital cost of the project, improving all of the scenarios Net Present Value by an amount equal to the grant. Refer to **Appendix J** for detailed economic calculations, which include estimated annual operation, maintenance and insurance cost of the wind turbines.

6.6 Community Wind

Rural landowners who own land with good wind resources have traditionally benefited from a wind project by leasing their land to large wind developers who sell the wind energy and pay the land owners a lease payment for hosting one or more wind turbines. A community wind project is term used to describe a project that is initiated locally and a community-owned project. Community wind projects can be owned by a variety of individuals including local residents, small business owners, local organizations including schools and universities, Native American Tribes, rural electric cooperatives, municipalities, utilities, and others in the community or region. These projects can range from a single turbine to a community-owned commercial-scale wind farm. There are a growing number of community wind projects in the U.S. Community wind projects have been installed throughout the country and are in the planning stages in virtually every state with wind power development underway.

A key feature of a community wind project is that local community members own and have a significant financial stake in the project beyond just land lease payments and tax revenue. A project having community based support is more likely to be accepted by a higher percentage of the local residents when they have an opportunity to participate in the project financially and share in the risks and rewards. These projects keep more dollars in local communities, preserve local energy independence and protect the environment. Ownership could be sponsored and managed by the Town, usually through an appointed board, where ownership options are defined and stakes are offered in shares. Share classes could be defined by factors such as ownership of land upon which project is constructed, proximity to the project, where project participants closest to the project are offered preferred shares, followed by residents and businesses (taxpayers) within of the Town, and then the region, then the State. The number of ownership classes can be as varied as necessary or desired locally. Ownership shares can be divided into blocks based on percentage of project cost and revenues allocated commensurately. Blocks of shares are offered based on predefined divisions and any unallocated (shares not purchased) are offered in subsequent class offering until all shares in the project are allocated (sold), thus raising the capital needed to develop the project. Any unallocated shares would be purchased and owned by the project sponsor (Town) who would be prepared to own 100% of the project if there is no interest and no shares are sold. Prices of shares could reflect adjustments based on degree of perceived impact of the project based on distance, such that those participants who are closest to project have greater financial incentives from development of the project. Again, given the low wind resource, a wind turbine project is unlikely to attract community interest.

7.0 PROJECT RISK FACTORS

There are risk factors inherent with implementation of a wind turbine generator. Most of the risk factors associated with wind turbines have been investigated and are well documented in the literature. Proponents and advocates of developing wind power, which include the America Wind Energy Association (AWEA), have developed publications designed to educate and dispel certain myths associate with the risks and hazards of operating modern wind turbines. The risk factors considered for this study include: Hazards to human health and safety; Hazards with aeronautical navigation or interference with radar and other facilities; and Financial risks. Each of the factors is discussed below.

7.1 Human Health and Safety

The hazards to human health and safety include basic life safety issues associated with construction of the wind turbine. Given the height of the theses facilities, there is a risk of slip, trip or falling during construction, where complex rigging operations are involved. This factor is effectively mitigated through use of trained, experienced personnel during the construction, operation and maintenance phases.

There is also a risk, however small, of a catastrophic structural failure of the turbine and potentially resulting in death or serious bodily injury from falling ice, ice throw, parts or components. Installing fencing around the perimeter of the wind turbine can mitigate safety issues. Access limitation and control over the personnel who have access to the wind turbine will mitigate some of safety related risk factors. Security and access to the facility can be closely monitored and restricted, further reducing the risk of injury or harm.

Much publicity and study has been given recently to wind turbine sounds and potential health effects associated with wind turbines. The alleged health effects, commonly referred to as wind turbine syndrome, include reported symptoms such as tinnitus, headache, nausea, vertigo, sleeplessness, and agitation. While the scope of this study is not intended to address these issues, we believe that these issues tend to be raised by a segment of the population who may be annoyed by wind turbines and have a general predisposition of dislike towards wind turbines. Notwithstanding, we acknowledge that wind turbines are large industrial pieces of modern equipment which do make sounds and can be seen, sometimes at great distances due to their size, and the opinions of this segment of the population who are opposed to wind turbines should not be summarily discounted and such opinions should be heard and considered in the siting of any wind turbine project where residential population might be affected by an operating wind turbine.

7.2 Hazards to Navigation and Radar

There is a risk that wind turbines can result in interference with radar or pose a hazard to aeronautical navigation. The hazard to navigation may be mitigated through installation of additional navigation aids; however, the evaluation of the costs and benefits of these types of improvements are beyond the scope of this assessment. As noted earlier, a request for determination for a nearby location has been filed with the FAA. Preliminary studies indicate that a structure height of up to 500 feet AGL would not likely pose a hazard to air navigation.

7.3 Financial Risk

As discussed briefly in the preceding sections, there are several economic risk factors that could significantly impact the expected financial performance of the proposed project. These factors are as follows:

Turbine Cost and Availability
Based upon the research conducted for this study, procuring a single commercial scale turbine is not a straightforward process. There are relatively few established vendors with proven equipment that are interested in selling a single turbine, and pricing is subject to significant variability due to procurement timing, currency exchange rates, and other factors. It is clear that definitive pricing for the turbine sizes evaluated for this project will not be available until a procurement decision is made. In addition, it should be noted that current delivery schedules for a single large scale wind turbine, assuming a turbine can be procured, range from 12 to 24 months, or more. Several manufactures of a 600 kW wind turbines (Elecon, RRB) have begun to fill single turbine orders in the North American market; however, many second or third tier turbine suppliers have difficulty providing maintenance and support service resulting in increased turbine down time. Construction-pricing variability (cost of concrete, steel, etc.) also becomes a significant secondary concern for budgeting purposes.

Energy Regulatory Framework
The passage of the Green Communities Act of Massachusetts in July 2008 which increased the net metering criteria for wind generators from 60 kW to 2 MW, with the ability for virtual net metering, created a framework with significantly positive impacts on the financial performance for eligible renewable energy projects. The increased size and ability for virtual net metering, which previously limited use of energy generated from a renewable energy project to on site use, with excess power made available to the grid at wholesale rates, now permits excess power to be applied to other meters in the same ISO NE load zone to receive the credits mandated by the legislation. Net metering takes effect on December 1 under an order adopted by Department of Public Utilities (DPU) on November 13, 2009. The Act stipulates net metering credits for municipalities include credit for the per kilowatt hour default service rate, distribution, transmission and per kilowatt hour transition charges.

8.0 CONCLUSIONS AND RECOMMENDATIONS

A feasibility study has been completed for the proposed construction of one large scale wind turbine in the Town of Millbury, Massachusetts. The study presents a comprehensive review of the critical factors and considerations analyzed as part of the feasibility for installing a wind turbine at the Butler Farm property located at 44 Singletary Road. This feasibility study incorporated thorough evaluation of virtual MET mast and existing published wind data; electrical usage, consumption and generation; economics; environmental, avian and noise impacts; engineering assessments and permitting issues towards development of a commercial-scale wind turbine.

The feasibility study addresses the technical and economic feasibility of construction of one 100 kW to 1.8 MW wind turbine at the Butler Farm site in Millbury. Conceptually, construction of a single large scale wind turbine could be used offset electrical consumption at multiple Town-owned facilities through virtual net metering. Based on the results of this study, installation of a wind energy conversion facility is considered technically viable, but not economically viable based on low predicated long term wind resources. Predicted long term wind speeds of 5.2 at a height of 80 meters was determined to be unfavorable for development of a commercial scale wind turbine at the Butler Farm Site. Aesthetic concerns, potential sound impacts and the degree of public support is also a potential limiting factor.

The cost for design, permitting, procurement and construction of a single 100 kW to 1.8 MW wind turbine is on the order of $2,700 to $10,300 to per kW. A project of this size is estimated to cost on the order of $1.03M to $4.60M for a 100 kW and 1.8 MW wind turbine, respectively. The standard figures of merit, including: Net Present Value, Net Cash Flow, Benefit to Cost Ratio and Internal Rate of Return were all substantially negative, based on the low annual energy output from the low predicted wind speeds. Estimated capacity factors ranged from 4.7% to 10% are predicted long term average wind speeds of 5.2 m/s at a height of 80 meters. While commercially purchased wind modeling data suggested higher annual wind speeds of 6.5 m/s at 80 meters, correlation of actual on-site measurements to nearby long term data sources contradicts this suggestion.

Based upon the above, it is our opinion that development of a single large-scale wind turbine is technically feasible, but not economically viable.

9.0 9.0 REFERENCES

American Wind Energy Association and The American Bird Conservancy. May 18-19, 2004, *Proceedings of the Wind Energy and Birds/Bats Workshop: Understanding and Resolving Bird and Bat Impacts,* Washington, D.C.

American Wind Energy Association, Facts About Wind Energy And Noise, http://www.awea.org

American Wind Energy Association, Wind Power Myths vs. Facts, http://www.awea.org

Boere, G.C., Galbraith, C.A. and Stroud, D.A. (eds). Waterbirds Around the World, Stationery Office, Edinburgh, U.K. 960 pp. (2006).

Department of Defense, Missile Defense Agency, Wind Turbine Analysis for Cape Cod Air Force Station Early Warning Radar and Beale Air Force Base Upgraded Early Warning Radar, Spring 2007

Higgins, Robert C., Analysis for Financial Management, Fifth Edition, 1998, University of Washington, Irwin/McGraw Hill.

ISO New England Inc., 2005 New England Marginal Emission Rate Analysis, July 2007

Massachusetts Geographic Information Systems (Mass GIS), 2007, Various Data Layers. Office of Geographic and Environmental Information, Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Rogers, A.L., Manwell, J.F., and Wright, S., Wind Turbine Acoustic Noise, 2002, Amended 2006, Renewable Energy Research Laboratory, Department of Mechanical and Industrial Engineering, University of Massachusetts at Amherst, Amherst, MA 01003

Skehan, J.W., 1997, Assembly and Dispersal of Supercontinents: The view from Avalon: Journal of Geodynamics, v. 23, p. 237-262.

U.S. Geological Survey Open-File Report 03-221 A Pictorial Survey of the Bedrock Beneath Western Cape Cod, Massachusetts

Varian Semiconductor Equipment Associates, Inc., July 2005, Feasibility Study for Wind Turbine Installation, in association with Massachusetts Technology Collaborative, et al.

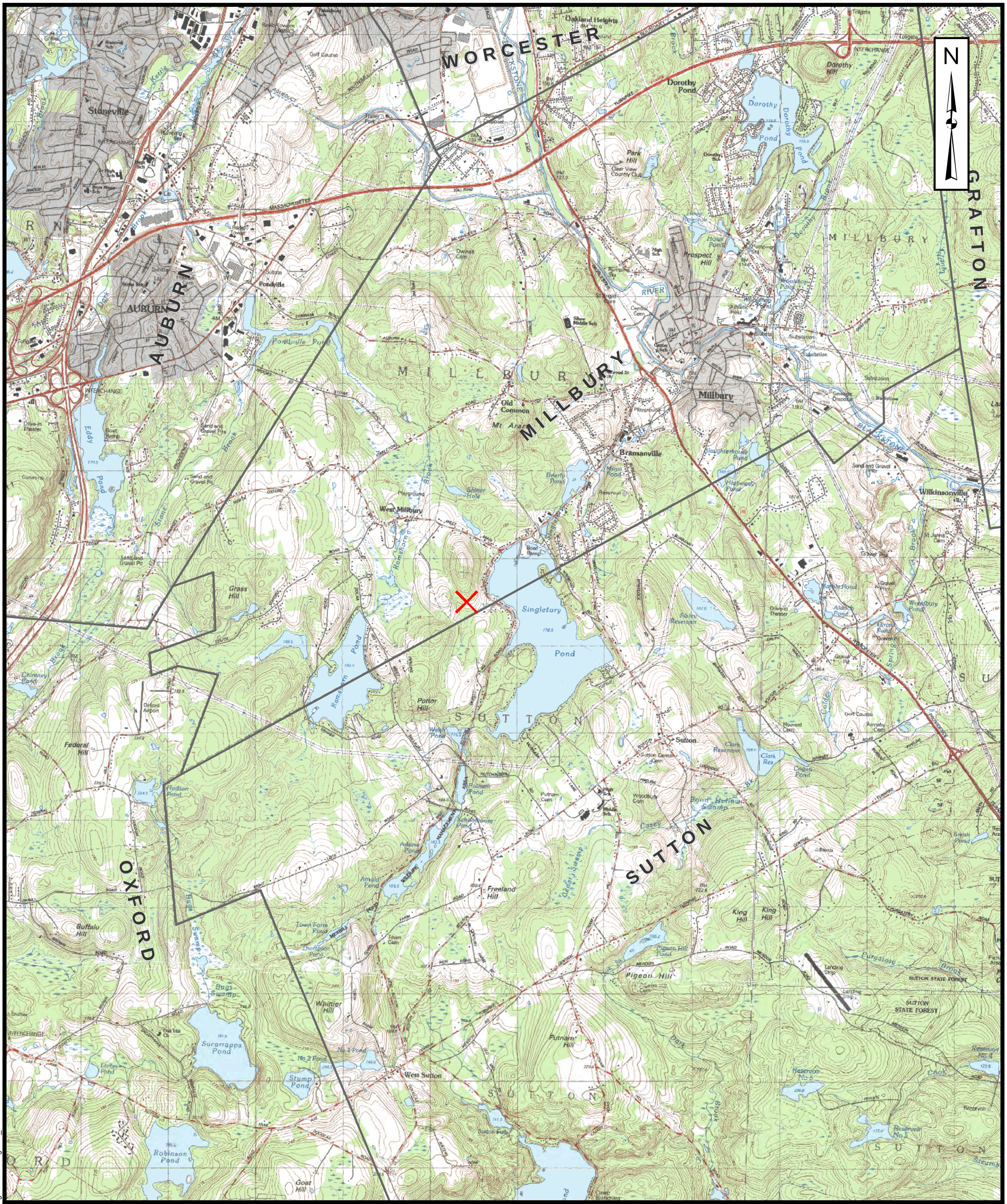
Wernham, C., Toms, M., Marchant, J., Clark, J., Siriwardena, G., and Baillie, S., 2002. The Migration Atlas: Movements of the Birds of Britain and Ireland. T & A.D. Poyser, London, UK. 884 pp.

Windustry, Policy and Research. http://www.windustry.org/policy-amp-research/policy-and-research-about-wind-energy.

Zen, E-an, Goldsmith, Richard, Ratcliffe, N.M., Robinson, Peter, Stanley, R.S., Hatch, N.L., Shride, A.F., Weed, E.G.A. and Wones, D.R., 1983, Bedrock geologic map of Massachusetts: U.S. Geological Survey, scale 1:250000.

Appendix A

Figures



Data Source:
USGS, Topographic Quadrangles 1979, 1974
Horizontal Datum: NAD1927
Vertical Datum: NGVD1929
Contour Interval: 10 feet

Ledgend

✕ **Proposed Turbine Location**

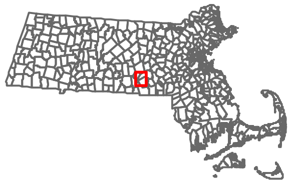
FIGURE 1
TOWN OF MILLBURY, MASSACHUSETTS
BUTLER FARM
WIND TURBINE FEASIBILITY STUDY

USGS Site Location Map

0 2,500 5,000 7,500 10,000

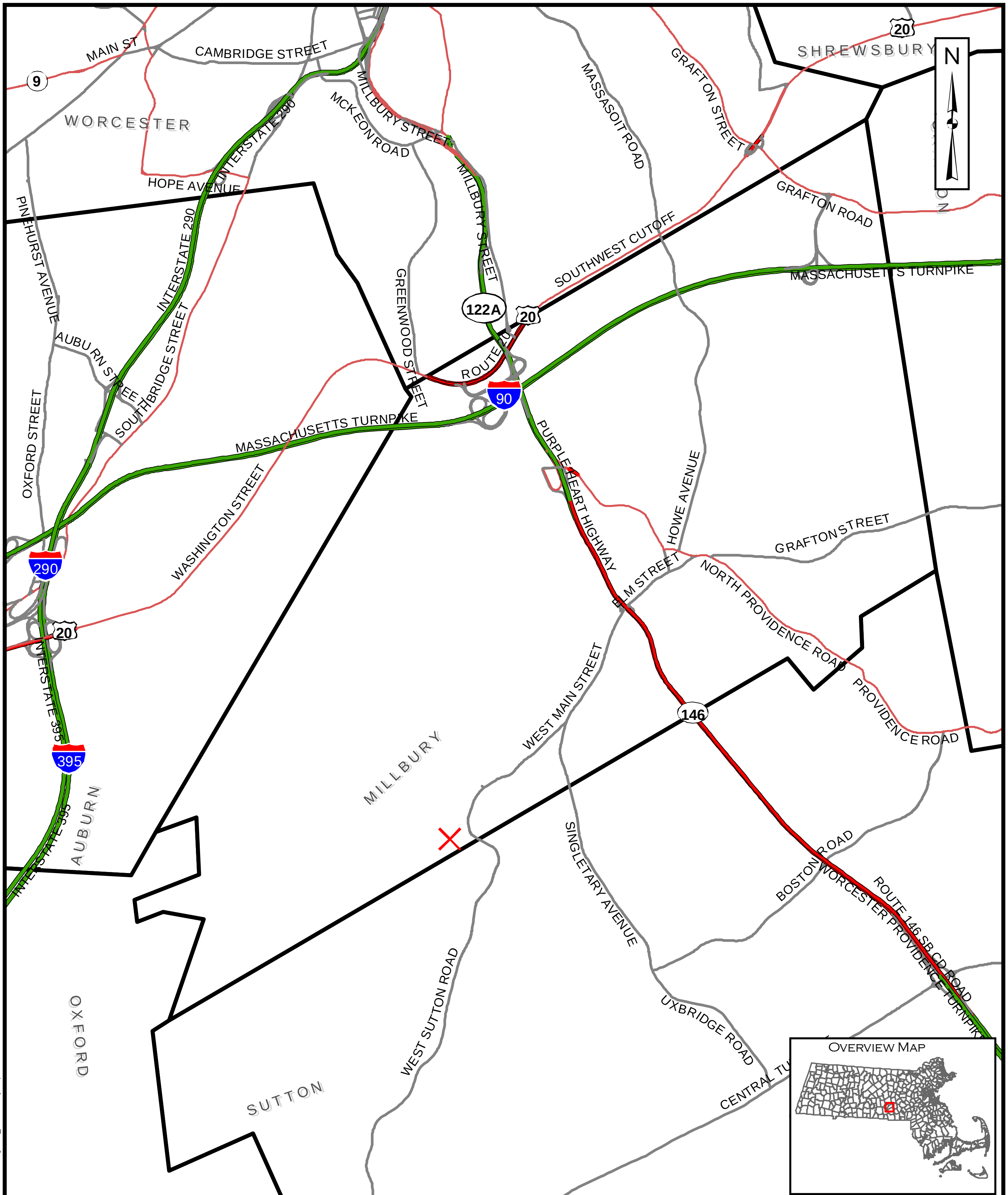
Scale in Feet

Overview Map



Weston&Sampson®

O:\Millbury MA\Wind Feasibility Study\Feasibility Study\Figures\GIS\Figure1_USGSSiteLocation.mxd 2010-11-22 16:46 mcbriena



Legend

Road Classification

- Limited Access Highway
- Multi-lane Hwy, not limited access
- Other Numbered Highway
- Major Road, Collector
- Proposed Turbine Location

FIGURE 2
TOWN OF MILLBURY, MASSACHUSETTS
BUTLER FARM
WIND TURBINE FEASIBILITY STUDY

Site Vicinity Map

0 2,500 5,000 7,500 10,000

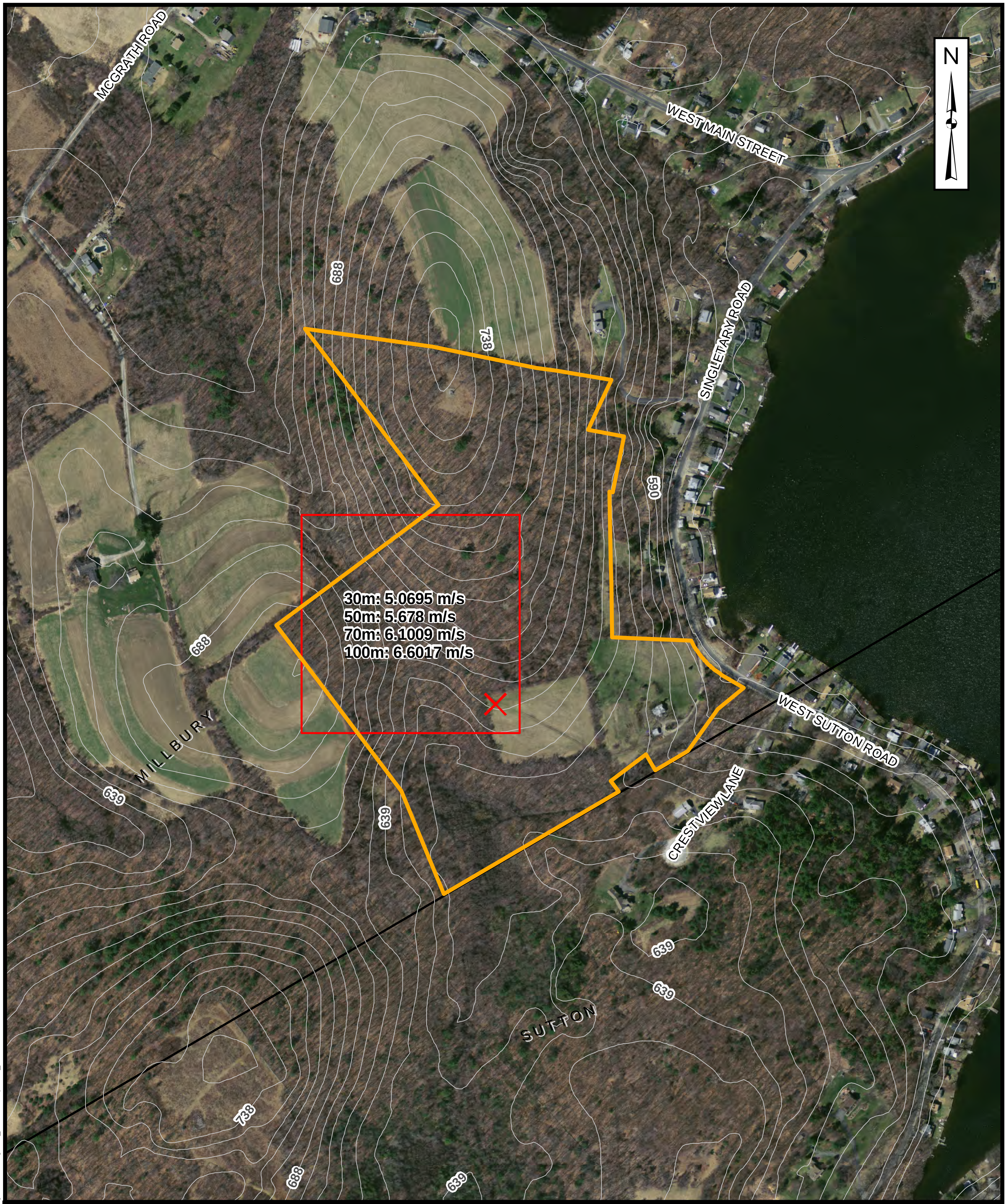
Scale in Feet

Data Source:

Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs

Weston&Sampson®

O:\Millbury MA\Wind Feasibility Study\Feasibility Study\Figures\GIS\Figure2_SiteVicinityMap.mxd 2010-11-23 08:30 mcbriena



Legend

10' Contour

Butler Farm Property

Proposed Turbine Location

Data Sources:
Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

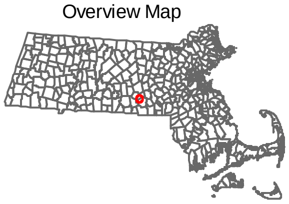
FIGURE 3
TOWN OF MILLBURY, MASSACHUSETTS
BUTLER FARM
WIND TURBINE FEASIBILITY STUDY

AWS Truewind Wind Speeds

0 250 500 750 1,000

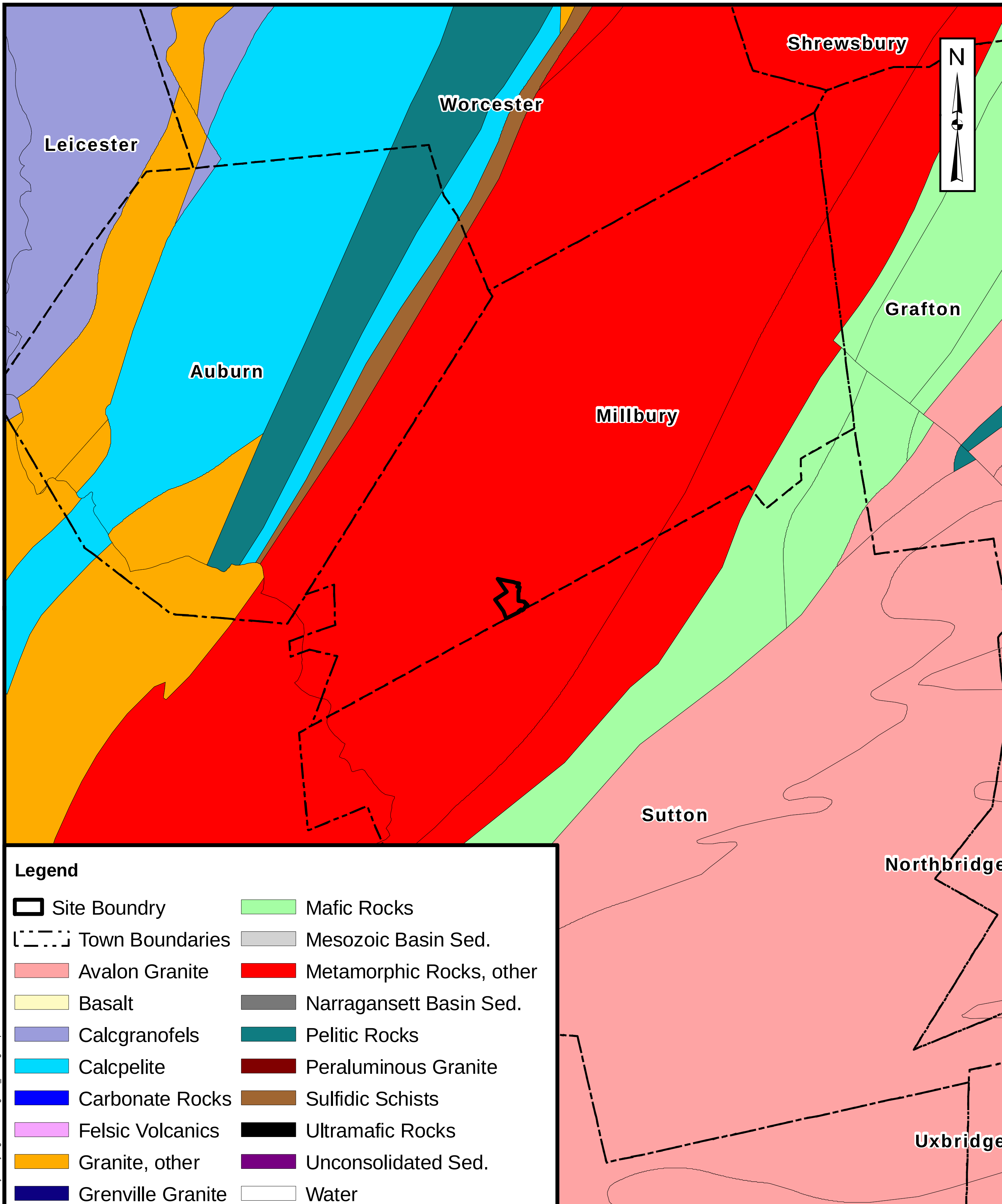
Scale in Feet

Overview Map



Weston&Sampson®

O:\Millbury MA\Wind Feasibility Study\Figures\GIS\Figure3_AWSwindSpeeds_Aerial.mxd 2010-11-23 10:12 mcbriena



Data Source:

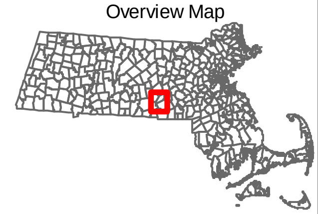
Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs

FIGURE 4
TOWN OF MILLBURY, MASSACHUSETTS
BUTLER FARM
WIND TURBINE FEASIBILITY STUDY

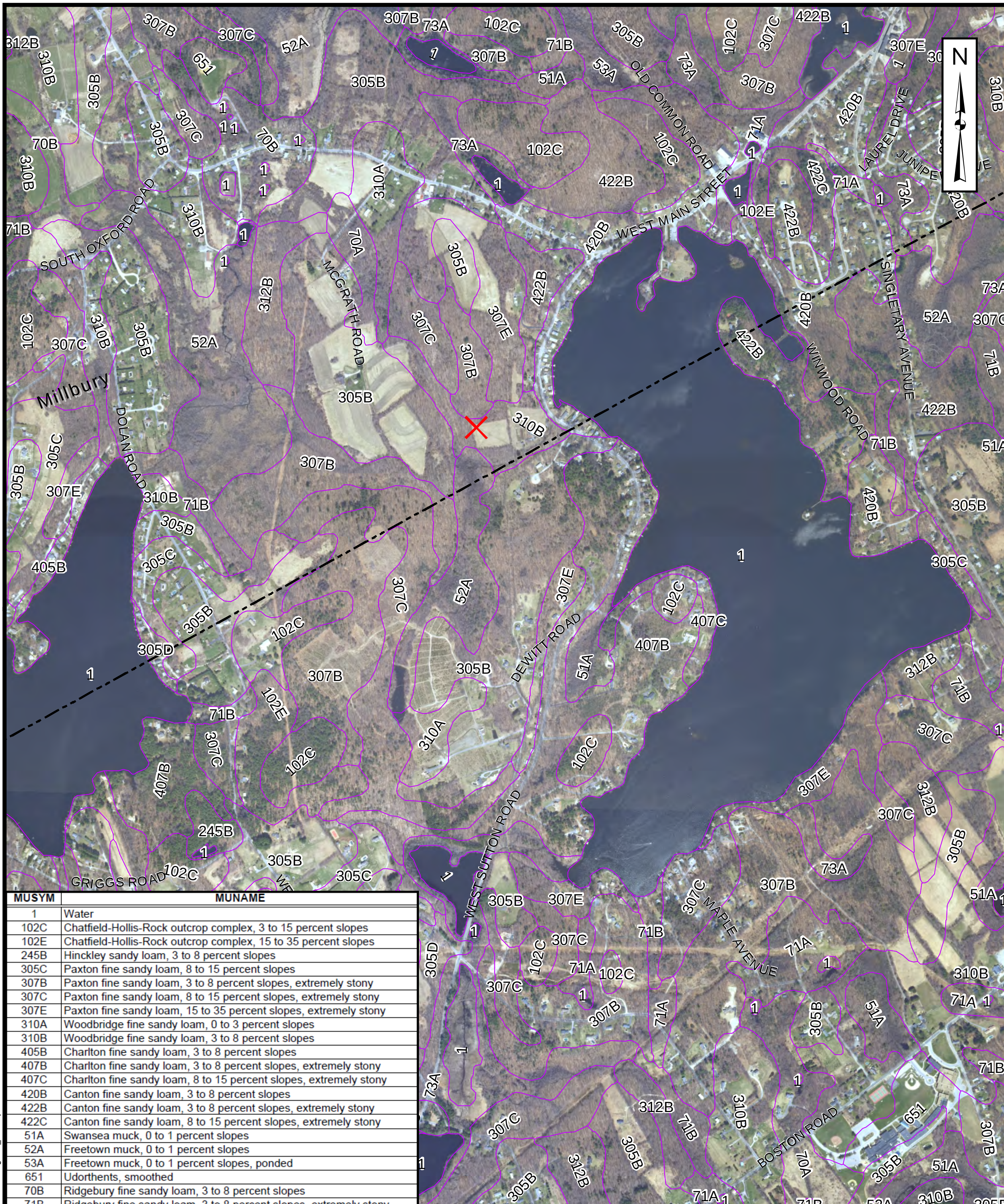
Geologic Map

Scale in Feet

Overview Map



Weston&Sampson



MUSYM	MUNAME
1	Water
102C	Chatfield-Hollis-Rock outcrop complex, 3 to 15 percent slopes
102E	Chatfield-Hollis-Rock outcrop complex, 15 to 35 percent slopes
245B	Hinckley sandy loam, 3 to 8 percent slopes
305C	Paxton fine sandy loam, 8 to 15 percent slopes
307B	Paxton fine sandy loam, 3 to 8 percent slopes, extremely stony
307C	Paxton fine sandy loam, 8 to 15 percent slopes, extremely stony
307E	Paxton fine sandy loam, 15 to 35 percent slopes, extremely stony
310A	Woodbridge fine sandy loam, 0 to 3 percent slopes
310B	Woodbridge fine sandy loam, 3 to 8 percent slopes
405B	Charlton fine sandy loam, 3 to 8 percent slopes
407B	Charlton fine sandy loam, 3 to 8 percent slopes, extremely stony
407C	Charlton fine sandy loam, 8 to 15 percent slopes, extremely stony
420B	Canton fine sandy loam, 3 to 8 percent slopes
422B	Canton fine sandy loam, 3 to 8 percent slopes, extremely stony
422C	Canton fine sandy loam, 8 to 15 percent slopes, extremely stony
51A	Swansea muck, 0 to 1 percent slopes
52A	Freetown muck, 0 to 1 percent slopes
53A	Freetown muck, 0 to 1 percent slopes, ponded
651	Udorthents, smoothed
70B	Ridgebury fine sandy loam, 3 to 8 percent slopes
71B	Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony

Legend

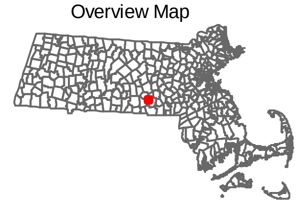
- Proposed Turbine Location
- Town Boundary
- Soils Polygons (SSURGO)

FIGURE 5
TOWN OF MILLBURY, MASSACHUSETTS
BUTLER FARM
WIND TURBINE FEASIBILITY STUDY

Soil Map

0 750 1,500 2,250 3,000
Scale in Feet

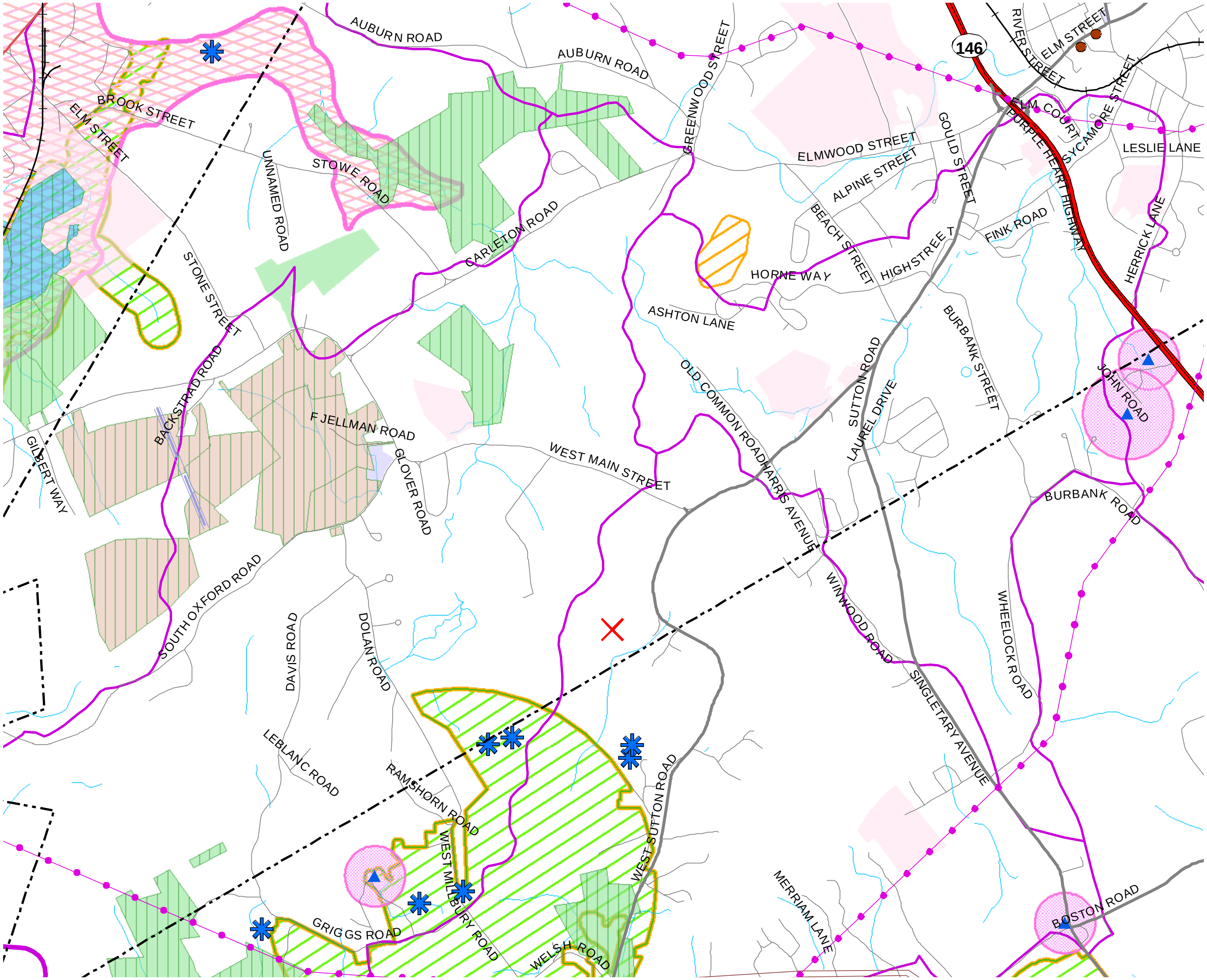
Overview Map



Data Source:
Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs

Weston&Sampson

O:\Millbury MA\Wind Feasibility Study\Figures\GIS\Figure5_SoilMap.mxd 2010-11-23 11:41 mcbriena



Legend

- Proposed Turbine Location
- State Register of Historic Places
- Town Boundaries
- State Boundary
- Ground Water
- Surface Water
- Non-Community
- NHESP Certified Vernal Pools
- Railroads by Ownership
- Pipeline
- Pipeline Arbitrary Extension
- Powerline
- Powerline Arbitrary Extension
- Ski Lift/Tramway
- Substation
- Landing Strip/Airport
- Highway Exit Locations

All Roads

Road Classification

- Limited Access Highway
- Multi-lane Hwy, not limited access
- Other Numbered Highway
- Major Road, Collector
- Minor Road, Arterial
- Sub-basins
- Major Basins
- Protected Open Space
- Conservation
- Recreation
- Recreation and Conservation
- Agriculture
- Habitat
- Historical/Cultural
- Scenic (Official Designation Only)
- Water Supply
- Flood Control
- Underwater
- Other
- Unknown
- ACECs
- Zone A
- IWPAs
- DEP Approved Zone IIs
- River, Stream
- Predominantly Open Water
- NHESP Estimated Habitats of Rare Wildlife
- NHESP Priority Habitats of Rare Species

N

2,400 1,200 0 2,400 Feet

0.5 0.25 0 0.5 Miles

Data Source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs

Notes: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs. Fill in this area with other notes as needed.

FIGURE 6

Area Receptors Map
Wind Turbine Feasibility Study
Town of Millbury, MA

Weston&Sampson®

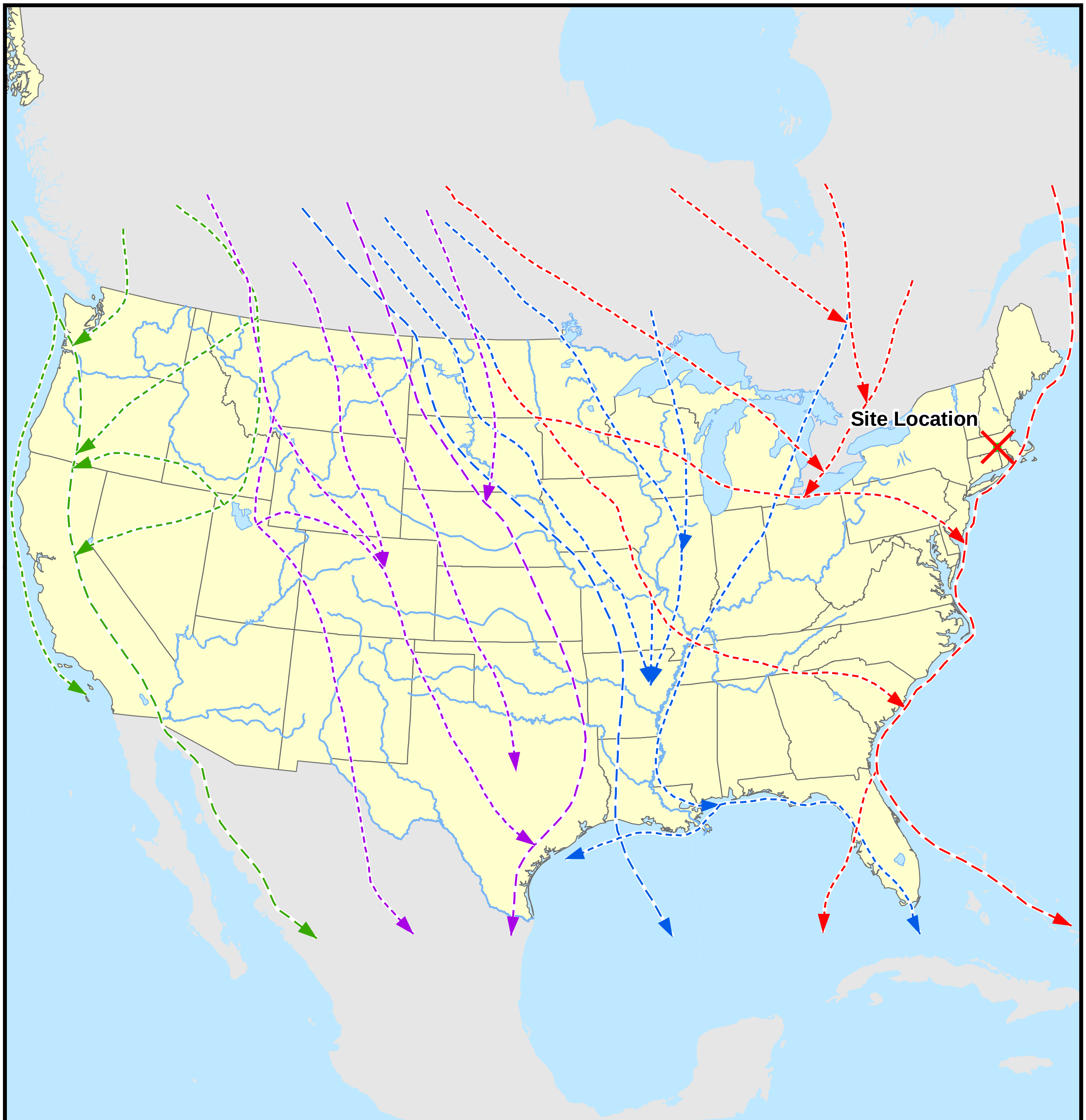


FIGURE 7
TOWN OF MILLBURY, MASSACHUSETTS
WIND TURBINE FEASIBILITY STUDY

North American Migration Flyways with Principal Routes

Proposed Turbine Location

Flyway Name, Size

- ATLANTIC, PRIMARY
- ATLANTIC, SECONDARY
- CENTRAL, PRIMARY
- CENTRAL, SECONDARY
- MISSISSIPPI, PRIMARY
- MISSISSIPPI, SECONDARY
- PACIFIC, PRIMARY
- PACIFIC, SECONDARY

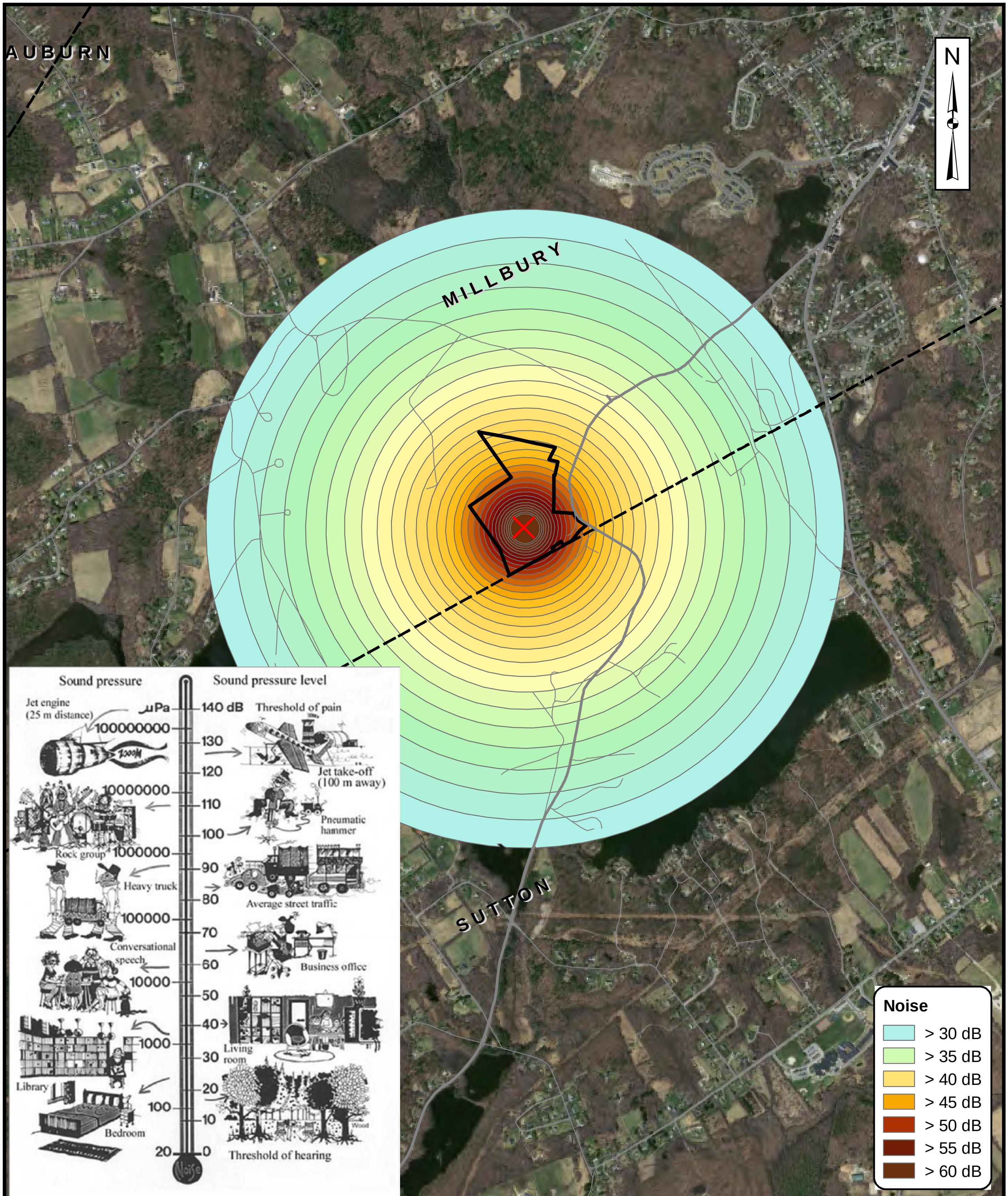
Data acquired from:
http://www.birdnature.com/allflyways.html

Disclaimer:

Map not prepared by W&S, Inc.
W&S, Inc. does not assume
responsibility for any possible
misrepresentations or incorrect data.

Weston&Sampson

O:\Millbury MA\Wind Feasibility Study\Feasibility Study\Figures\GIS\Figure7_NorthAmericanMigrationFlywaysMap.mxd 2010/12/09 15:58 mcbriena



Legend

Proposed Turbine Location

Site Boundary

Town Boundary

Data Sources:
- Weston & Sampson, Inc.
- Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs

FIGURE 8
TOWN OF MILLBURY, MASSACHUSETTS
BUTLER FARM
WIND TURBINE FEASIBILITY STUDY

Sound Decibel Isoline Map

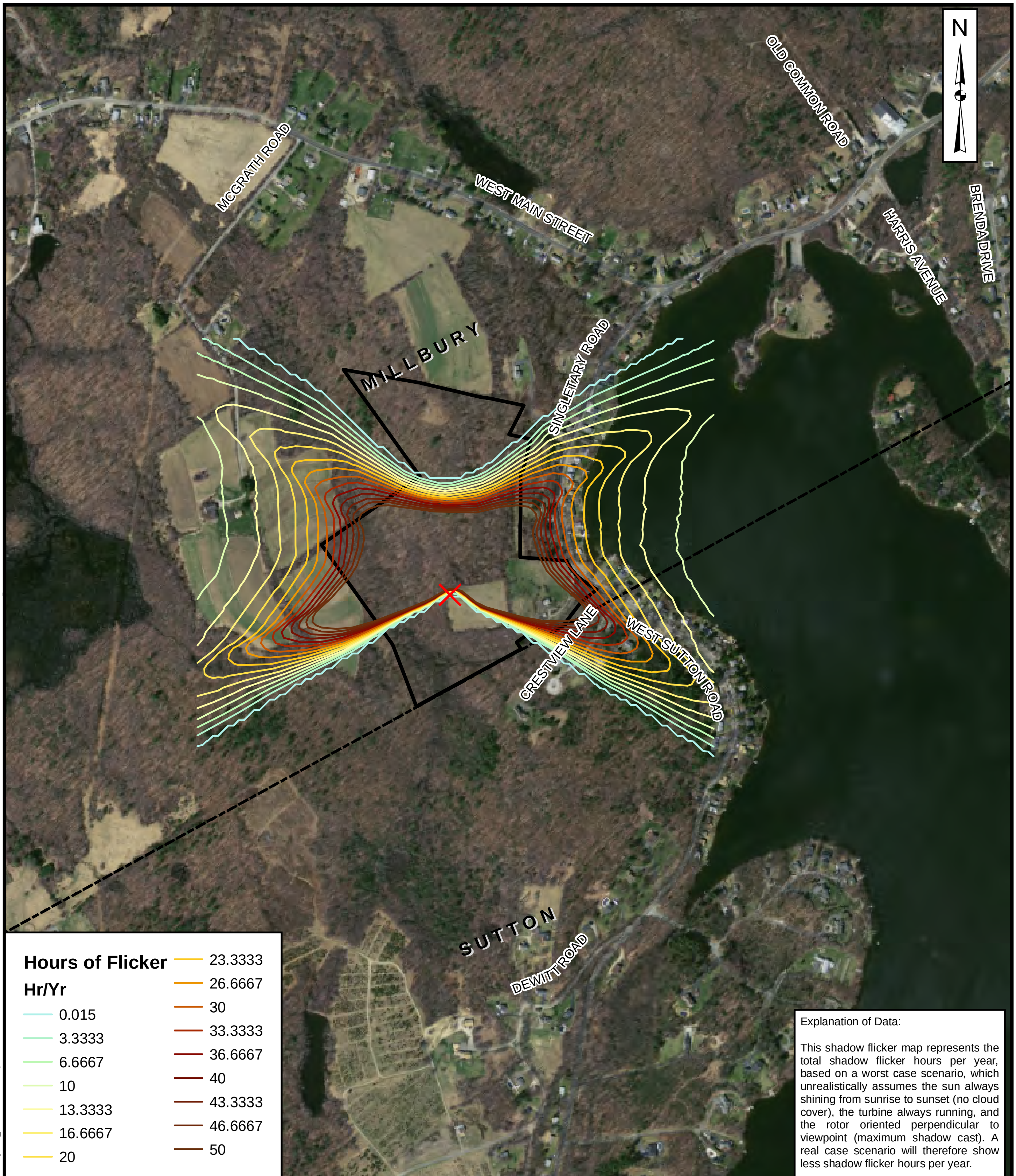
0 500 1,000 1,500 2,000

Scale In Feet

Overview Map

Weston&Sampson®

\\Gisds\gis\DataStore\UnitedStates\NewEngland\MA\Barnstable\Mashpee\Project\Renewable Energy\Figure8_DecibelMap.mxd 12/5/2009 1:05:11 PM duijveso

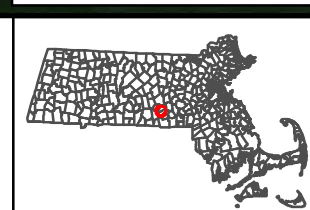


Legend

Site Boundary
Town Boundary
Proposed Turbine Location

FIGURE 9
TOWN OF MILLBURY, MASSACHUSETTS
BUTLER FARM
WIND TURBINE FEASIBILITY STUDY

Shadow Flicker Map



Data Sources:
- Weston & Sampson, Inc.
- Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs

0 750 1,500 2,250 3,000

Scale In Feet

Weston&Sampson®

O:\Millbury MA\Wind Feasibility Study\Feasibility Study\Figures\GIS\Figure9_ShadowFlickerMap.mxd 2010/12/10 11:44 mcbriena

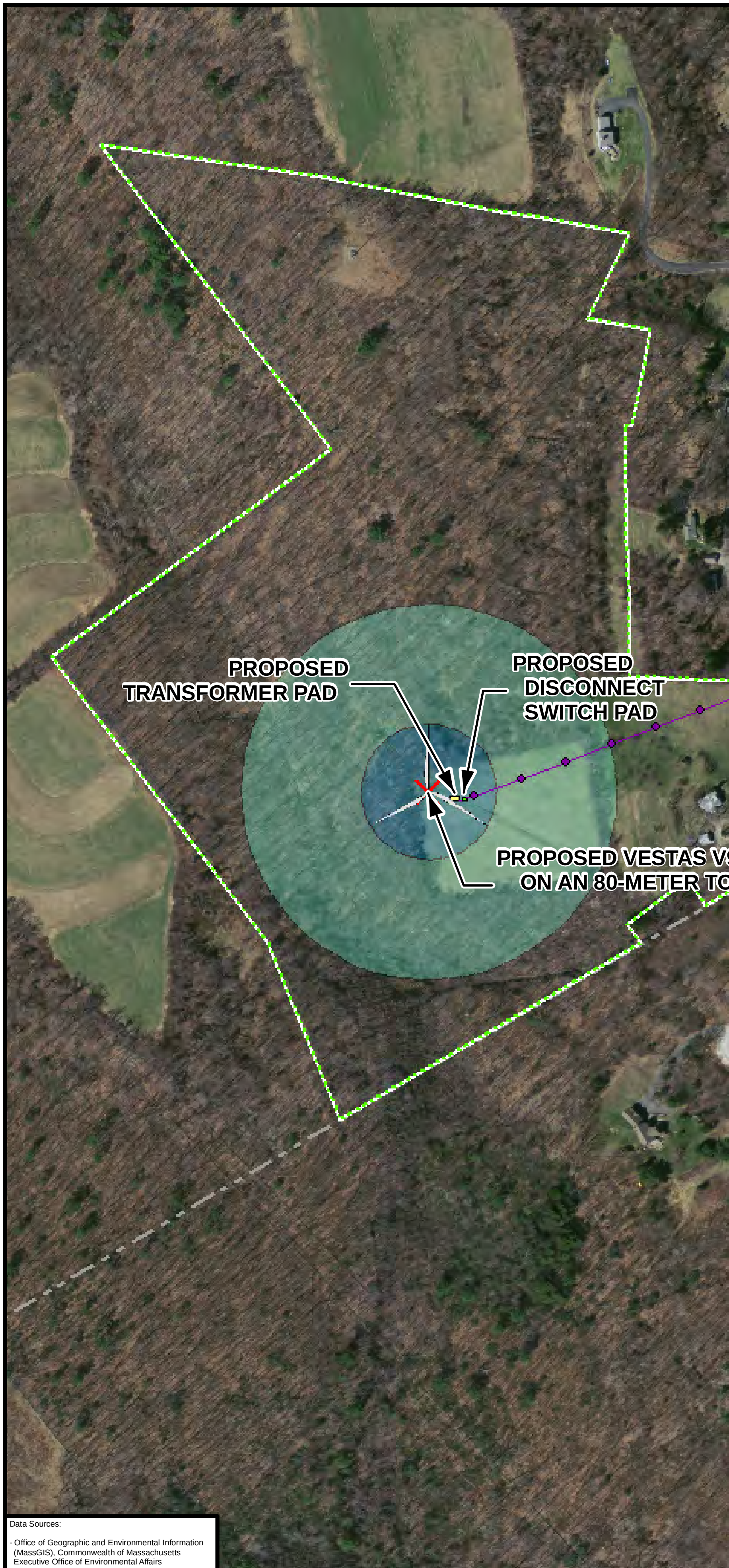


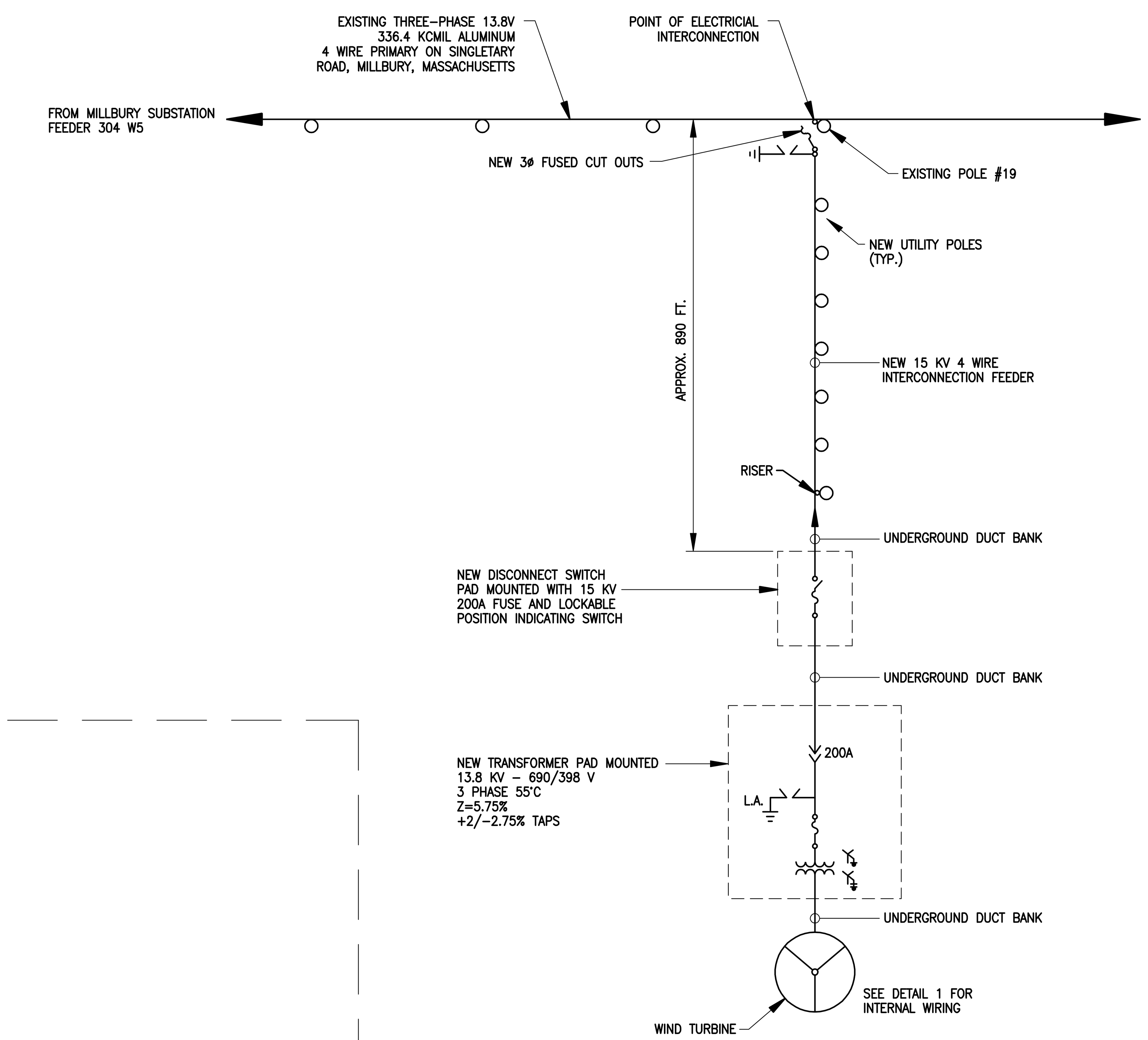
FIGURE 10

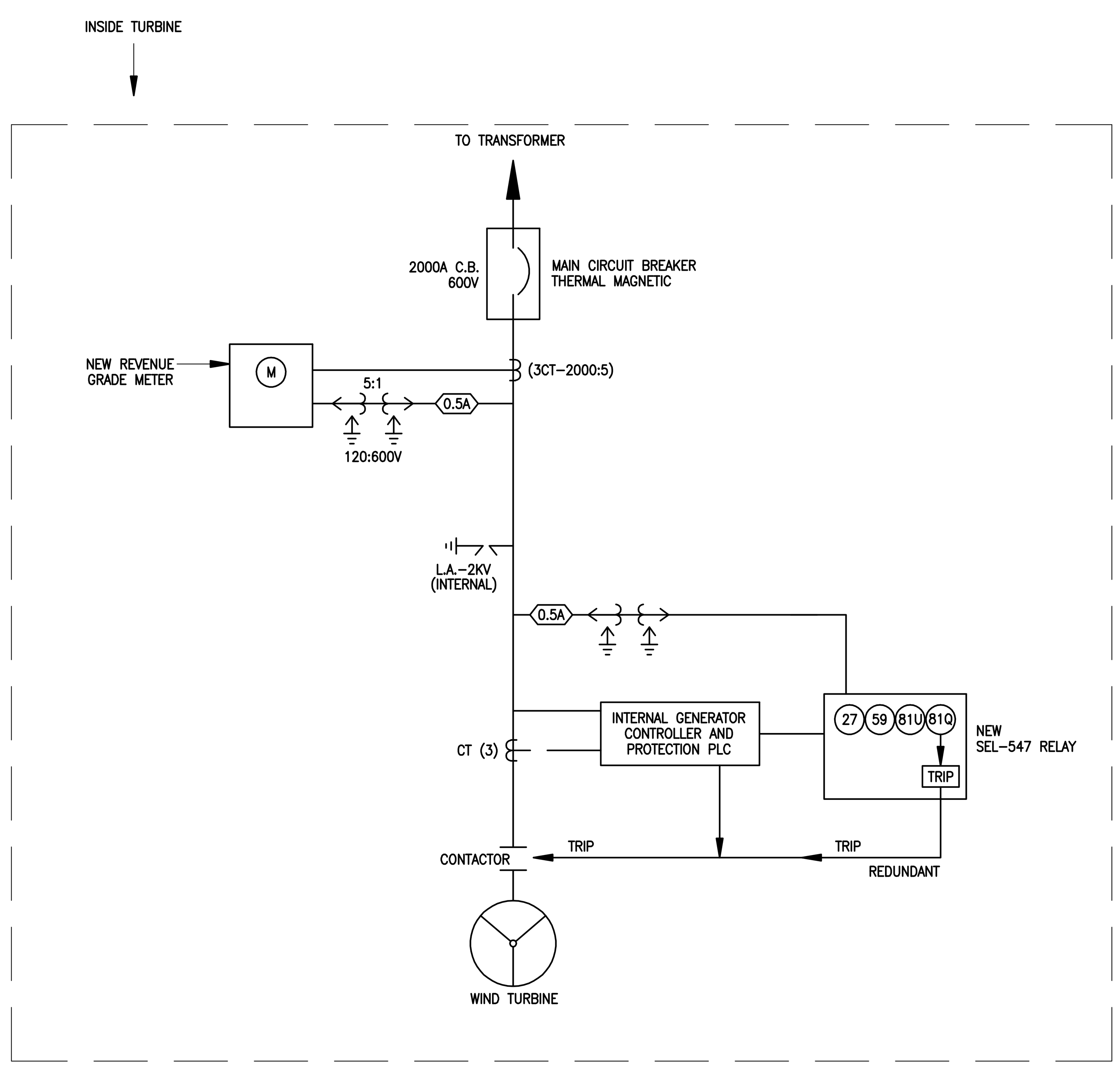
TOWN OF MILLBURY, MA
PROPOSED WIND ENERGY FACILITY

CONCEPTUAL SITE PLAN

DECEMBER 2010 SCALE: NOTED

Weston&Sampson®





DETAIL 1 — TURBINE GRID PROTECTION

NOT TO SCALE

CONDUIT INSTALLATION NOTES

1. THIS DRAWING IS BASED ON INFORMATION AND DRAWINGS PROVIDED BY TOWN OF MILLBURY. THIS DRAWING IS FOR INFORMATION ONLY. THE CONTRACTOR SHALL VERIFY ALL LOCATIONS, DEVICES, MATERIALS, AND EQUIPMENT PRIOR TO MAKING ANY MODIFICATIONS OR ADDITIONS.
2. ALL MATERIALS FURNISHED UNDER THIS CONTRACT SHALL BE IN ACCORDANCE WITH THE LATEST APPLICABLE STANDARDS OF ANSI, NEMA, OSHA, UL NFPA-70, AND THE MASS ELECTRICAL CODE WITH REGARDS TO MATERIAL, DESIGN, CONSTRUCTION AND TESTING.
3. CONTRACTOR SHALL NOTIFY DIG SAFE PRIOR TO ANY EXCAVATION.
4. LOCATIONS OF WATER, SEWER, ELECTRIC AND GAS ARE APPROXIMATE AND FOR REFERENCE ONLY. CONTRACTOR SHALL INSPECT SITE AND FOLLOW ALL DIG SAFE MARKINGS. CONTRACTOR SHALL NOTIFY ALL UTILITIES PRIOR TO EXCAVATION.
5. CONTRACTOR SHALL RESTORE ALL DISTURBED AREAS TO ORIGINAL CONDITIONS.
6. CONTRACTOR TO PERFORM WORK AS SHOWN.
7. THIS DIAGRAM INDICATES A TYPICAL WIND TURBINE INTERCONNECTION AT BUTLER FARMS. THE TRANSFORMER SIZE, THE DISCONNECT SWITCH AND THE UNDER GROUND RACEWAY WILL VARY ACCORDING TO THE WIND TURBINE SELECTED. FOR MORE INFORMATION REFER TO THE ELECTRICAL INTERCONNECTION DETAILS SECTION OF THE REPORT.

ONE-LINE POWER DIAGRAM SYMBOLS

- LOAD-BREAK SWITCH FUSE, SIZE AS DIRECTED
- TRANSFORMER, SIZE AS INDICATED (WYE-WYE GND TYPICAL)
- CIRCUIT BREAKER
- DRAW-OUT CIRCUIT BREAKER
- CURRENT TRANSFORMER
- POTENTIAL TRANSFORMER
- SOLID STATE TRIP UNIT
- GROUND
- (A) AMMETER
- AS AMMETER SWITCH
- (XX) PROTCOLIVE RELAY XX=TABLE BELOW
- (V) VOLTMETER
- VS VOLTMETER SWITCH
- T2 DRY TYPE TRANSFORMER "2" INDICATES SIZE, REFER TO DRY TYPE TRANSFORMER SCHEDULE
- L.A. LIGHTING ARRESTER
- CABLE TERMINATION / LOAD-BREAK ELBOW
- FUSED CUT-OUT
- GROUP-OPERATED AIR-BREAK (GOAB) SWITCH
- (M) REVENUE METER (BY UTILITY)
- 200A 200A LOAD BREAK ELBOWS

RELAY FUNCTION TABLE

DEVICE NO.	DESCRIPTION
27T	TIME UNDER VOLTAGE RELAY
27I	INSTANTANEOUS UNDER VOLTAGE RELAY
32F	FORWARD OVER POWER RELAY
32R	REVERSE POWER RELAY
46	NEGATIVE PHASE SEQUENCE OVERCURRENT RELAY
47	REVERSE PHASE VOLTAGE RELAY
50/51	INSTANTANEOUS / TIME OVERCURRENT RELAY
51N	GROUND OVERCURRENT RELAY
59I	INSTANTANEOUS OVERVOLTAGE RELAY
59T	TIME OVERVOLTAGE RELAY
60	VOLTAGE BALANCE RELAY
81/O	OVER FREQUENCY RELAY
81/U	UNDER FREQUENCY RELAY

Weston&Sampson®
100 Foxborough Blvd., S.250, Foxborough, MA
(508) 698-3034 (800) SAMPSON
www.westonandsampson.com

No.	Date	Dr.By	Ck.By	App.By	Description

A P P R O V E D

REGISTERED PROFESSIONAL ENGINEER — DATE

MILLBURY, MASSACHUSETTS
BUTLER FARMS, MILLBURY, MASSACHUSETTS
MILLBURY WIND TURBINE PROJECT

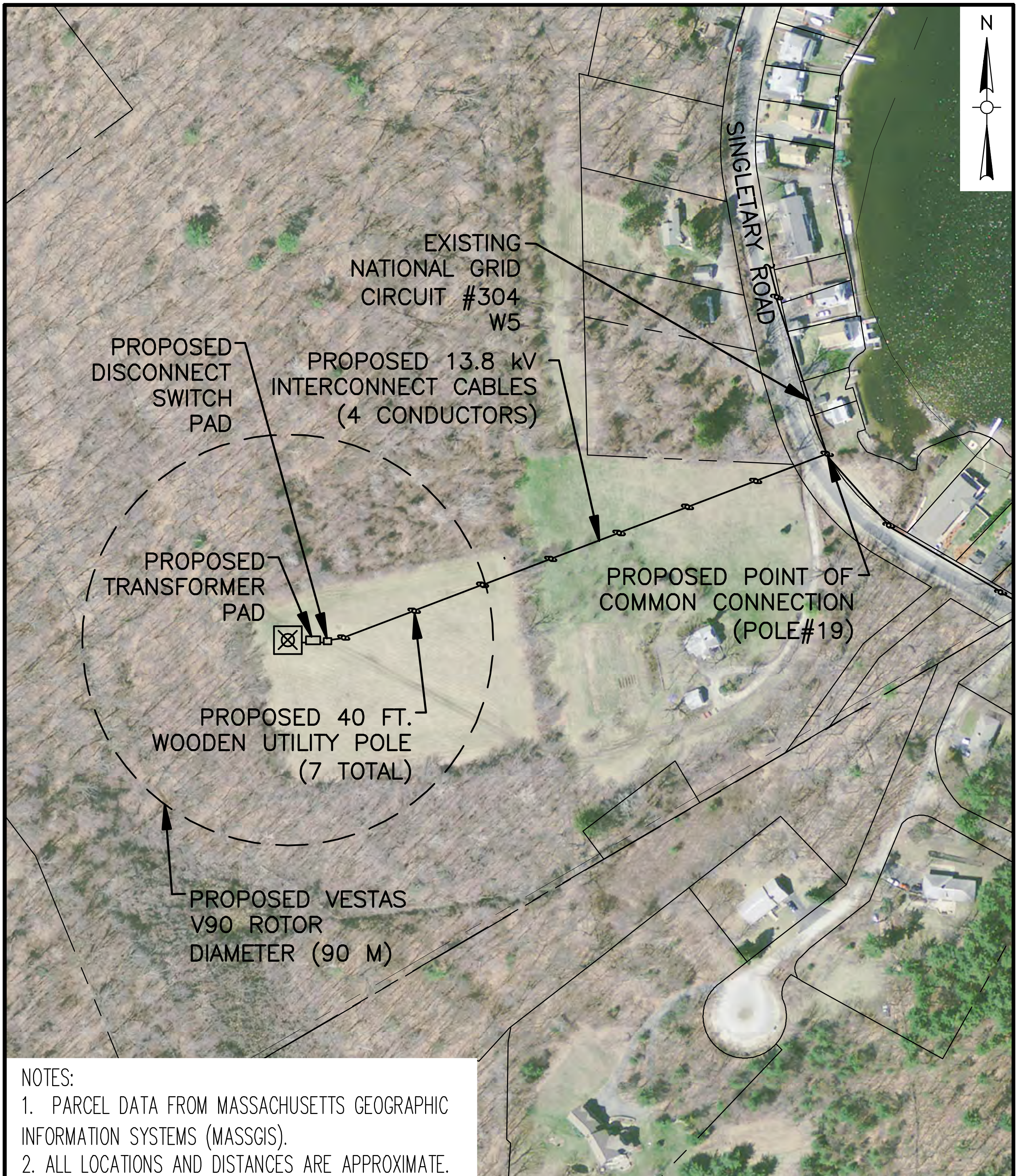
PROPOSED ONE-LINE DIAGRAM

FILE NO.	CADD NO.	SCALE:	CONTRACT:	JOB NO.	DR.BY	DSN.BY	CHK.BY	APP.BY
–	DIAGRAM	N.T.S.	–	2100506	PJS	WRK	WRK	ERB

E-1

SHEET – OF –

O:\Millbury MA\Wind Feasibility Study\Feasibility Study\CAD\ONE-LINE DIAGRAM.dwg



NOTES:
1. PARCEL DATA FROM MASSACHUSETTS GEOGRAPHIC INFORMATION SYSTEMS (MASSGIS).
2. ALL LOCATIONS AND DISTANCES ARE APPROXIMATE.

FIGURE 12
TOWN OF MILLBURY, MA.
WIND FEASIBILITY REPORT

CONCEPTUAL ELECTRICAL LAYOUT

SCALE: 1"=200'

0 200 400

O:\Millbury MA\Wind Feasibility Study\Feasibility Study\CAD\GIS Data.dwg

Appendix B

University of Massachusetts Wind Energy Center Report

University of Massachusetts
Wind Energy Center
Department of Mechanical & Industrial Engineering
160 Governors Drive, Amherst, MA 01003-9265
Tel: 413-545-4359 Fax: 577-1301
www.umass.edu/windenergy

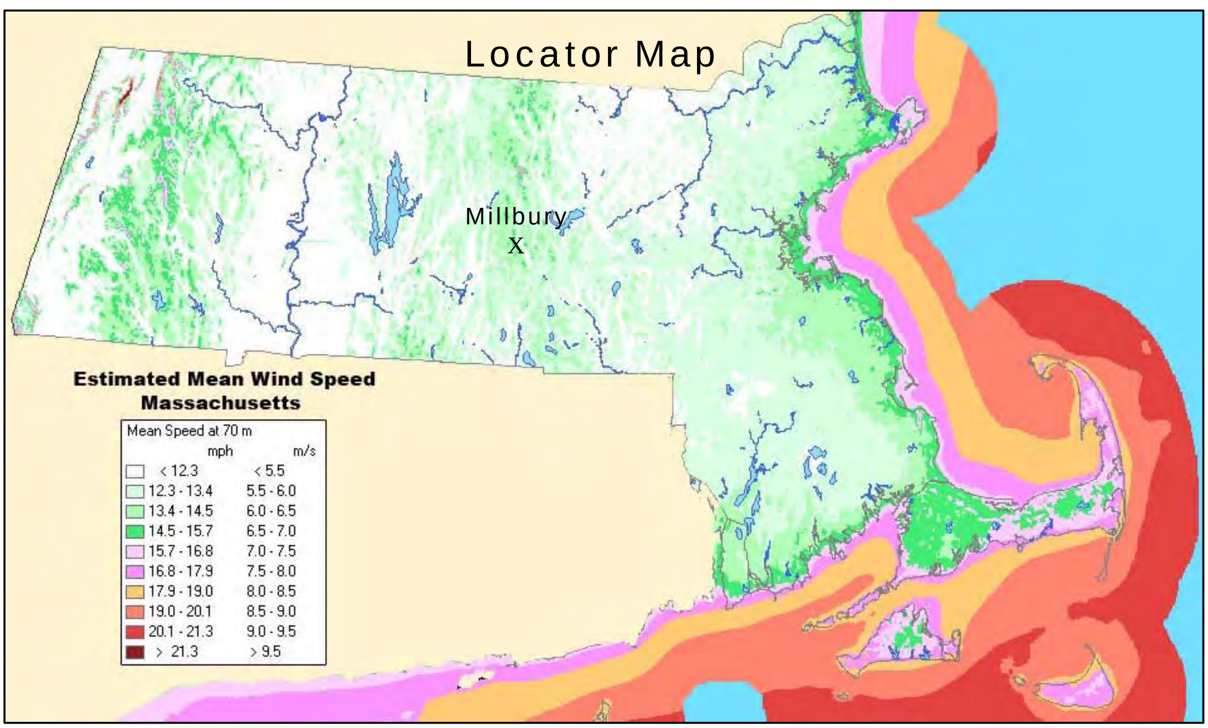
Siting Considerations for a Wind Turbine

Prepared by: Mary Knipe

Report date: June 30, 2009

Site visit date: May 22, 2009

Table of contents



I. Introduction

At the request of the Massachusetts Technology Collaborative, Mary Knipe of the University of Massachusetts Wind Energy Center (WEC), formerly the Renewable Energy Research Laboratory (RERL) has conducted an initial assessment of three potential wind sites in the town of Millbury, Massachusetts in order to evaluate the suitability for medium and utility-scale wind turbines.

Mary Knipe and Lynn Di Tullio of the WEC visited the potential wind turbine and/or wind-monitoring sites in Millbury along with Laurie Connors, the town planner for the town of Millbury.

The report is in the form of a broad "fatal flaw" analysis, which is designed to determine whether the town should move forward in considering a utility-scale wind project. Many factors are discussed in this report, not all of which present major influence at these sites; at the end of the report, the factors most significant for the proposed sites are summarized.

The "Locator Map" on the previous page is an AWS-TrueWind map of the estimated mean wind speeds in Massachusetts at 70 meters height. Areas of primary interest for utility-scale wind power have estimated mean wind speeds of 6.5 m/s or greater (dark green or more). On this map, the town of Millbury is marked with an "X".

Appendix A: Provides site specific details in tabular form.

Appendix B: Focuses on siting considerations for wind-monitoring towers (met towers) in Millbury. Wind monitoring is an important aspect in determining feasibility.

Appendix C: Provides wind resource maps, topographic maps, ortho (aerial) photos, and figures for the sites.

For more background information

This report assumes some familiarity with wind resource assessment, wind power siting, and other issues that arise with wind power technology. For an introduction to these areas, please refer to WEC's Community Wind Fact Sheets, which are available on the web at: http://www.ceere.org/rerl/about_wind/.

These sheets include information on the following subjects:

- Wind Technology Today
- Performance, Integration, & Economics
- Capacity Factor, Intermittency, and what happens when the wind doesn't blow?
- An Introduction to Major Factors that Influence Community Wind Economics
- Impacts & Issues
- Siting in Communities
- Resource Assessment
- Interpreting Your Wind Resource Data
- Permitting in Your Community

More information on wind turbine technology, policy, and general information can be found at these websites:

- American Wind Energy Association, www.awea.org
- Danish Wind Industry Association, www.windpower.org

Use of this report

This engineering report is intended to be used in consultation with the WEC as the town explores its options for wind development sites.

II. Sites Considered

Representatives of the town requested that three sites be evaluated for their suitability for utility scale wind power projects. General details related to the sites are listed below.

1. **Site 1:** Butler Farm- A 50-acre site containing meadow, old orchard, woods, office/meeting space.
2. **Site 2:** Davidson Sanctuary- 28-acre heavily wooded site containing a stream, rolling and some steep hills, and a spring.
3. **Site 3:** Stowe Meadows- 150-acre heavily wooded site containing hills, and a portion of Ramshorn Brook.

Detailed information about each site is located in **Appendix A**. For aerial photos, see **Appendix C**.

III. Wind Turbine Siting Considerations

Purpose

The purpose of this section is to consider whether there are any "fatal flaws" to siting a wind turbine at the proposed locations. For this discussion, we examine the potential for a "utility-" or "commercial-scale" (600 – 2,500 kW) turbine. The blade-tip heights of these turbines range between 250 and 450 feet. A medium-sized (250 kW or similar) turbine is also considered; these have blade-tip heights ranging from 150 to 250 feet.

The following characteristics are important in considering a wind turbine site, and are examined in this report:

A. Predicted Wind Resource

B. Noise

C. Environmental Issues and Permitting

D. Proximity to Airports

E. Wind Turbine Component Transportation & Access

F. Distance to Transmission/Distribution Lines for Power Distribution

G. Net-metering

H. Production Estimates for Selected Turbines

Each section below briefly describes why the characteristic is important in general and then discusses it in particular for these sites. Site information is also presented in tabular form in **Appendix A**. The corresponding lines are noted in parentheses after each subject line.

A. Predicted Wind Resource

About wind resource in general

The economics of wind power at a given site depend on many factors; one of the most important is wind speed. Understanding wind speed and turbulence is critical to estimating the energy that can be produced at a given site. The power in wind is related to its speed, and small changes or inaccuracies in estimated wind speed can mean big changes in annual energy production. For these reasons, wind speed is the first criterion to examine when considering a wind power project.

The primary motivation for investigating the winds at a proposed wind power site is to gain an improved understanding of project feasibility and returns, and thus a lowering of investment risk. Better, longer, and more site-specific data can help to minimize this risk. Additional information regarding the monitoring of wind resources can be found in **Appendix B**.

Wind speeds increase with elevation, so wind speeds are always given at a specific height. For first-pass production estimates, the mean wind speed at the proposed hub-height is used:

- For utility-scale turbines, refer to mean wind speeds at a height of 70 meters, which falls between common hub-heights of 65 and 80 meters.
- For medium-scale wind turbines, consider 50 meters.

When considering wind resource at this screening stage, we look at several factors:

TrueWind estimates: An initial site screening can use estimated wind speeds based on computer models by AWS TrueWind; (http://www.mtpc.org/renewableenergy/Community_Wind/wind_maps.htm), for more detail the wind is monitored on site. Wind monitoring logistics are discussed in **Appendix B.**

Existing wind data: High-quality wind data from nearby locations can be useful, primarily for correlation with on-site data. Concurrent, long-term, nearby data is most useful. Wind resource data collected by WEC are available on the web: http://www.ceere.org/rerl/publications/resource_data/.

Obstacles to wind: Obstacles cause both turbulence and slowing of the wind. If the surrounding landscape is built up, forested, or otherwise rough, turbulence will increase. These are important factors in site selection for a wind turbine because they affect its power production and longevity, and may affect the type of turbine that can function reliably a particular site.

TrueWind estimates of annual average wind speed (Lines 8-12)

The AWS TrueWind estimates of annual average wind speed at heights of 70 and 50 meters for the Millbury sites are listed in the table below.

AWS TrueWind Estimates of annual average wind speeds at selected heights

Hub height	Butler Farm	Davidson Sanctuary	Stowe Meadows
70 m	6.1 m/s	6.2 m/s	6.3 m/s
50 m	5.7 m/s	5.8 m/s	5.9 m/s

Other available wind data (Line 13)

In general, data can be used to reliably predict wind speeds within a one- to two-mile radius of where it was collected. This is not a hard rule; in fact, several things influence wind speeds at a particular site, including local weather patterns, surface roughness, elevation, etc. For the most accurate understanding of wind characteristics at a particular site, on-site wind monitoring is advisable.

The WEC has monitored wind speeds in the towns of Paxton and West Boylston. These towns are too far from Millbury in order to reliably predict wind characteristics there, especially given the complexity of the terrain at the proposed site. If the Town of Millbury pursues a utility scale wind project, then on-site wind monitoring is strongly advised.

Obstacles to wind flow (Lines 18-19)

AWS indicates that obstacle interference occurs downwind at a distance of about 10-20 times the obstacle height, up to a height of about twice that of the obstacle itself. Obstacle interference may be a siting constraint particularly if small- or medium-scale turbines are considered, which typically have hub heights in the range of 150 to 250 feet.

Wind shear, which is defined as the difference in wind speed and direction over a relatively short distance in the atmosphere, often occurs over areas featuring severe changes in elevation. Excessive wind shear can upset the normal operation of a wind turbine, and may decrease the turbine's lifetime.

Obstacles to wind flow at the sites are not necessarily fatal flaws for a utility scale wind project. In some cases, a taller turbine tower may be necessary to avoid the effects obstacle interference. In the event that a particular site is chosen for a utility scale wind project, wind data collected on-site would inform the turbine selection and siting decisions.

B. Noise

About Noise in general

Noise considerations generally take two forms, state regulatory compliance and nuisance levels at nearby residences:

A. *Regulatory compliance:* Massachusetts State regulations do not allow a rise of 10 dB or greater above background levels at a property boundary (Massachusetts Air Pollution Control Regulations, Regulation 310 CMR 7.10). Regulatory compliance will rarely impose a siting constraint on a large modern wind turbine, since in most cases modern turbines are quiet enough to meet these criteria easily.

B. *Human annoyance:* Aside from Massachusetts regulations, residences should also be taken into consideration. Any eventual wind turbine would be sited such that it would be minimally audible at the nearest residences. At this stage, to check for fatal flaws, the following rule of thumb can be used to minimize possible noise: Site wind turbines at least three times the blade-tip height from residences. Distances from mixed-use areas may be shorter. Note that noise considerations can influence not only <u>siting</u>, but also <u>sizing</u> decisions.

For example, this first-pass rule of thumb tells us that a turbine with a 77-meter rotor diameter on a 60-meter tower should be about 300 meters (60 + 77/2 = 98.5, times 3 comes to ~300 m or ~1000 feet) from residences. Other turbine sizes would suggest other distances. Note that many factors affect the transmission of sound and that this is a rule of thumb only.

The three-times-blade-tip height suggestion is not an inflexible rule; wind turbines can be and often are positioned closer to residences. This initial recommendation is meant to be the beginning of a conversation among project stakeholders. If the town would like to consider a site closer than this distance, then a more detailed sound study could be performed on site. This study would take into account the actual ambient levels and terrain at the site and would then supersede the rough rule of thumb.

Noise at the Millbury sites (Lines 20-21)

There appear to be locations at each of the sites in Millbury that will be 300 meters to a residence which is an adequate distance to residences for utility-scale turbines. Residence buffer maps for medium and utility scale turbines at each site are in **Appendix C**.

Note: These recommendations are not hard rules, but rather first pass estimates based upon the "three time blade-tip height" guideline. If the town pursues a wind project, it is advisable to complete a detailed noise study which takes into account actual ambient sound levels and terrain at the site. This study would supersede the rule of thumb.

C. Environmental Issues and Permitting

Environmental permitting in general

At this early stage, the following items are reviewed:

- State designations of Natural Heritage & Endangered Species Program (NHESP), Open Space, Wetlands, and other land-use designations or restrictions
- Massachusetts Audubon Society Important Bird Areas (IBA)
- Current or former landfill

The permitting implications of these designations are not clear-cut in all cases. For instance, a "Core Habitat" designation may require a filing with the NHESP, but does not eliminate the possibility of a wind turbine installation. Compatibility of some land-use restrictions with wind power has not yet been determined.

Please note that this report is based on publicly available information and conversations with town representatives. There may, however, be other land-use restrictions, unregistered wetlands, etc. of which WEC is not aware. It is the town's responsibility to ensure the environmental appropriateness of the chosen site.

Environmental permitting at the Millbury sites (Lines 22-26)

All of the sites in Millbury are in the Blackstone River National Heritage Corridor Important Bird Area. There are wetlands on or bordering the parcels. According to the town's site survey application the Davidson Sanctuary is designated as a NHESP Priority Habitat of Rare Species and Estimated Habitat of Rare Wildlife and a portion of the property is also designated as a BioMap Supporting Natural Landscape. Davidson Sanctuary has trails that are maintained and used often. The Stowe Meadows site is conservation land and is designated as a NHESP BioMap Supporting Natural Landscape.

Although these designations are not expected to be a fatal flaw for the proposed sites, the WEC recommends investigating all applicable environmental designations as soon as possible.

D. Proximity to Airports

About airspace in general

The form "7460-1 - Notice Of Proposed Construction or Alteration" must be filed with the Federal Aviation Administration (FAA) before construction of any structure over 200 feet (i.e. all utility-scale wind turbines). The corresponding form for the Massachusetts Aeronautics Commission (MAC form E10, Request for Airspace Review) must also be filed.

These filings are reviewed by the FAA and the Department of Defense (DOD) for any potential obstruction or interference with air traffic, aircraft navigation/communication systems, military RADAR, etc. This process typically takes about three months for a first response. We recommend that these filings, or a detailed analysis of airspace issues, be undertaken as soon as possible if a site is seriously being considered for a wind turbine.

The U.S. Air Force recently published a policy to "contest … windmill farms within radar line of sight of the national Air Defense and Homeland Security Radars." In Massachusetts, these include the Long Range Radar Sites in North Truro, Boston, and in the foothills of the Berkshires.[1] Nevertheless, wind projects have been approved within 60 nautical miles of these long-range radar sites.

While we cannot predict the FAA or DOD response, most sites that are not within about 3-5 miles (5-8 kilometers) of a public or military airport are not considered a hazard to air traffic. At this preliminary stage, we look for fatal flaws by considering the distance to public and military runways.

Note that the FAA requires that any structure over 200' be lit. All utility-scale wind power installations are lit.

Airspace at the Millbury sites (Line 27)

No major airports are located within 8 kilometers (~5 miles) of the proposed sites.

The Radar Pre-Screening Tool, found on the FAA website, evaluates the potential impacts of obstructions on Air Defense and Homeland Security radars or Weather Surveillance Radar-1988 Doppler radars. A preliminary screening has indicated that a wind project at the proposed sites would likely impact Air Defense and Homeland Security Radars and weather radar operations. An aeronautical study would be required in the event that a wind project is planned for any of the proposed sites.

Any potential impacts on the Long Range Radar system would be reviewed as part of the 7460-1 process. If any of the sites are considered for a wind turbine project, then early filing of the FAA 7460-1 form is recommended.

E. Wind Turbine Component Transportation & Access

About transportation and access in general

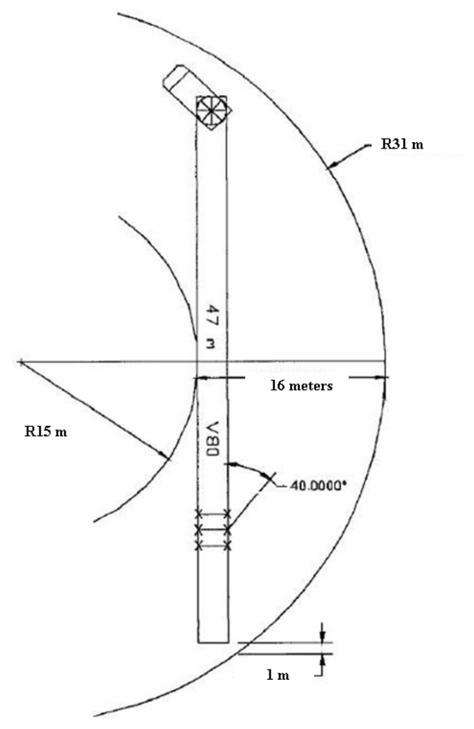
With blades up to 130 feet long, modern wind turbines require transportation on roads with fairly large turning radii and only small changes in slope. The illustration on the next page shows the set of turning radii (in meters) required for transporting one of the 47-meter turbine blades of a Vestas V80, a 1.8 M W

[1] The FAA offers a "Long Range Radar Tool" that displays these 60 nautical mile radius areas. See their Obstruction Evaluation/Airport Airspace Analysis (OE/AAA) website: https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showLongRangeRadarToolForm

machine. Transportation accessibility for turbine installation is an important consideration for a potential wind turbine site.

Transportation and access to the Millbury sites (Line 17)

While transportation costs are certain to factor in substantially to the overall economics of a wind power project in Millbury, access does not appear to be a fatal flaw at this time. If the town decides to pursue a project, it is advisable that an access plan, which includes detailed transportation routes and cost estimates, be completed as a next step. The extent to which road construction and improvements would be needed would depend on the size of the turbine chosen for the site.



F. Distance to Transmission/Distribution Lines for Power Distribution

About power distribution in general

The power generated by any installed wind turbine must be transported to adequately sized lines, either on the "load side" of a meter, or out to transmission or distribution lines. Proximity to utility distribution or transmission lines is an important cost consideration for a wind turbine project.

Power distribution at the Millbury sites (Line 16)

Millbury's power is provided by National Grid. There is a 69 kV transmission line 0.5 mile to the east of the Stowe Meadow site (1 mile from the Davidson Sanctuary site). There is also a 69 kV transmission line to the west of the Butler farm site approximately 1.4 miles away. More detailed information about lines in proximity to the sites was unavailable at the time of this report. Whether or not the local power lines at the sites would be in need of upgrading depends upon both the rating of the lines as well as the size of the intended wind project. This issue would be explored in greater detail in a later feasibility study.

Transmission lines in Millbury are shown in **Figure 2** in **Appendix C.**

G. Net Metering

Massachusetts regulations allow customer-sited wind projects of up to 2 MW in size to qualify for net-metering. In this manner, towns are able to offset the retail cost of electricity consumed at municipal sites with power produced by a wind project. Any net excess generation would then be credited towards the town's energy bill during the following month. Further, "virtual" net-metering provisions allow towns to aggregate and offset multiple municipal loads with power produced by a single wind project, so long as their meters are under the same distribution company and located in the same ISO-NE load zone. Recoverable electricity costs include associated default service, transmission, transition, and distribution kWh charges. Other specifics will be spelled out in the forthcoming rulemaking process by appropriate regulatory authorities (Department of Public Utilities).

H. Production Estimates for Selected Turbines

The following table provides rough estimates of energy production at the proposed sites for wind turbines in the range of 250 kW to 2.0 MW.

These estimates are based upon the following general capacity factor correlation, which provides a reasonable approximation for wind speeds between 4 and 10 m/s.*

$$capacity\ \ factor = 0.087 \times V_{ave}(m/s) - \frac{P_{rated}(kW)}{D^2(m)}$$

Where:

V_{ave} = average wind speed at the site
P_{rated} = rated power of the turbine
D = rotor diameter of the turbine

*Equation taken from Renewable and Efficient Electric Power Systems by G.M. Masters, 2004.

The capacity factor estimates were then used to approximate the production of various turbines at the proposed sites. The results of these calculations are presented in the table below.

Power Production Estimates					
Wind Turbine (rated power)	**Hub Height (meters)**	**Blade Tip Height (meters)**	**Estimated Annual Mean Wind Speed at Hub Height (m/s)**	**Estimated Capacity Factor**	**Estimated Annual Energy Production (kWh/year)**
FL 250 (250 kW)	42	57	5.5	0.20	394,200
Enertech E48 (600 kW)	50	74	5.8	0.24	1,261,400
EWT D900 (0.9MW)	50	77	5.8	0.19	1,135,300
Nordic N1000 (1 MW)	70	99.5	6.2	0.25	1,971,000
GE 1.5sl (1.5 MW)	61.4*	99.9	6.0**	0.27	3,193,000
Vestas 2.0 (2.0 MW)	67*	107	6.2***	0.22	3,468,900

*Other tower heights are available.

**Wind Speed Estimate for height of 60 meters used.

***Wind Speed Estimate for height of 70 meters used.

Readers of this report should keep in mind that these production figures are *extremely* rough at best, and are meant to provide the Town of Millbury with conservative estimates of production for various turbines at the proposed site. Note also that the equation used in this calculation is only general correlation based upon few parameters, and these numbers are not an adequate comparison of performance between turbine models.

IV. Conclusions

The town of Millbury is interested in a wind power project at three locations on town land. It is estimated that all of the sites feature fair wind speeds for a utility-scale wind project. The sites are near residences but appear to have some areas that are an adequate distance for the "three time blade-tip height" guideline for noise impacts from utility-scale turbines. The potential need to construct access roads into the Millbury sites will add to the overall costs of the project.

All of the Millbury sites could accommodate a medium scale or full utility scale wind turbine. Each site has room for more than one wind turbine. The number possible would depend on the size of the turbine and other factors such as terrain. It may be easier to find a site for a small utility scale turbine or a medium scale turbine since the residences nearby limit the area available for siting of utility scale turbines more severely. This is especially true at the Davidson Sanctuary and Butler Farm sites. Project proponents should be aware that smaller projects typically have longer payback periods.

The presence of on-site loads is no longer given as much importance due to the recently adopted 'virtual' net-metering provisions which are likely to allow municipalities to aggregate and off-set multiple municipal loads; further, these loads need not be located in the same location as the generation facility. As mentioned previously, the precise implications of the legislation will be determined in the forthcoming rulemaking process by appropriate regulatory authorities.

Next steps (Line 29)

After deciding whether or not to pursue a wind project at a proposed site, establishing full feasibility (which may include wind resource monitoring) is an important next step.

The wind monitoring process and siting considerations are discussed in **Appendix B**. In addition to wind monitoring and public outreach, some, though not necessarily all, of the following site-specific items related to pursuing wind power at the sites would be explored in a full-feasibility study.

- Preliminary economic analysis
- File FAA form 7460-1
- Local ordinances related to structure heights
- Logistics and costs of transporting turbine components and installing equipment
- Noise and electrical interconnection studies

A preliminary economic analysis may be critical in helping the Town of Millbury decide upon a site. For an introduction to economic issues, please consult the WEC's Community Wind Fact Sheet related to community wind economics, which is available on-line:

An Introduction to Major Factors that Influence Community Wind Economics

Appendix A: Site Survey Data

Key:

Green shading: Particularly **positive** aspect that distinguishes this site from the others.

Yellow shading: Significant **constraints**: these items may force micrositing choices, or may make the site difficult.

Red shading: Fatal flaws: these make placement **impossible** at this site.

Refer to the report "Wind Power in Millbury: Siting Considerations for a Wind Turbine" for a discussion of these data.

Table 1: Summary Data Table

Millbury				
		Site 1: Butler Farm	**Site 2:** Davidson Sanctuary	**Site 3:** Stowe Meadows
Site Overview				
1	Description, current land use	Meadow	Heavily wooded	Heavily wooded
2	Address	44 Singletary Road, Millbury, MA	West Main Street, Millbury, MA	Carleton Road/ Stowe Road, Millbury, MA
3	Owner	Town of Millbury	Town of Millbury	Town of Millbury

Millbury				
		Site 1: Butler Farm	**Site 2:** Davidson Sanctuary	**Site 3:** Stowe Meadows
4	NAD 83, lat & long	42.1667° N, -71.7914° W	42.1803°N, -71.8104° W	42.187803, -71.795503
5	Degrees, Min., Sec.	42°10'0.12"N, 71°47'28.96"W	42°10'49.13"N, 71°48'37.48"W	42°11'16.09"N, 71°47'43.81"W
6	Elevation (feet)	759	721	658
7	Notes	-	-	-
Wind Speeds				
Estimated Mean Speeds* in m/s **(to convert m/s to mph, multiply by 2.24)**				
8	At height of 100 m	6.6 m/s	6.7 m/s	6.7 m/s
9	At height of 70 m	6.1 m/s	6.2 m/s	6.3 m/s
10	At height of 50 m	5.7 m/s	5.8 m/s	5.9 m/s
11	At height of 30 m	5.1 m/s	5.3 m/s	5.4 m/s
12	Wind Speed Summary (poor, fair, good, very good):	Fair	Fair	Fair
13	Existing wind data	Closest wind data is in Paxton	Closest wind data is in Paxton	Closest wind data is in Paxton

Millbury				
		Site 1: Butler Farm	**Site 2:** Davidson Sanctuary	**Site 3:** Stowe Meadows
Wind Turbine Considerations:				
Economic				
14	On-site Electric Loads	Yes	No	No
15	Electric Loads, kWh/year	687 kWh (July 1, 2007 – June 30, 2008)	-	-
16	Distance to Distribution/ Transmission lines**	0.4 miles to transmission,	1 mile from transmission lines	0.5 miles to transmission lines
17	Access for blade transportation**	Does not appear to be a fatal flaw	Does not appear to be a fatal flaw	Does not appear to be a fatal flaw
Obstructions to wind				
18	Terrain	70% wooded	Woodlands and streams	Heavily wooded
19	Obstacles to wind	Mature trees	Mature trees	Mature trees
Noise				
20	Nearby residential areas:	Yes	Yes	Yes
21	Radius to residences: (m): (ideally >~300m for utility scale‡)	Only some areas 300 meters	Only some areas 300 meters	400 meters, some residences nearby

Millbury				
		Site 1: Butler Farm	**Site 2:** Davidson Sanctuary	**Site 3:** Stowe Meadows
Environmental Permitting †				
22	Designated by the Natural Heritage & Endangered Species Program as a Core Habitat or a Supporting Natural Landscape?	No	This site is designated as a NHESP Priority Habitat of Rare Species and Estimated Habitat of Rare Wildlife. A portion of the property is also designated as a BioMap Supporting Natural Landscape.	The property is designated as a NHESP BioMap Supporting Natural Landscape.
23	Designated by the DEP as Wetlands?	None on the parcel	Some on the parcel	Some on the parcel
24	Designated by the Massachusetts Audubon Society as an Important Bird Area?	All Millbury sites are in Black Stone River Valley National Heritage Corridor IBA	All Millbury sites are in Black Stone River Valley National Heritage Corridor IBA	All Millbury sites are in Black Stone River Valley National Heritage Corridor IBA
25	Is the site a current or former land-fill? *(WEC does not install met towers on landfills)*	No	No	No
26	Other land-use restrictions?	-	-	-
Other permitting				
27	Distance to airport(s)	There are no major airports within 5 miles of the proposed sites. 12 miles to Worcester Regional Airport	There are no major airports within 5 miles of the proposed sites. 12 miles to Worcester Regional Airport	There are no major airports within 5 miles of the proposed sites. 12 miles to Worcester Regional Airport
Wind Turbine: Conclusions				
28	***Primary constraint(s):*** *If this site is of interest for a utility-scale wind turbine, what factors will most affect feasibility and/or micrositing?*	-Proximity to residences	-Current heavy recreational use -Proximity to residences	-No road access -Proximity to residences

Millbury				
		Site 1: Butler Farm	**Site 2:** Davidson Sanctuary	**Site 3:** Stowe Meadows
29	***Next step / To be determined*** *To pursue wind power at this site, these items should be explored first (along with wind monitoring and public outreach):*	- Preliminary Economic analysis - File FAA form 7460-1 for the desired turbine height - Investigate logistics of transporting turbine components and installation equipment to site - Preliminary Electrical Interconnection study	- Preliminary Economic analysis - File FAA form 7460-1 for the desired turbine height - Investigate logistics of transporting turbine components and installation equipment to site - Preliminary Electrical Interconnection study	- Preliminary Economic analysis - File FAA form 7460-1 for the desired turbine height - Investigate logistics of transporting turbine components and installation equipment to site - Preliminary Electrical Interconnection study
30	***Recommendation*** *Should the town consider this site for a utility-scale wind turbine?*	Yes	Yes	Yes
	For a medium-scale wind turbine? ***See also the discussion section.***	Yes	Yes	Yes
31	***Multiple Turbines*** *If the town is interested in installing more than one utility-scale turbine, how many could fit at this site?*	Two	Two	Two, maybe three

Millbury				
		Site 1: Butler Farm	**Site 2:** Davidson Sanctuary	**Site 3:** Stowe Meadows
Met Tower: Siting Factors				
32	Space availability & level terrain	Level fields available	Heavily wooded, limited level terrain	Heavily wooded, limited level terrain
33	Power lines or other obstructions to met tower. *(Met tower must be set at least 1.5 x the tower height away from power lines.)*	No	No	No
34	Obstacles to wind	Mature trees	Mature trees	Mature trees
35	Clearing requirements	Some clearing may be needed at the edge of the fields.	Yes, there are no open areas	Yes, there are no open areas
36	Soil quality – for met tower anchors	Woodbridge/Paxton fine sandy loams	Paxton fine sandy loam	Paxton/Canton fine sandy loam (some areas are extremely stony), freetown muck
37	Road Access – for met tower installation	There is an access road to both potential met tower sites	No Access roads available	Access possible via gas line right of way off of Auburn Road
38	Security	Site is used by the public but does not appear vandalized.	Popular recreation site	Remote site with unused trails
39	Existing towers on or near site	Yes, Fire communications tower	No	No
40	Distance to AC power if lighting is required	136 meters (446 feet) to house	-	-
41	Compatibility: If this site were chosen for a wind turbine but not a met tower, where else could wind be monitored?	Stowe Meadows is a little over a mile away.	Stowe Meadows is less than a mile from this parcel.	Butler Farm is a little over a mile away.

Millbury				
		Site 1: Butler Farm	**Site 2:** Davidson Sanctuary	**Site 3:** Stowe Meadows
Met Tower: Primary Constraint				
42	What factors will most affect feasibility and/or siting of a met tower here?	Permission from neighboring parcel owner to site met tower in field near top of the hill.	Road access	Road access
Met Tower: Recommendation				
43	Recommended site:	Yes	No	Yes
44	Recommended met tower height (meters)	50	50	50

Notes:

* Estimated Mean Annual Wind speeds, in m/s: based on the AWS-TrueWind computer models.

‡ Note that this will vary based on location, turbine size, terrain, ambient noise, etc.

** These items can have significant impacts on installation costs. The intention of this report is not to estimate the costs of these items, but only looks for indications of fatal flaw. However, if one appears to be an issue for the chosen site, it may be advisable to study it further relatively early in the project.

† Please note that this report is based on publicly available information and conversations with site owner representatives. There may, however, be other land-use restrictions, unregistered wetlands, etc. of which WEC is not aware. It is the town's responsibility to ensure the environmental appropriateness of the chosen site.

Appendix B: Wind-Monitoring Logistics

Traditionally, wind is monitored for about a year with a met tower. Some sites may be suitable for other types of monitoring, though this section concentrates on the siting of a met tower. Figure 1 in **Appendix C** is a schematic of a met tower.

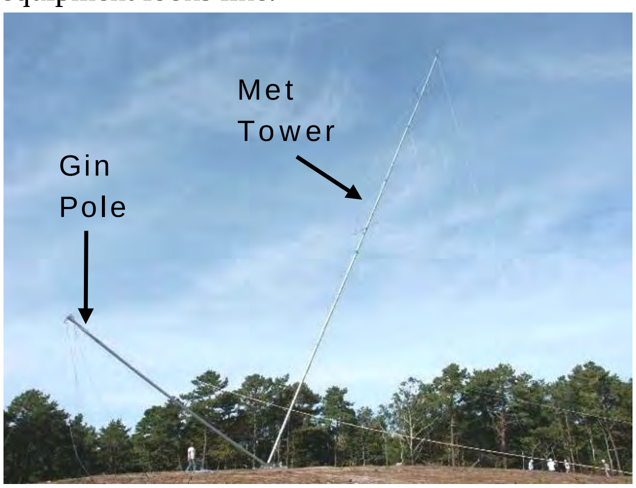
About met towers

Most met towers are temporary structures that do not require a foundation and are supported by guy wires in 4 directions. Towers are usually 40 meters (131') or 50 meters (164') tall. In most cases, standard utility anchors are used to anchor the guy wires. The number and type of anchors required depends on the particular site. They will be proof-tested at installation to make sure they can hold the required load.

The tower is raised using a winch; no crane is required. The tower consists of a set of 6" diameter pipes that stack together; the whole set-up can be brought in on a pick-up truck.

The pictures on this page give an idea of what this equipment looks like.

A met tower base-plate sits directly on the ground.



In the process of raising a met tower, the "gin pole" gives the winch leverage to lift the tower.

Typical 6-foot-long utility screw-in anchor

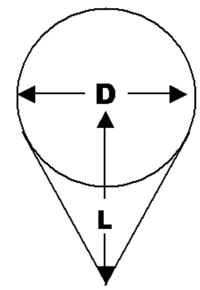
WEC's truck loaded with the sections of a 50-meter met tower

An anchor, installed, with 2 guy wires attached

Space required for a met tower

Clearing is necessary both for met tower installation and to reduce ground effect disturbance during data collection. The cleared area is shaped like a circle for the guy wires, with an additional "wedge" in which the tower is assembled before being raised. An additional buffer is then cleared around that area to leave some area to work. The **minimum** cleared areas for guyed towers are:

Tower Height	D (Guy Diam.)	L (Space to lay the tower down)	Approximate total envelope to be cleared
40 meter (131')	160 feet	135 feet	240 x 190 feet
50 meter (164')	240 feet	165 feet	310 x 270 feet
60 meter (197')	400 feet	198 feet	350 x 350 feet
Dimensions of a football field, for comparison:			*300 x 160 feet*



In general, a larger cleared area reduces the disturbances seen by the instruments, and improves data quality. Therefore, **a cleared area larger than the minimum size is preferred**.

While it is not necessary to pull stumps, removing as much obstruction and underbrush as possible will facilitate the raising of the tower. Guy-wires will be pulled across this field, and any obstacles that entangle the wires make the job more difficult.

It is also essential that there not be any electric or telephone wires within 1.5 times the height of the tower, i.e. 200 feet of a 40 m tower, 250 feet of a 50 m tower or 300 feet of a 60 m tower.

Trees must be cleared at least the height of the trees away from the anchors to eliminate the danger of a falling tree hitting the guys. For example, a 50-foot-tall tree within less than 50 feet of an anchor must be cut down.

Note that it is possible to use some of this cleared area after the met tower has been installed; in other words, after installation, the space is left largely open.

Met Tower Siting Considerations

Generally speaking, wind speed and turbulence should be monitored at, or as close as possible to, the preferred wind turbine site. However, met tower siting involves certain additional considerations, and it may not always be possible to monitor wind at the proposed turbine site. This section provides an overview of the feasibility of placing a met tower in Millbury.

Space Availability at the Millbury sites (Line 32-34)

At Butler Farm there was a field near the farmhouse that would be large enough for a met tower installation but the field is down the hill from better winds. At the top of the hill there is a small police communications tower. Another field just outside to the north of the boundary of the Butler Farm is a much better site for a met tower. (See figure 8 for layout of met towers at the two fields. The town may be able to work out an agreement with the neighboring property owner to use the field for a met tower. The Stowe Meadow site would require extensive clearing of trees to site a met tower. Figure 13 shows a potential area to place a met tower. The Davidson Sanctuary has foot paths and a potential site is indicated on the topographic map shown in figure 18. Davidson Sanctuary is more heavily used by recreational visitors and it was recommended that the other sites be considered first for wind monitoring since clearing trees here would be unpopular.

Clearing requirements (Line 35)

Stowe Meadows and the Davidson Sanctuary are heavily wooded and would require extensive clearing. There is an underground gas line going through the Stowe Meadows parcel which provides a 30-foot wide path that runs north-south which clear of trees. This may provide for truck or ATV access off of Auburn Road to an interior site for the installation of a met tower. No other paths or roads are available at the Stowe Meadows parcel. There are no utility lines on the parcel. Some clearing may be needed to site a met tower at the Butler Farm especially if a 60-meter tower is required.

Soil quality & anchor requirements (Line 36)

The soils at the sites were not tested, though it is not anticipated that soil quality would be a fatal flaw for these sites.

Accessibility for met tower installation (Line 37)

The Davidson Sanctuary and Stowe Meadows sites are heavily wooded and have no access roads. The underground gas line that runs north-south across the Stowe Meadows parcel is clear of trees. This may provide access to an area which could be cleared of trees for a met tower installation. Butler Farm has a field that is easily accessible by truck. The upper field on the neighboring property is also accessible by truck by an unpaved cart path.

Permitting: Local approval process

Some local permits may be required for the temporary met tower, such as building permits, zoning variances, DigSafe, etc**.**

Nearby airports & FAA restrictions for met towers

Most met towers are shorter than 200 feet and do not require registration with the FAA. If a 60 m tower is needed then FAA approval will be required.

Lighting

The FAA <u>does not require</u> met tower lighting at these sites if the tower is less than 200 feet.

Proximity of anemometry & turbine (Line 41)

While wind resource assessment directly on the proposed turbine site is preferred, it is not required. If wind data are collected in one spot, but a site for a wind turbine is later chosen in another nearby location, then a computer model that considers the wind data and terrain can be used to extrapolate the data from one location to the other. As the two sites become farther apart, however, the level of certainty in the data goes down and, consequently, the amount of risk in the investment increases. It is difficult to predict the rate at which the certainty changes with distance; this can only be estimated on a site-specific basis.

If the proposed turbine and met tower sites are close enough, measurements at one site could be used to evaluate the feasibility of a turbine at the other. Thus, an understanding of preferred turbine spots is necessary for choosing a met tower site.

The most-accurate and site-specific data would be provided through monitoring at the exact location of the intended wind project

Met tower size recommendation (Line 43-44)

There are usually two size options for met towers: 40-meter and 50-meter. The choice of a met tower depends on the site. If wind monitoring were pursued at the proposed sites, a 50-meter met tower is recommended. If required, a 60-meter tower could be used.

Conclusion: met tower siting recommendations

On-site wind monitoring is strongly advised where larger turbines are being considered, especially at sites featuring steep changes in elevation. Wind-monitoring options should be discussed further depending on the site and the turbine size considered. If the town is interested in installing a utility-scale wind turbine in Millbury, then on-site wind monitoring is recommended.

If a small- to medium-scale turbine is considered, wind monitoring is beneficial but may not be essential.

Appendix C: Maps, Photos, and Figures

Refer to the report "Wind Power in Millbury: Siting Considerations for a Wind Turbine" for a discussion of the following maps, photos, and figures.

Source for base maps:

Ortho (aerial) photographs are from the MassGIS website, www.mass.gov/mgis/dwn-imgs.htm. The entire commonwealth was photographed in April 2005, when deciduous trees were mostly bare and the ground was generally free of snow.

Topographic maps, roads, and town boundaries are also from MassGIS.

Mean wind speeds are AWS-Truewind's estimates for New England, 2003.

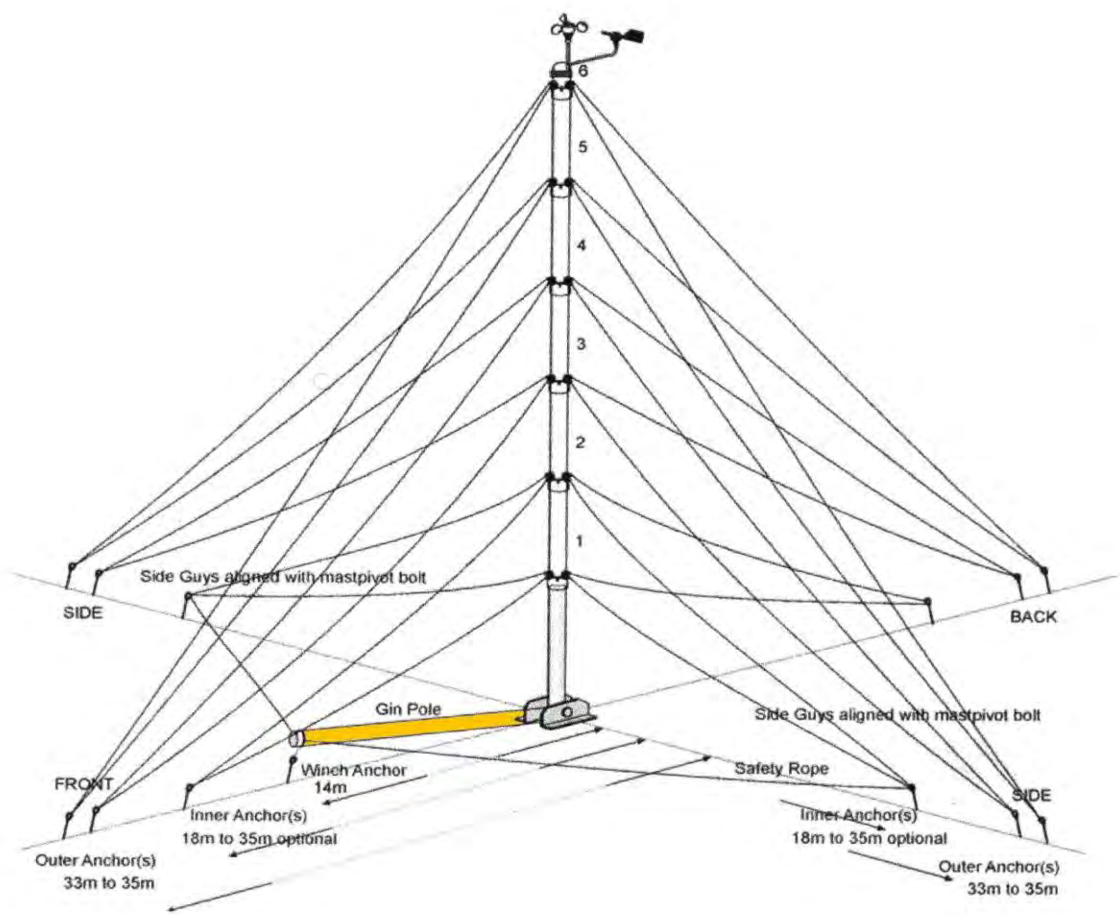


Figure 1: Guy line layout for a 50-meter met tower from Second Wind, Inc.

Millbury Sites

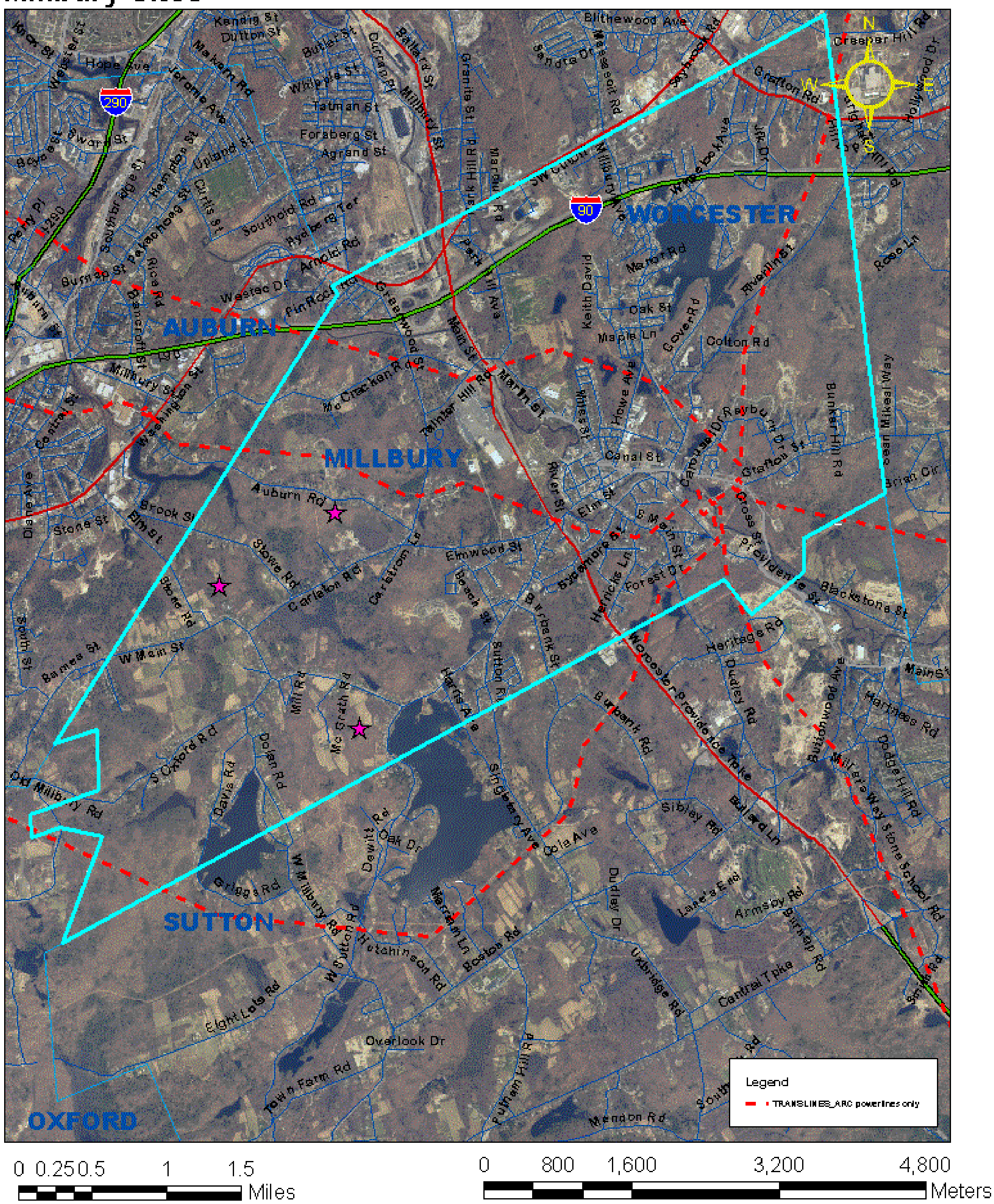


Figure 2: This figure displays an orthophotograph of the town of Millbury. Transmission lines are shown with a red dashed line. The proposed wind turbine sites are marked with a pink star.

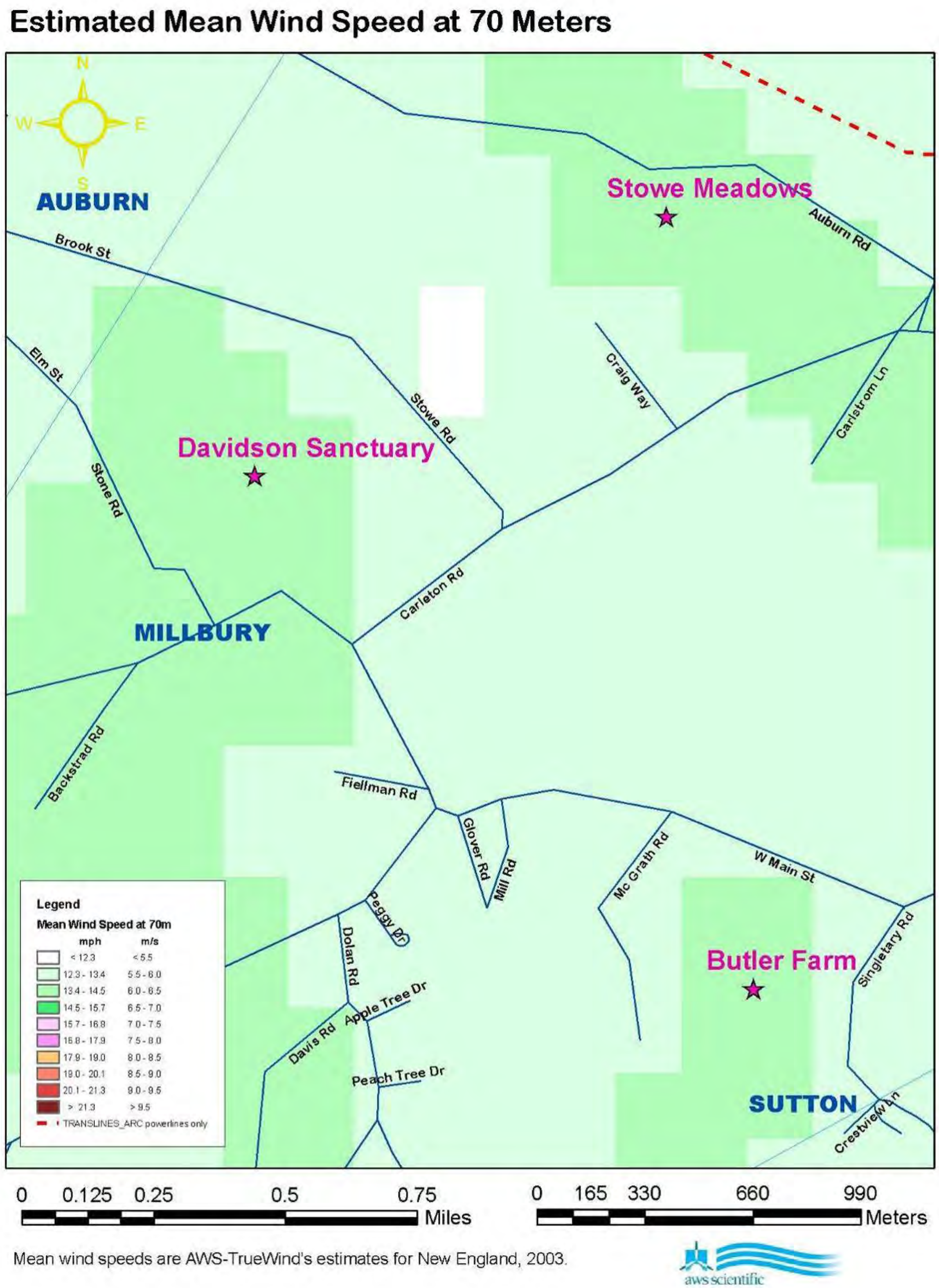


Figure 3: This figure displays AWS annual mean wind speeds at 70 meters. The proposed wind turbine sites are labeled and marked with pink stars.

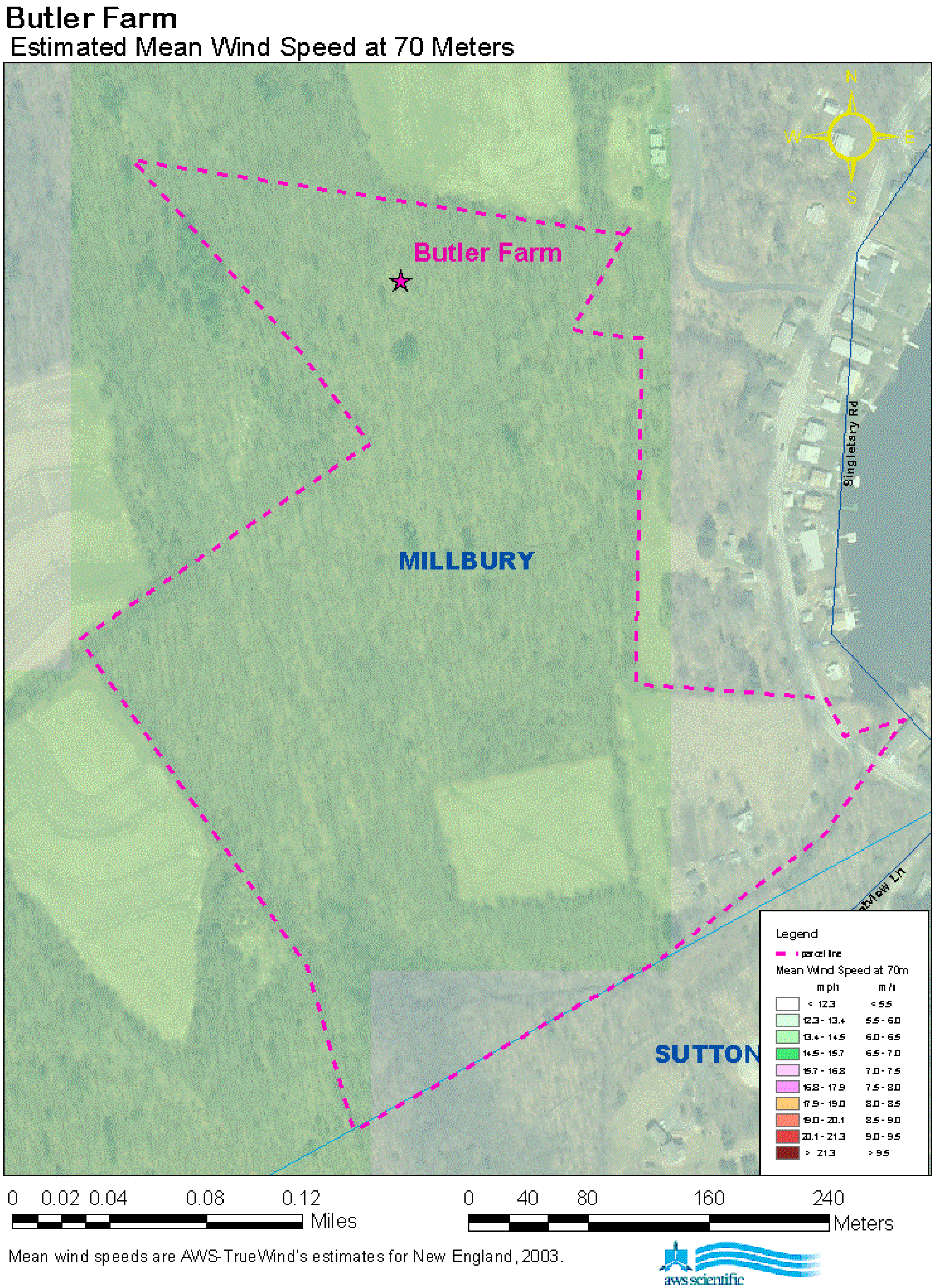


Figure 4: This figure displays an orthophotograph with a layer showing the AWS annual mean wind speeds at 70 meters. The pink dashed line shows the approximate boundary of the parcel.

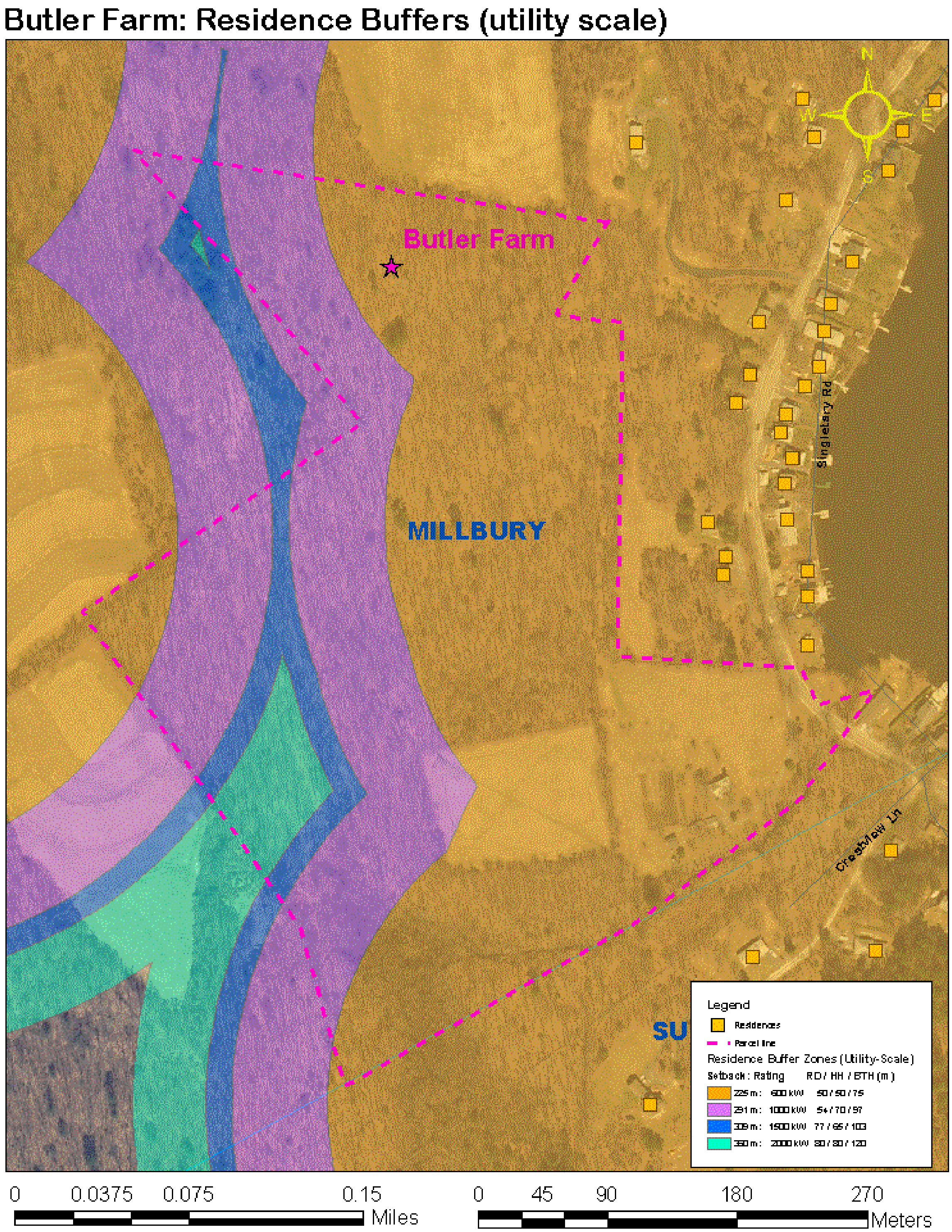


Figure 5: This figure displays an orthophotograph with a layer showing the residence buffers for utility-scale turbines near the Butler Farm site.

Butler Farm: Residence Buffers (medium scale)

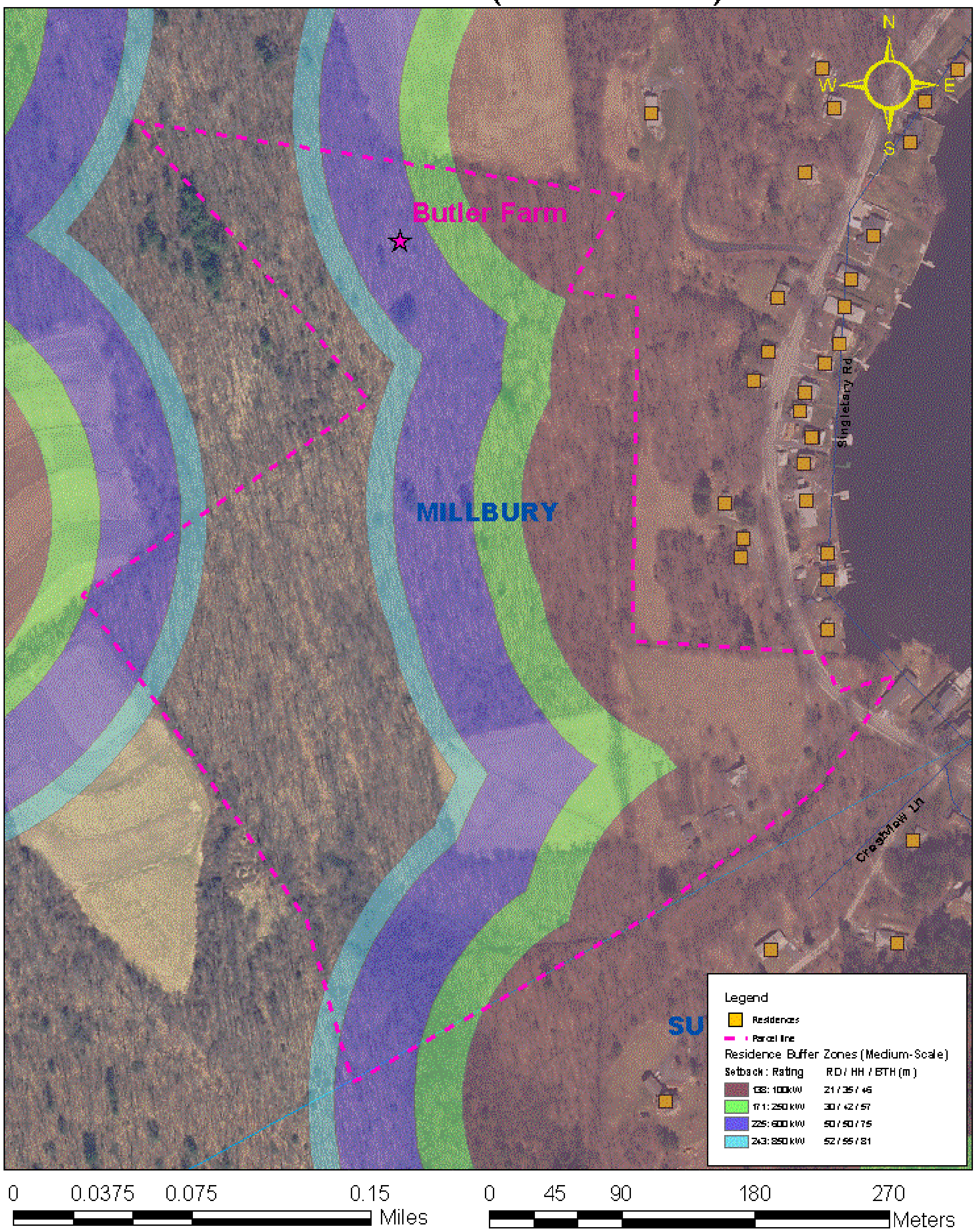


Figure 6: This figure displays an orthophotograph with a layer showing the residence buffers for medium-scale turbines near the Butler Farm site.

Butler Farm:
Habitat and Conservation, Protected and OpenSpace Lands

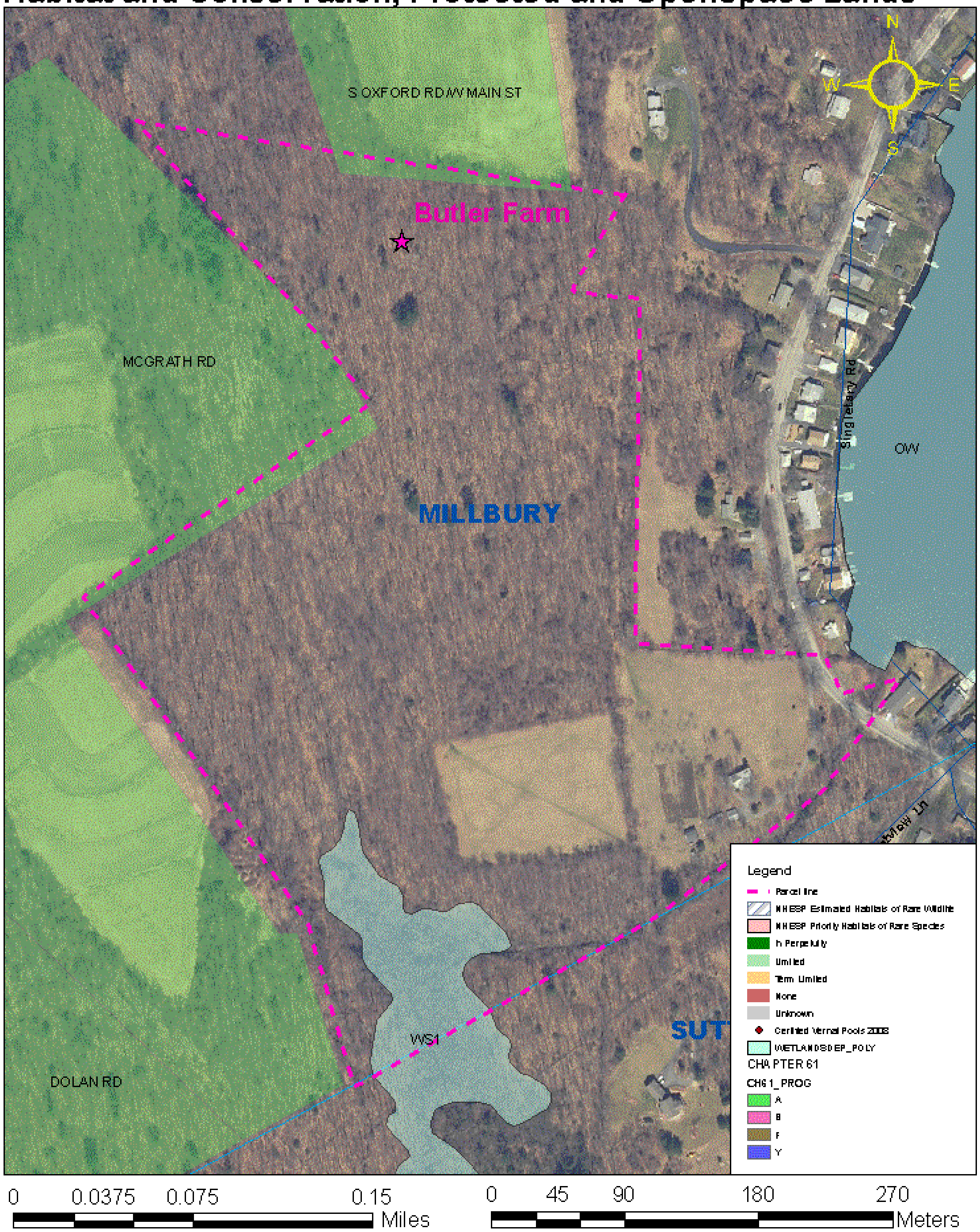


Figure 7: This figure displays an orthophotograph with a layer showing the wetlands and habitat designations near the Butler Farm site.

Butler Farm: Topography

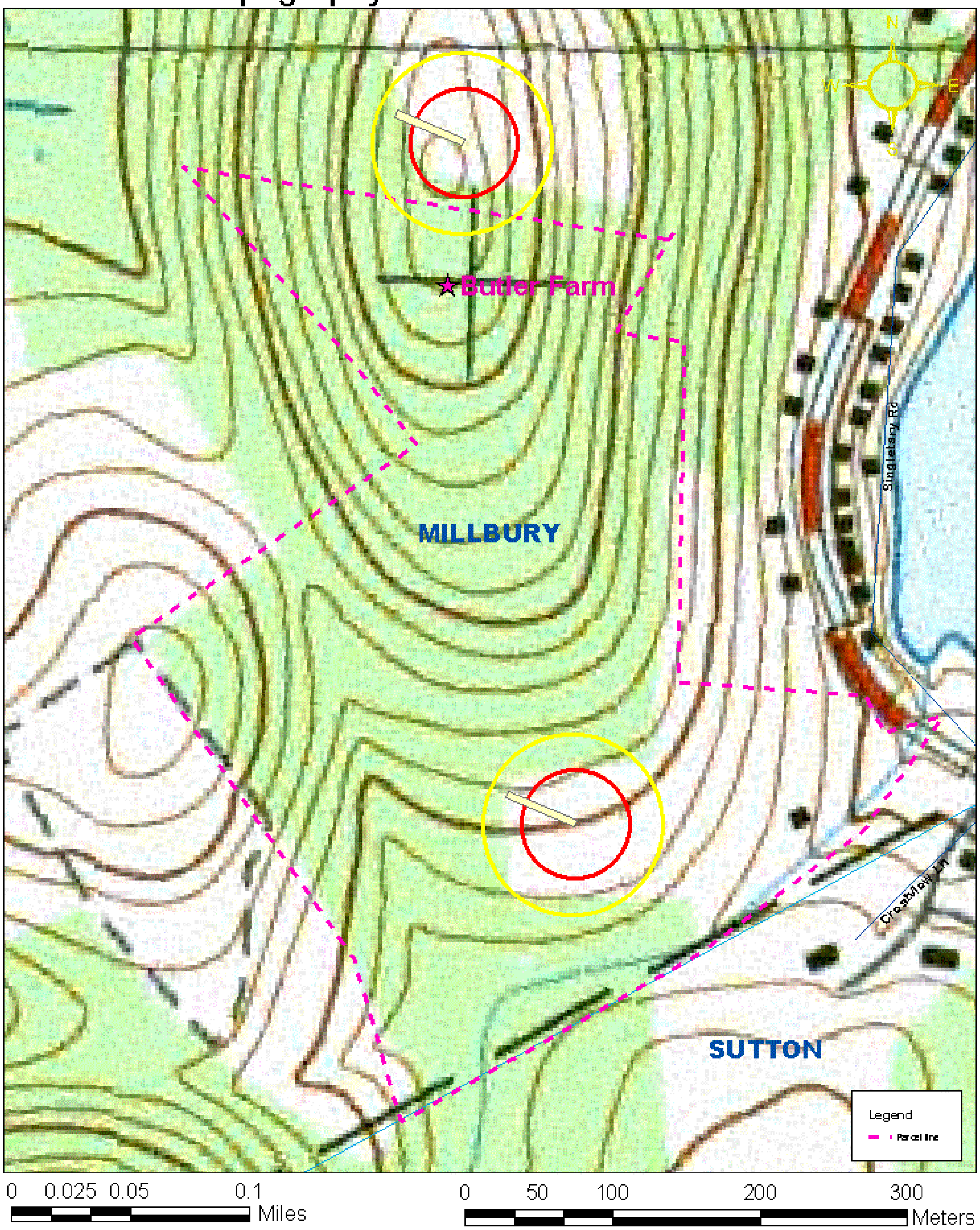


Figure 8: This figure displays the topography at the Butler Farm site. The red circles show a layout of a 50 meter tower and the yellow circle indicates the layout of the anchors for a 60 meter tower.

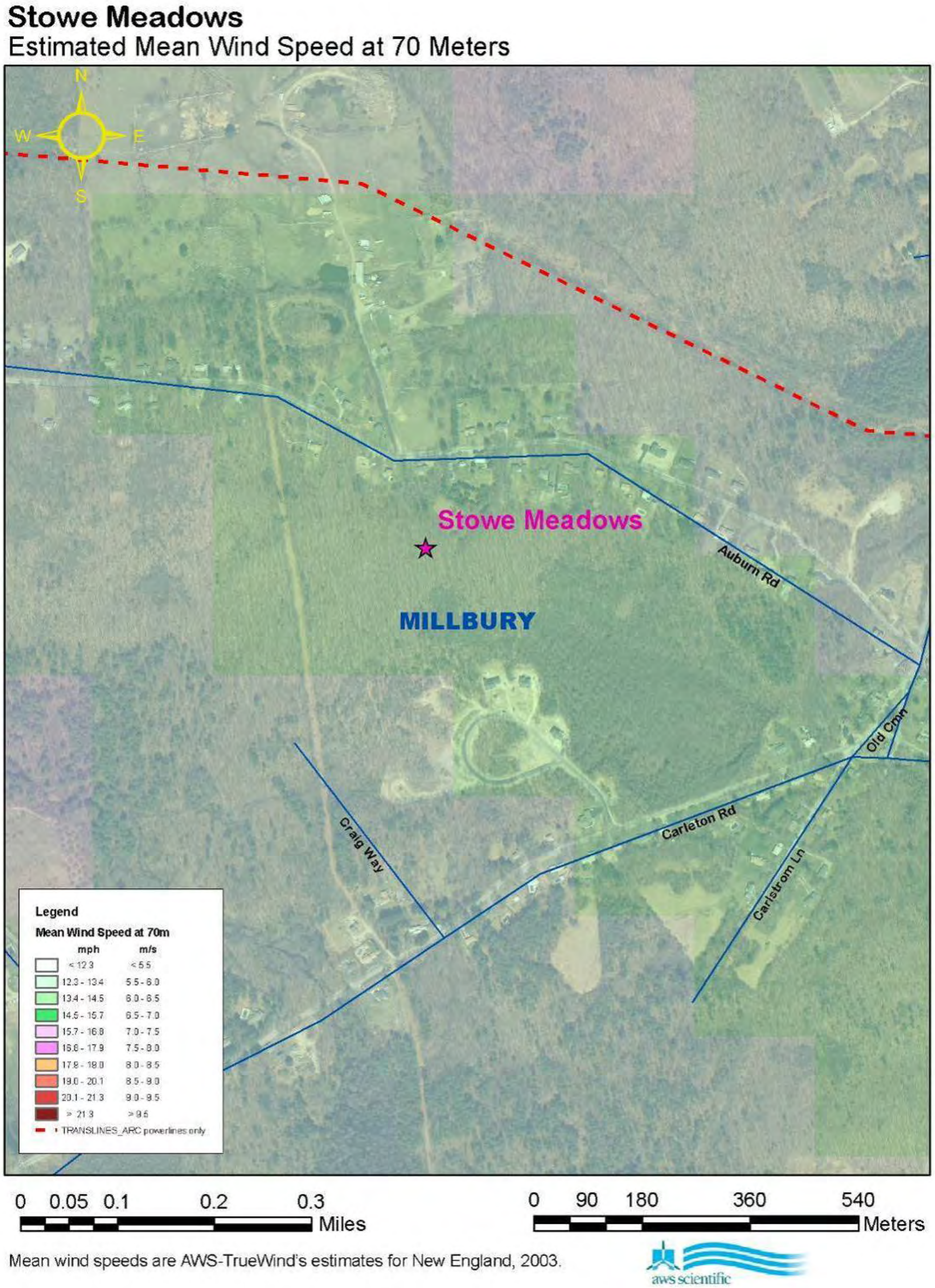


Figure 9: This figure displays orthophotograph with a layer showing AWS annual mean wind speeds at 70 meters near the Stowe Meadows site. The red dashed line is a transmission line.

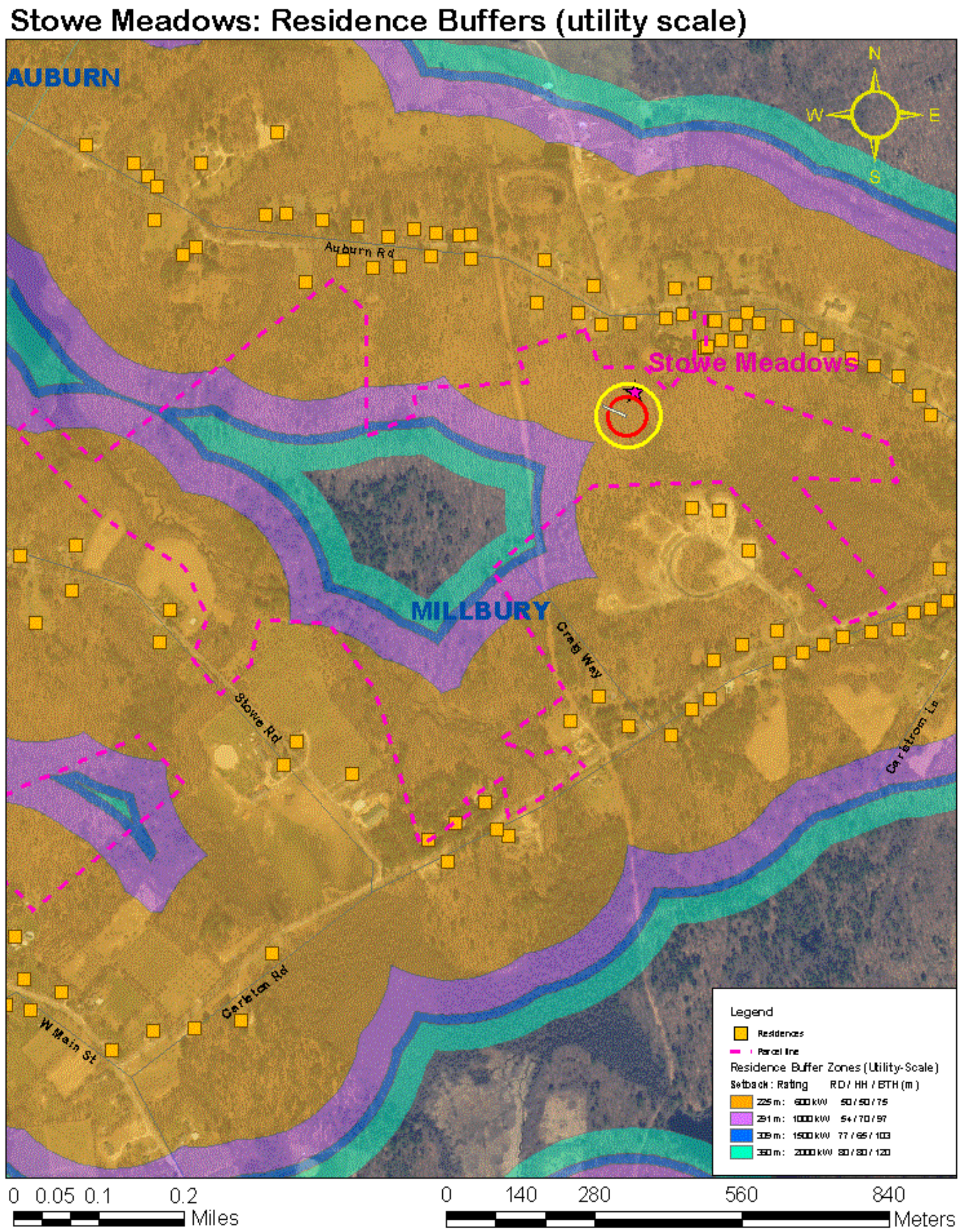


Figure 10: This figure displays an orthophotograph with a layer showing the residence buffers for utility-scale turbines near the Stowe Meadows site. The pink dashed line shows the approximate boundary of the parcel.

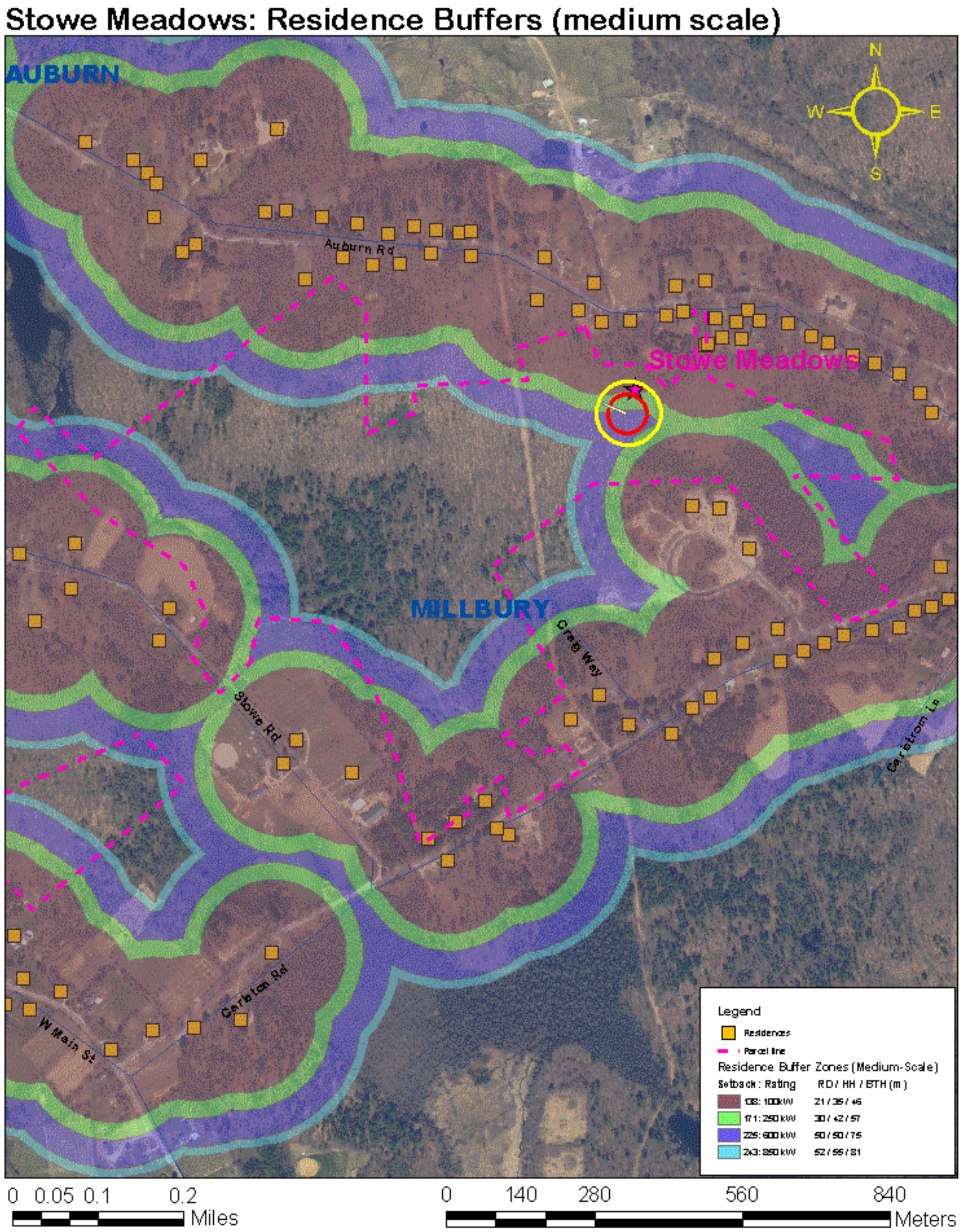


Figure 11: This figure displays an orthophotograph with a layer showing the residence buffers for medium-scale turbines near the Stowe Meadows site.

Stowe Meadows:
Habitat and Conservation, Protected and OpenSpace Lands

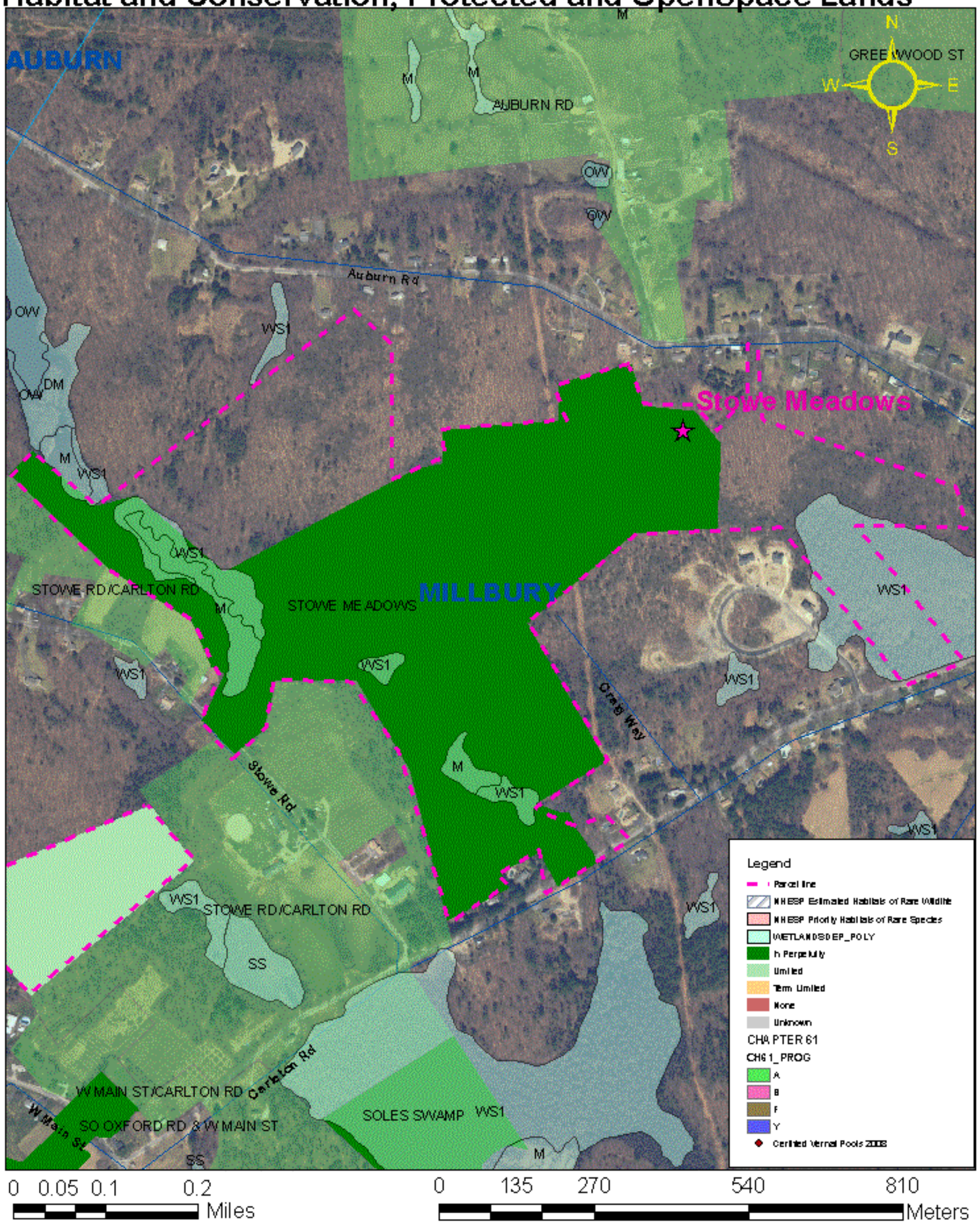


Figure 12: This figure displays OpenSpace protection and wetlands designations in the vicinity of the Stowe Meadows site.

Stowe Meadows: Topography

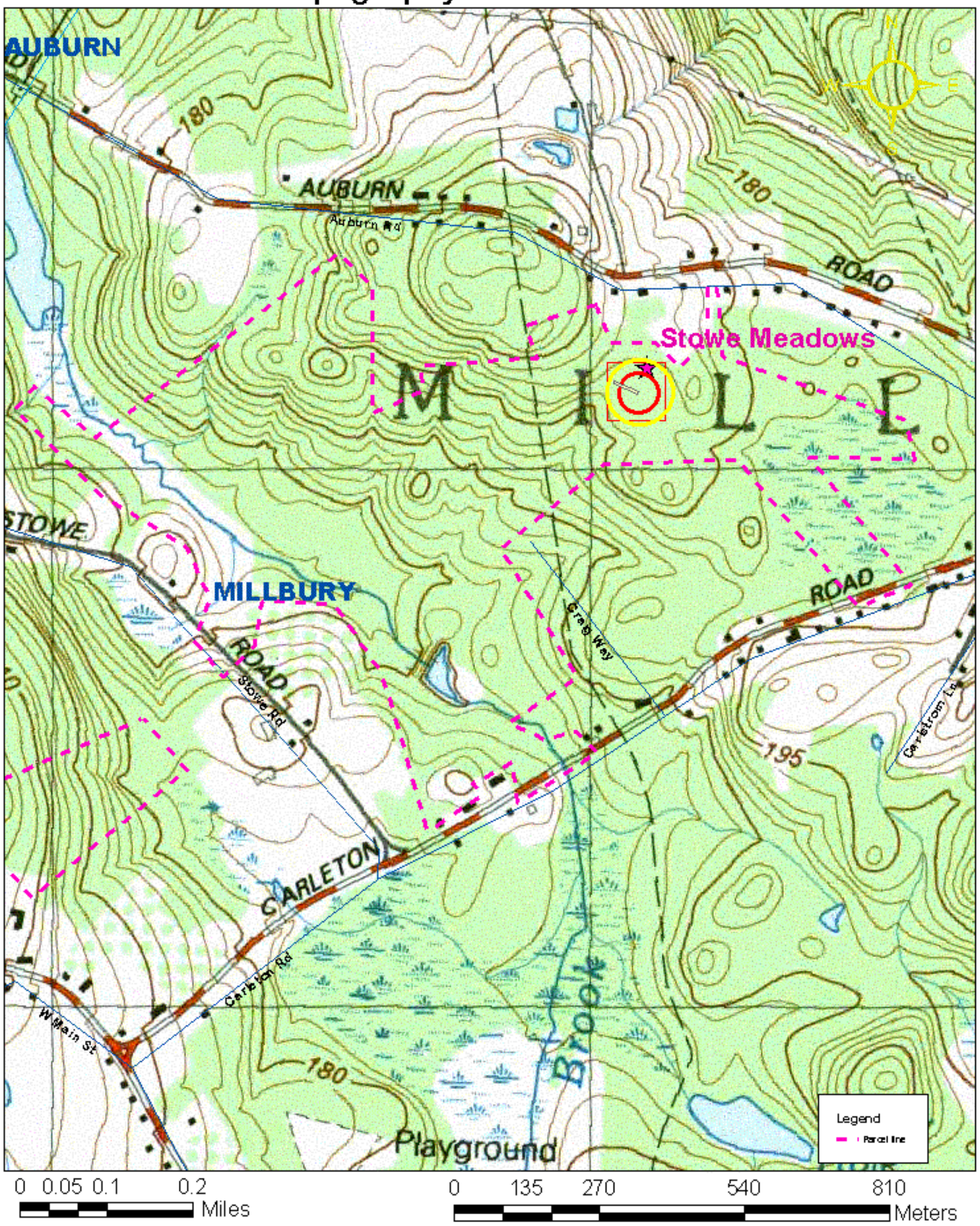


Figure 13: This figure displays the topography at the Stowe Meadows Sanctuary site. The red circle shows a layout of a 50-meter tower and the yellow circle indicates the layout of the anchors for a 60-meter tower.

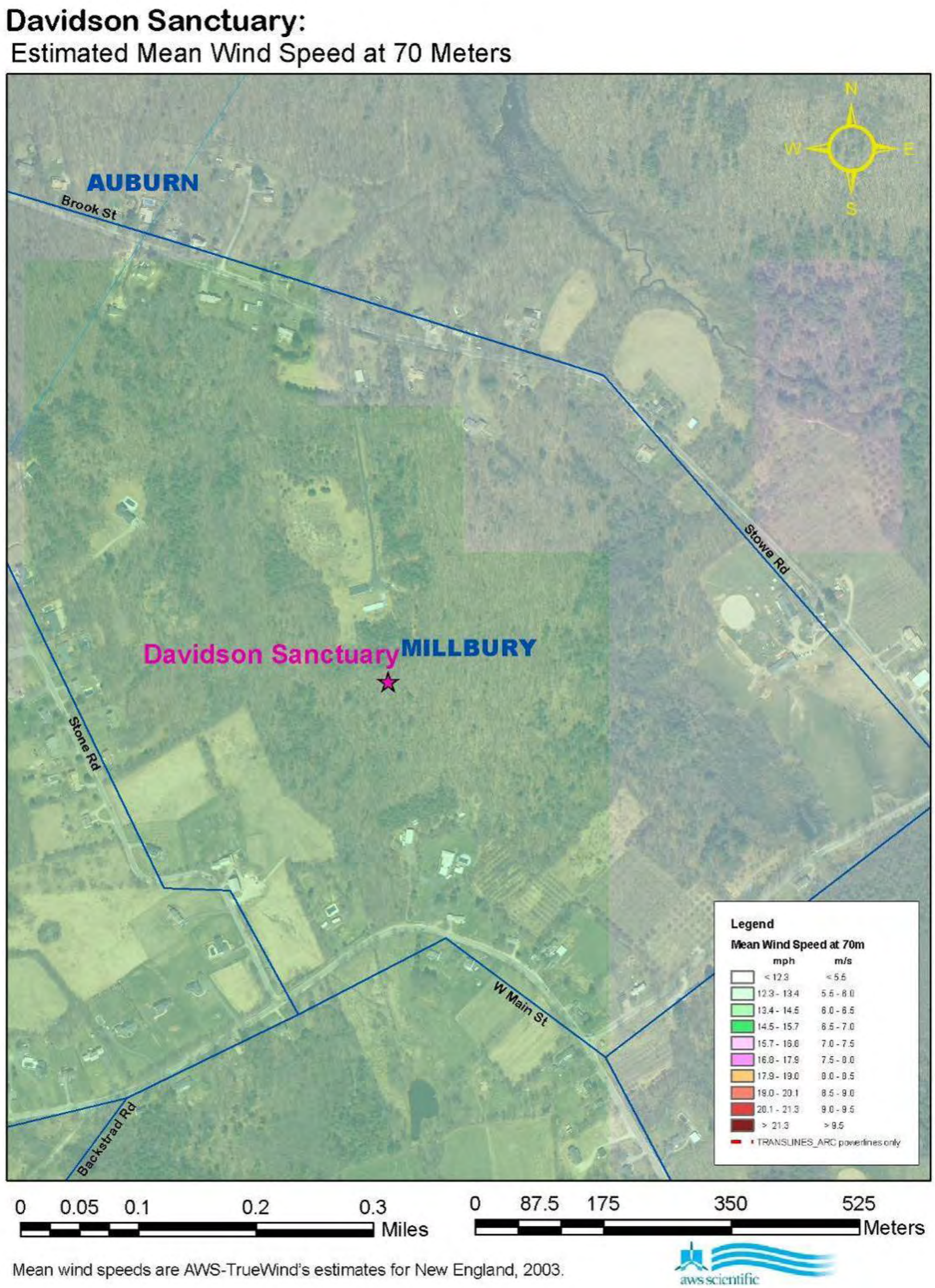


Figure 14: This figure displays an orthophotograph with a layer showing the AWS annual mean wind speeds at 70 meters.

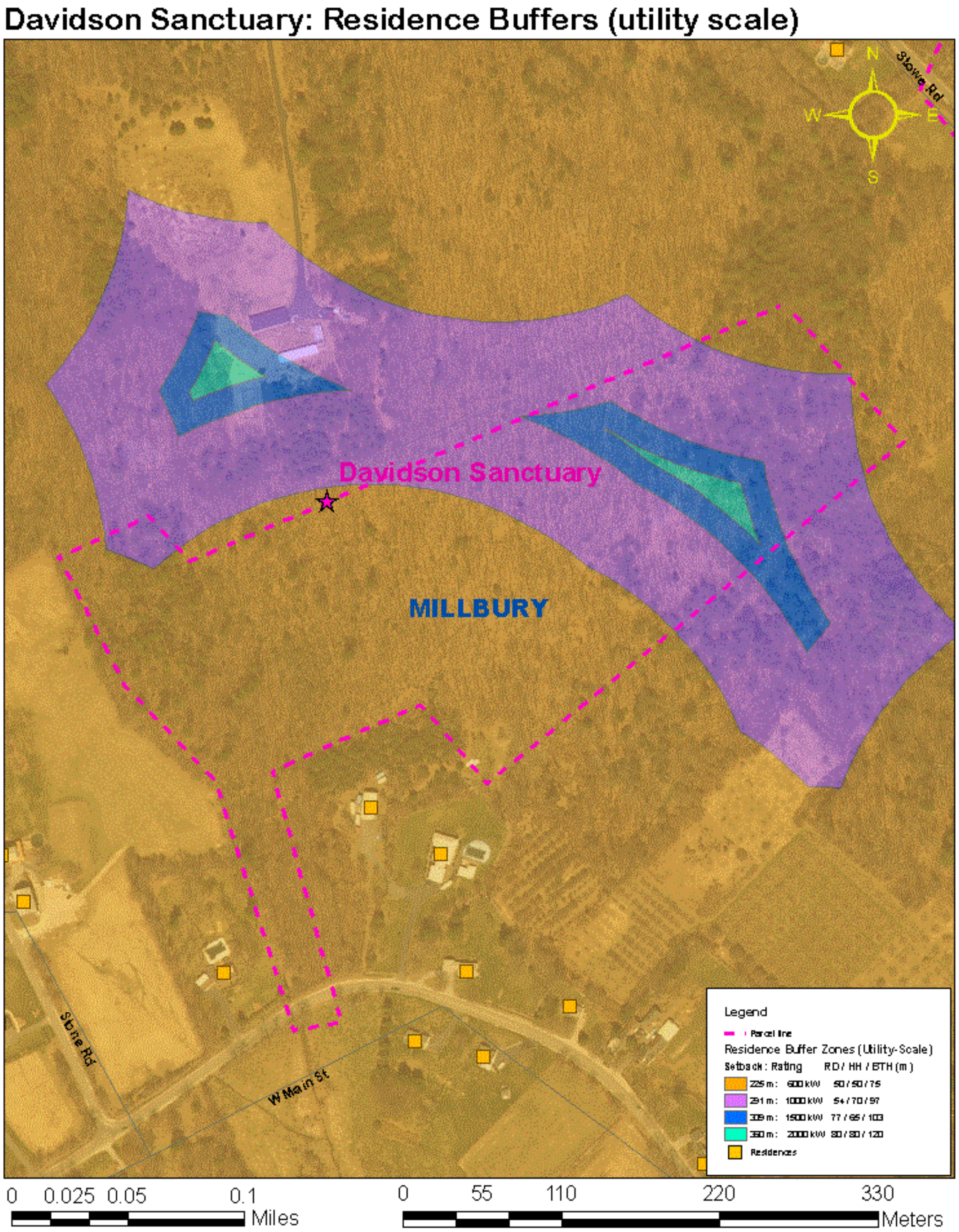


Figure 15: This figure displays an orthophotograph with a layer showing the residence buffers for utility-scale turbines near the Davidson Sanctuary site. The pink dashed line shows the approximate boundary of the parcel.

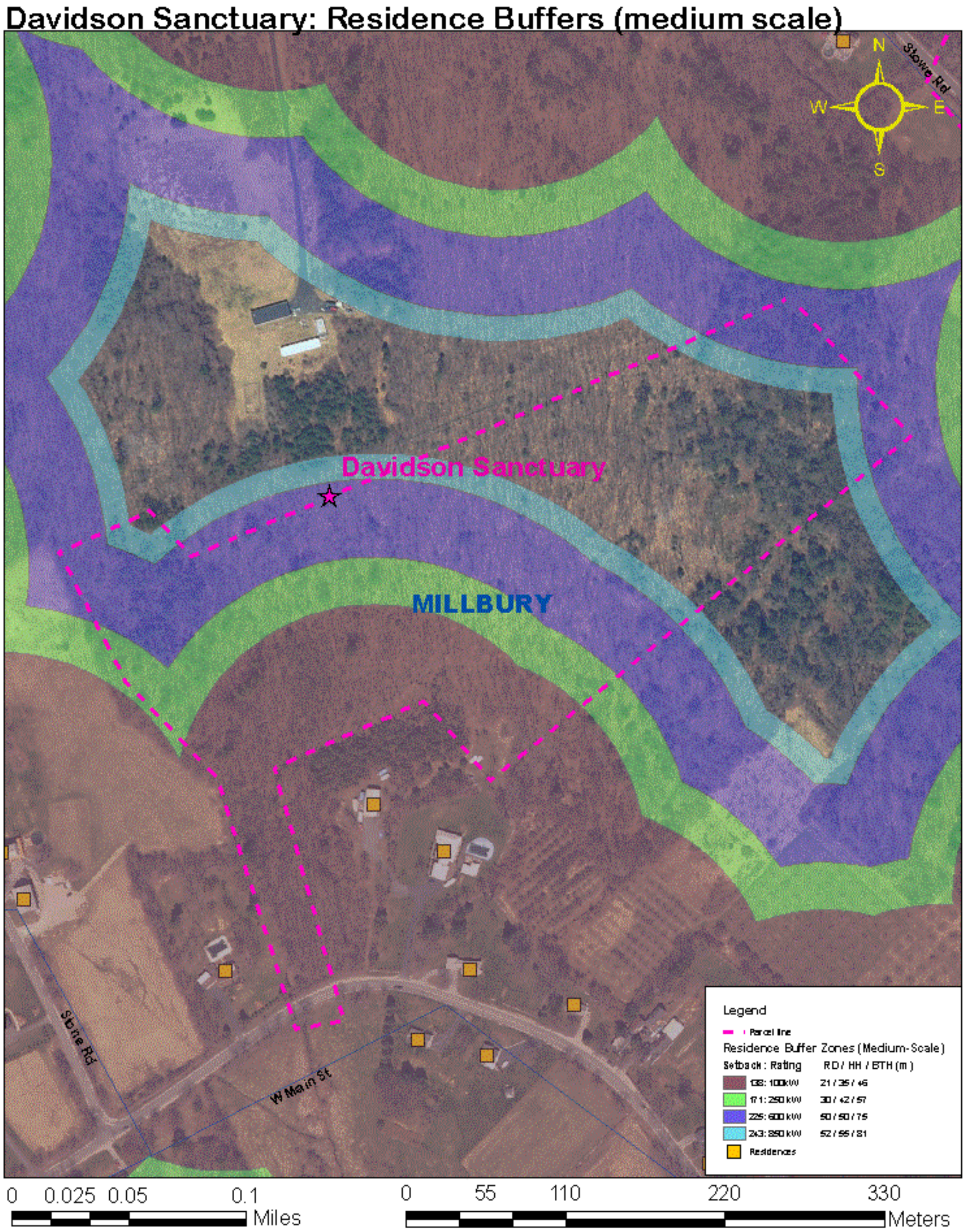


Figure 16: This figure displays an orthophotograph with a layer showing the residence buffers for medium-scale turbines near the Davidson Sanctuary site.

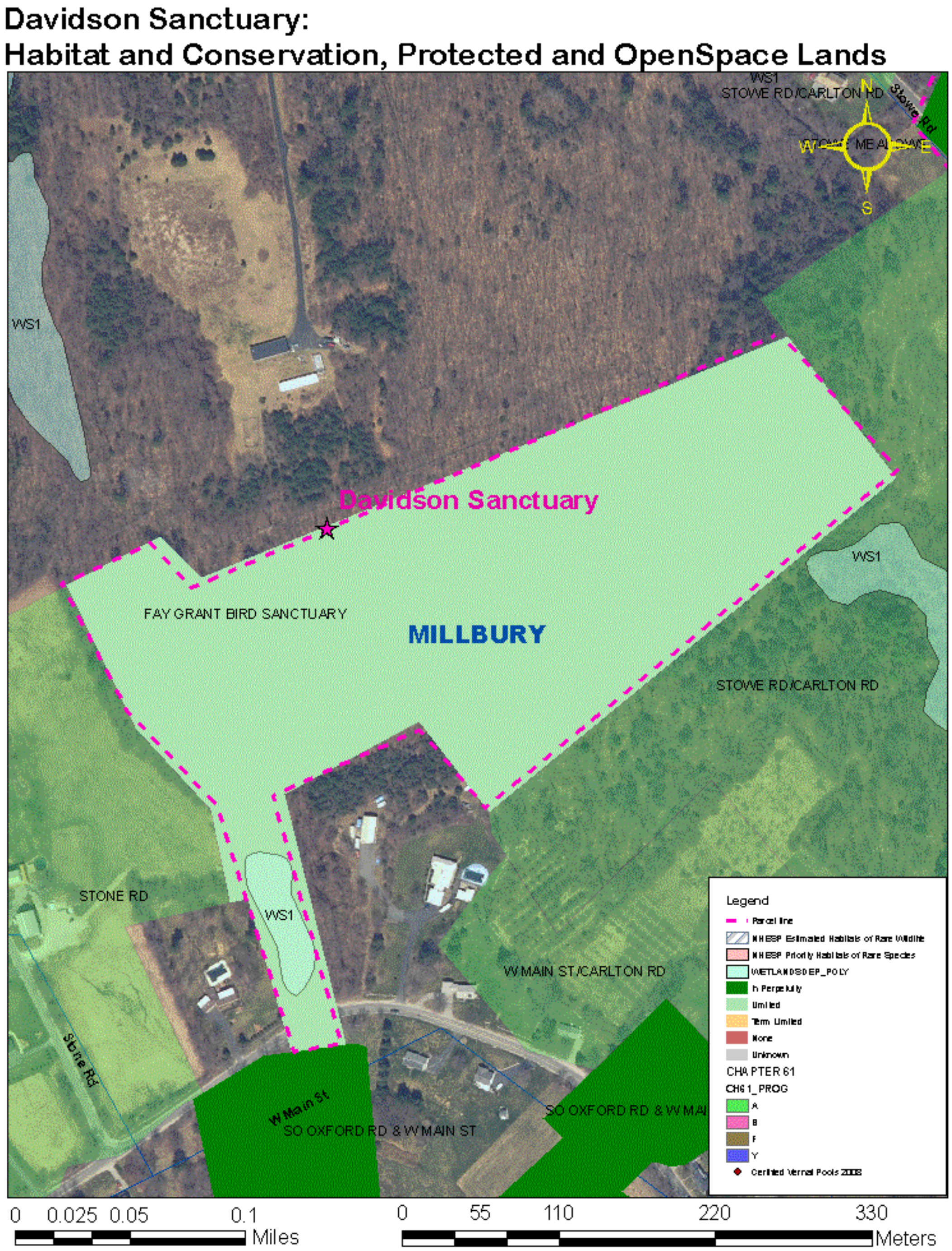


Figure 17: This figure displays OpenSpace protections and wetlands designations in the vicinity of the Davidson Sanctuary site.

Davidson Sanctuary: Topography

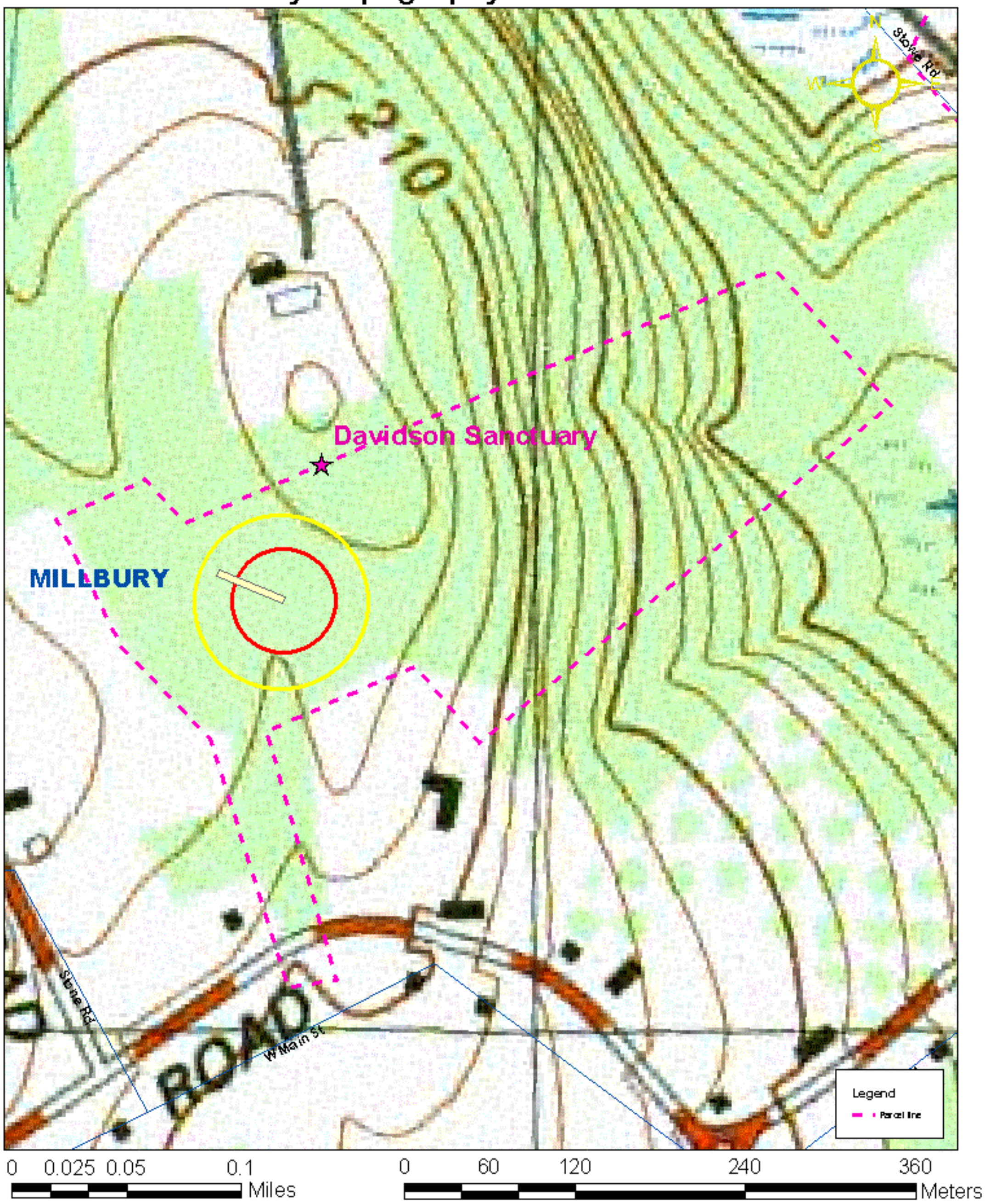


Figure 18: This figure displays the topography at the Davidson Sanctuary site. The red circle shows a layout of a 50-meter tower and the yellow circle indicates the layout of the anchors for a 60-meter tower.

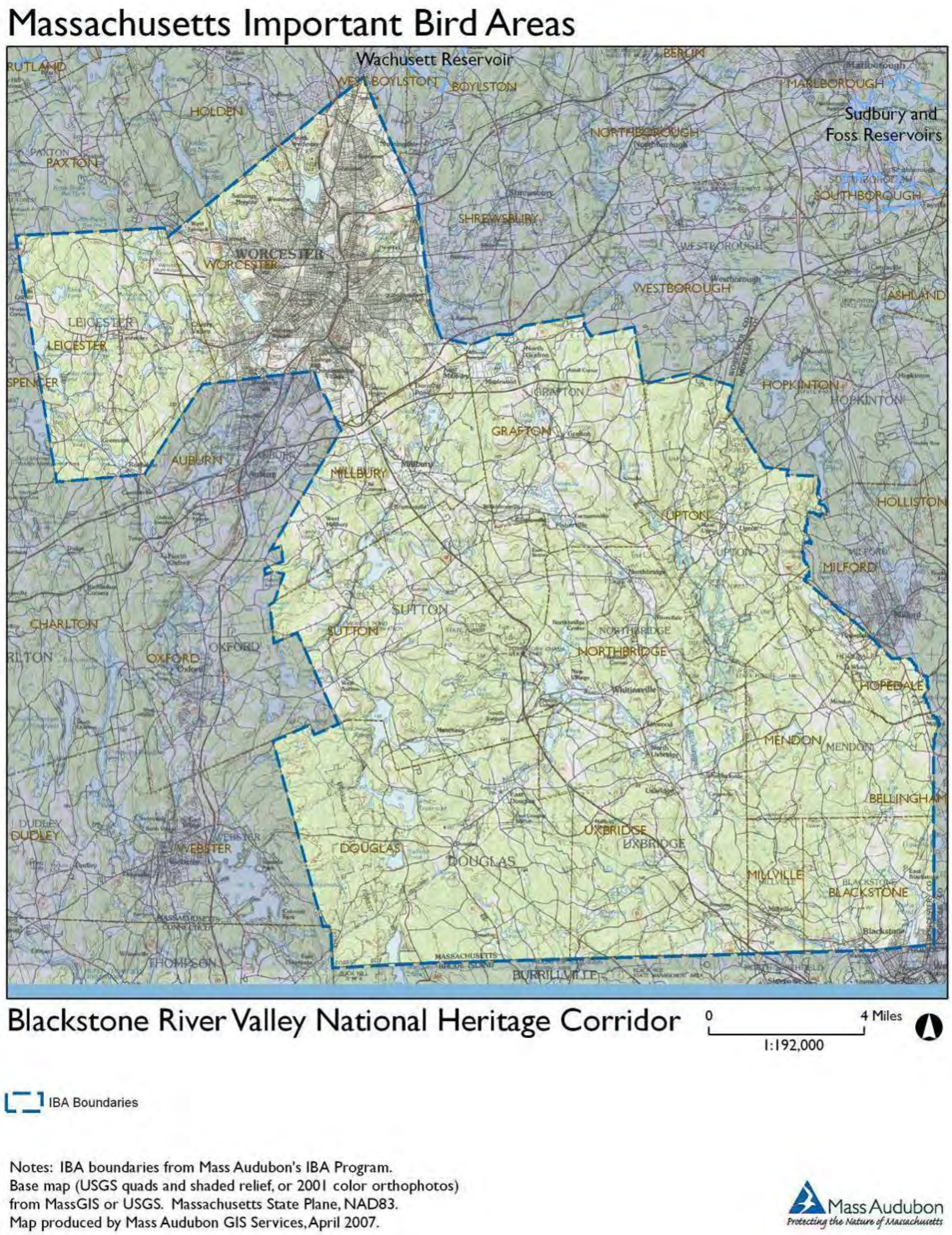


Figure 19: This figure shows a map of the Blackstone River Valley National Heritage Corridor IBA. All of the Millbury sites are located within the boundaries of this IBA.

Figure 20: This figure shows photo of the field to the west of the house at Butler Farm.

Figure 21: This figure shows photo of the fire communications tower at the top of the hill at Butler Farm.

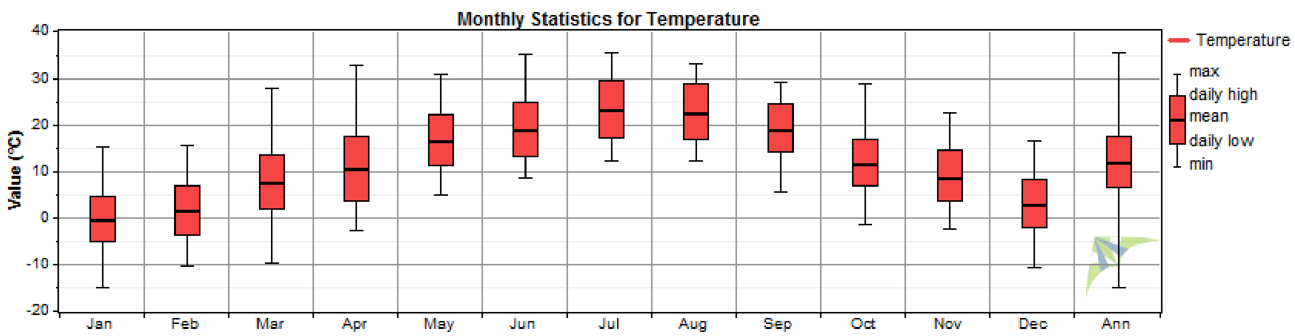
Appendix C

Wind Data Summary Reports and MET Data

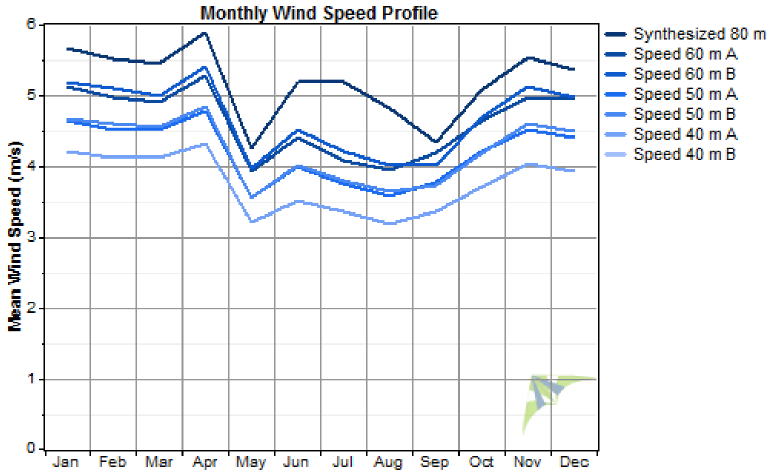
Data Set Properties

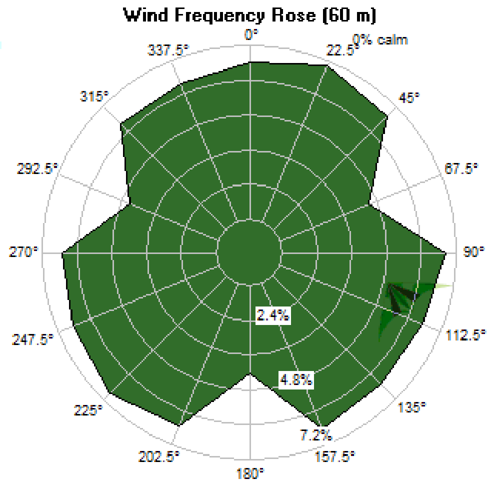
Report Created: 10/25/2012 13:49 using Windographer 2.4.7
Filter Settings: <Unflagged data>, Synthesized

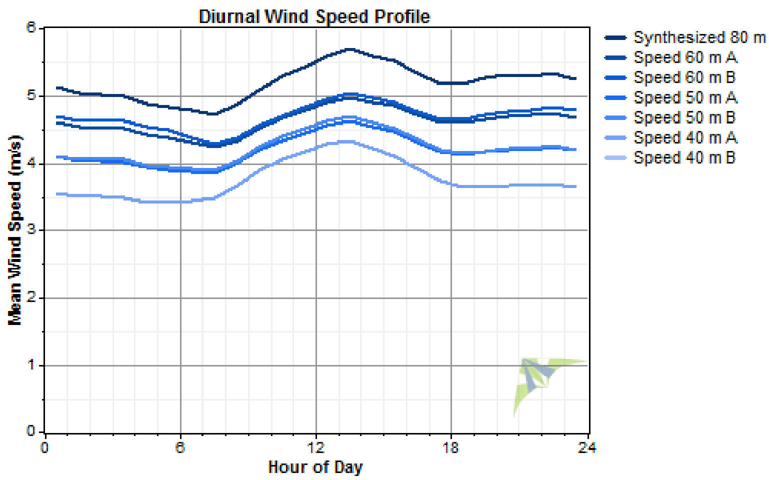
Variable	Value
Latitude	N 49° 9' 0.000"
Longitude	W 71° 47' 0.000"
Elevation	300 m
Start date	8/26/2011 00:00
End date	8/27/2012 00:00
Duration	12 months
Length of time step	10 minutes
Calm threshold	0 m/s
Mean temperature	11.7 °C
Mean pressure	651.5 mbar
Mean air density	0.799 kg/m³
Power density at 50m	37 W/m²
Wind power class	1 (Poor)
Power law exponent	n/a
Surface roughness	n/a
Roughness class	n/a
Roughness description	n/a

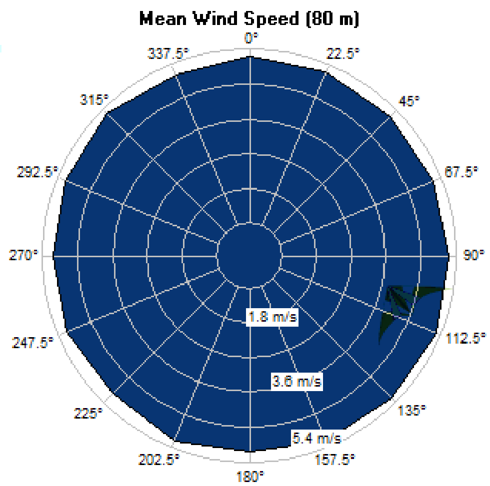


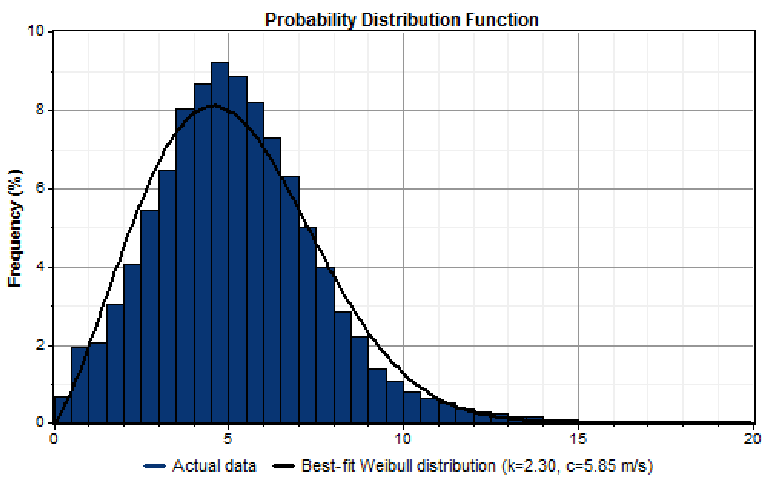
Wind Speed and Direction

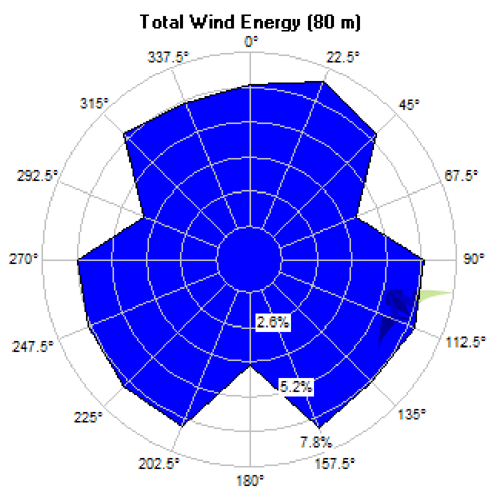




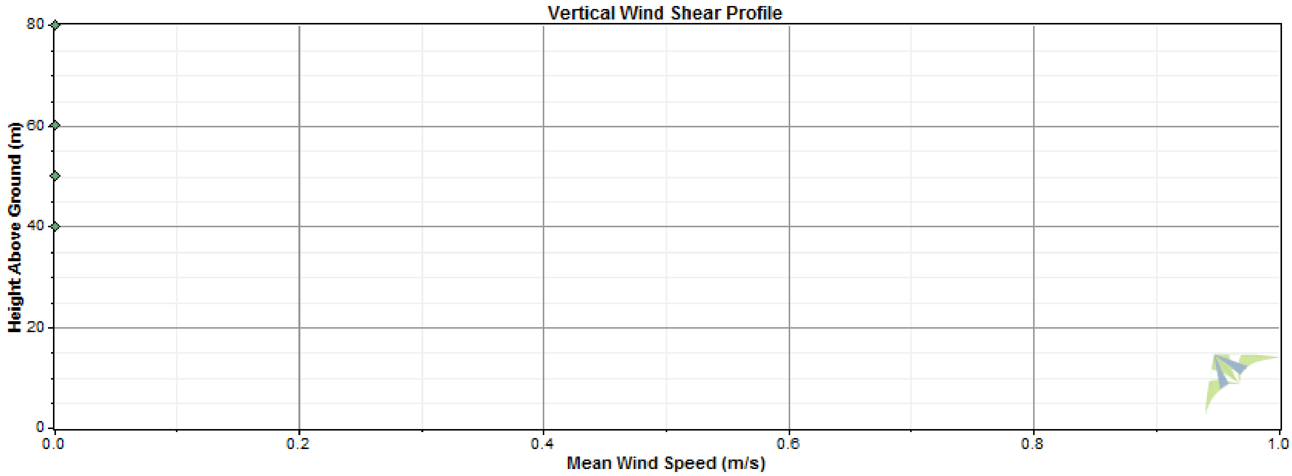


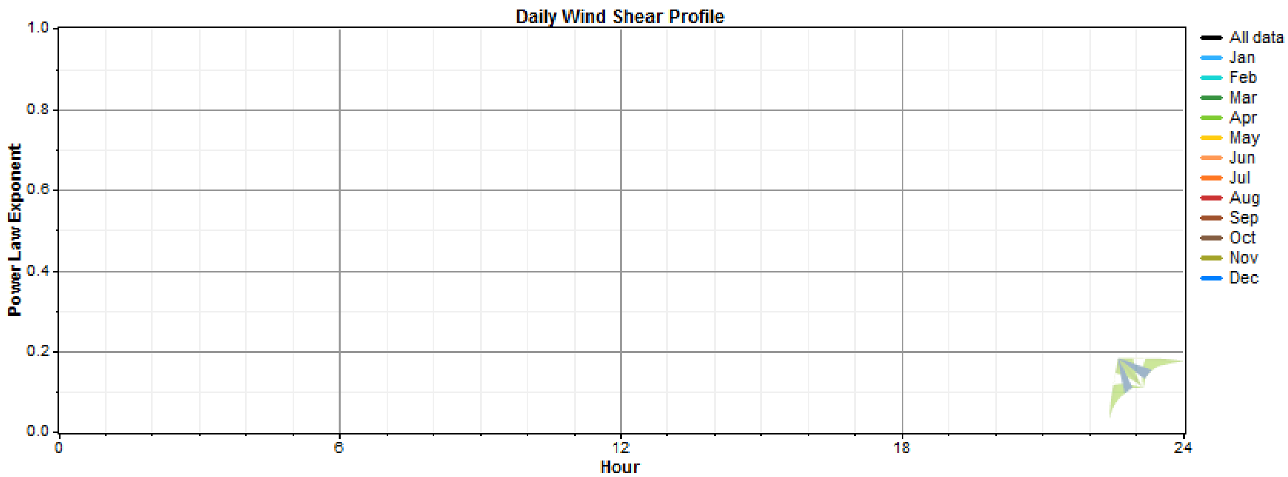


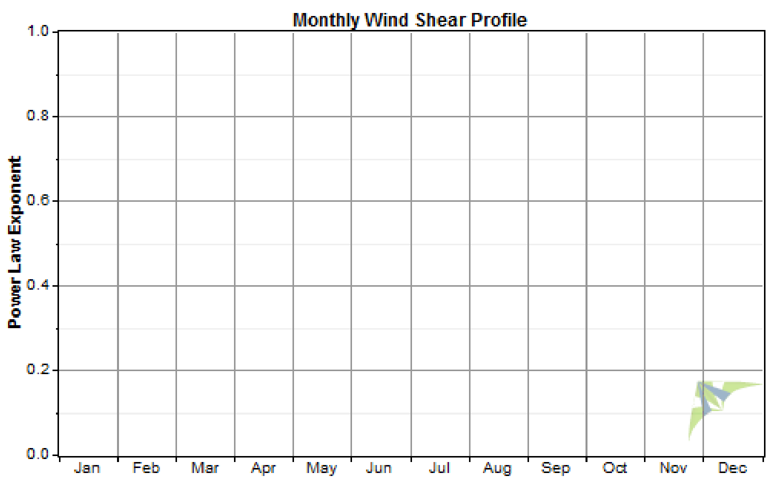


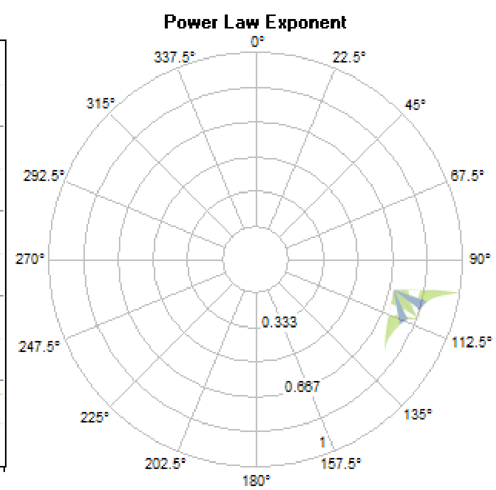


Wind Shear

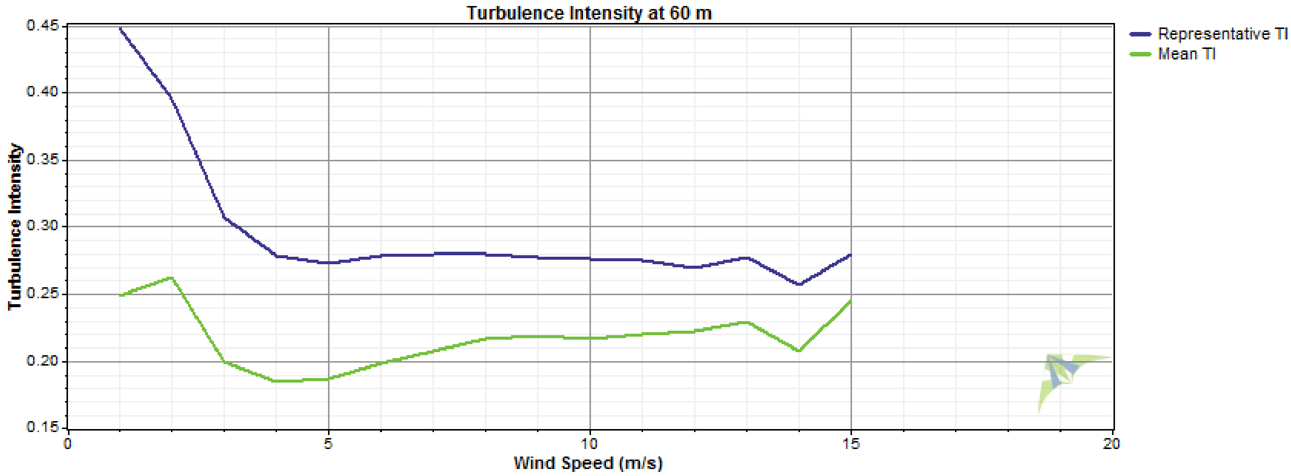

Vertical Wind Shear Profile
Height Above Ground (m)
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
Mean Wind Speed (m/s)

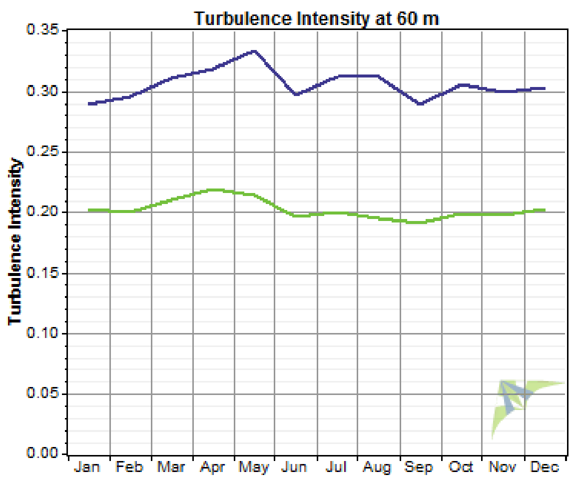

Daily Wind Shear Profile
Power Law Exponent
1.0
0.8
0.6
0.4
0.2
0.0
0
6
12
18
24
Hour
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

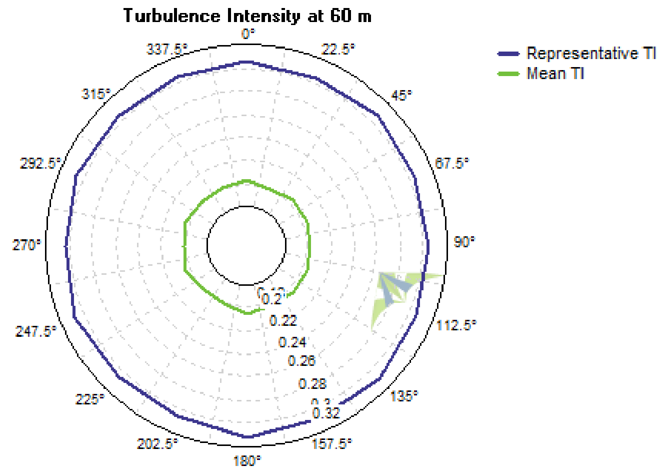

Monthly Wind Shear Profile
Power Law Exponent
1.0
0.8
0.6
0.4
0.2
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

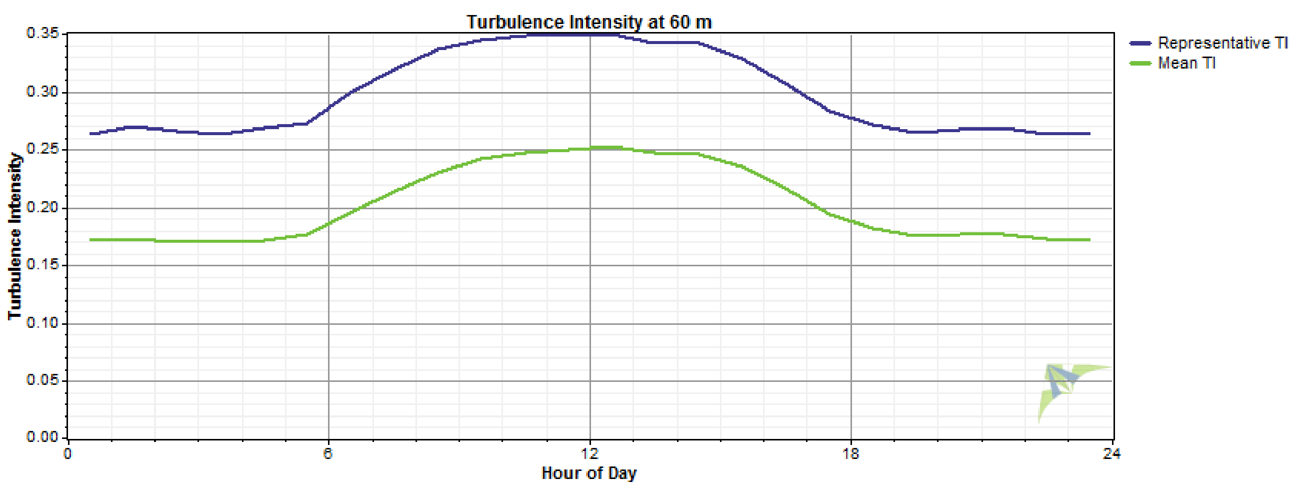

Power Law Exponent
0°
22.5°
45°
67.5°
90°
112.5°
135°
157.5°
180°
202.5°
225°
247.5°
270°
292.5°
315°
337.5°
0.333
0.667
1

Turbulence Intensity









Data Column Properties

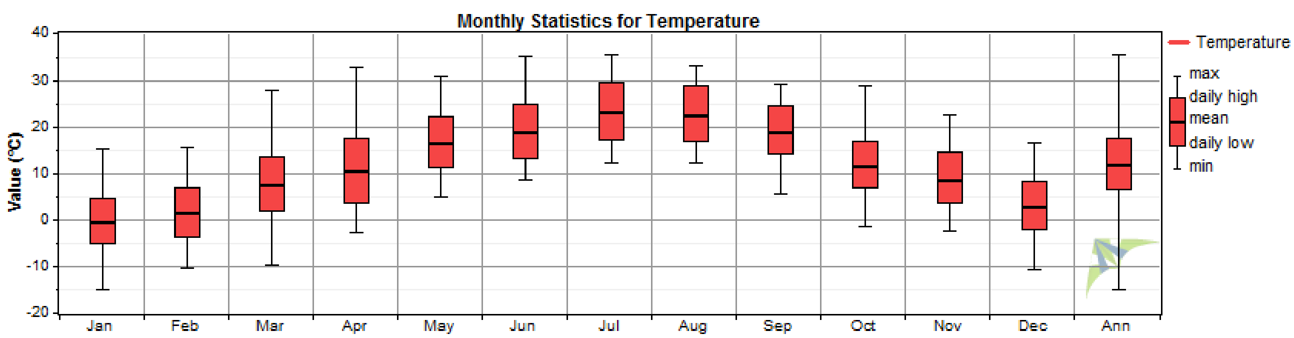
Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	Speed 60 m A	m/s	60 m	52,848	52,560	99.46	4.62	0.78	15.28	1.93
2	Speed 60 m A SD	m/s	60 m	52,848	52,560	99.46	0.922	0.000	4.900	0.516
3	Speed 60 m A Max	m/s	60 m	52,848	52,560	99.46	6.63	0.40	27.70	3.16
4	Speed 60 m A Min	m/s	60 m	52,848	52,560	99.46	2.006	0.400	8.800	1.167
5	Speed 60 m B	m/s	60 m	52,848	52,560	99.46	4.69	0.79	16.29	2.00
6	Speed 60 m B SD	m/s	60 m	52,848	52,560	99.46	0.916	0.000	5.100	0.517
7	Speed 60 m B Max	m/s	60 m	52,848	52,560	99.46	6.64	0.40	29.60	3.17
8	Speed 60 m B Min	m/s	60 m	52,848	52,560	99.46	2.070	0.400	9.100	1.223
9	Speed 50 m A	m/s	50 m	52,848	52,560	99.46	4.19	0.76	14.16	1.77
10	Speed 50 m A SD	m/s	50 m	52,848	52,560	99.46	0.92	0.00	4.70	0.51
11	Speed 50 m A Max	m/s	50 m	52,848	52,560	99.46	6.25	0.40	28.80	3.04
12	Speed 50 m A Min	m/s	50 m	52,848	52,560	99.46	1.667	0.400	8.300	1.023
13	Speed 50 m B	m/s	50 m	52,848	52,560	99.46	4.22	0.76	15.06	1.84
14	Speed 50 m B SD	m/s	50 m	52,848	52,560	99.46	0.929	0.000	4.700	0.510
15	Speed 50 m B Max	m/s	50 m	52,848	52,560	99.46	6.28	0.40	31.10	3.07
16	Speed 50 m B Min	m/s	50 m	52,848	52,560	99.46	1.655	0.400	7.600	1.064
17	Speed 40 m A	m/s	40 m	52,848	52,560	99.46	3.76	0.69	13.79	1.70
18	Speed 40 m A SD	m/s	40 m	52,848	52,560	99.46	0.926	0.000	4.500	0.505
19	Speed 40 m A Max	m/s	40 m	52,848	52,560	99.46	5.85	0.30	31.10	2.97
20	Speed 40 m A Min	m/s	40 m	52,848	52,560	99.46	1.257	0.300	6.800	0.905
21	Speed 40 m B	m/s	40 m	52,848	0	0.00				
22	Speed 40 m B SD	m/s	40 m	52,848	0	0.00				
23	Speed 40 m B Max	m/s	40 m	52,848	0	0.00				
24	Speed 40 m B Min	m/s	40 m	52,848	0	0.00				
25	Direction 60 m	°	60 m	52,848	52,560	99.46	29.9	8.0	360.0	104.3
26	Direction 60 m SD	°	60 m	52,848	52,560	99.46	13.7	0.0	107.0	8.8
27	Direction 60 m Max	°	60 m	52,848	52,560	99.46	134.8	0.0	359.0	109.3
28	Direction 60 m Min	°	60 m	52,848	52,560	99.46	138	138	138	0
29	Direction 40 m	°	40 m	52,848	52,560	99.46	243.7	0.0	359.0	92.3
30	Direction 40 m SD	°	40 m	52,848	52,560	99.46	16.8	0.0	117.0	10.3
31	Direction 40 m Max	°	40 m	52,848	52,560	99.46	198.9	0.0	359.0	93.0
32	Direction 40 m Min	°	40 m	52,848	52,560	99.46	318	318	318	0
33	Temperature	°C		52,848	52,560	99.46	11.73	-15.10	35.30	9.57
34	Temperature SD	°C		52,848	52,560	99.46	0.038	0.000	1.700	0.088
35	Temperature Max	°C		52,848	52,560	99.46	11.99	-15.00	35.60	9.61
36	Temperature Min	°C		52,848	52,560	99.46	11.56	-15.20	35.20	9.55
37	NRG #BP20 Barometric	mbar		52,848	52,560	99.46	651.5	651.1	651.2	0.4
38	NRG #BP20 Barometric SD	mB		52,848	52,560	99.46	0.132	0.000	0.300	0.050
39	NRG #BP20 Barometric Max	mB		52,848	52,560	99.46	651.9	651.1	651.9	0.4
40	NRG #BP20 Barometric Min	mB		52,848	52,560	99.46	650.8	650.7	651.1	0.2
41	Synthesized 80 m	m/s	80 m	52,848	52,848	100.00	5.19	0.40	18.56	2.36
42	Air Density	kg/m³		52,848	52,848	100.00	0.799	0.735	1.190	0.039
43	Speed 60 m A TI			52,848	52,560	99.46	0.202	0.000	0.746	0.081
44	Speed 60 m B TI			52,848	52,560	99.46	0.200	0.000	0.840	0.083
45	Speed 50 m A TI			52,848	52,560	99.46	0.223	0.000	0.849	0.088
46	Speed 50 m B TI			52,848	52,560	99.46	0.224	0.000	0.825	0.088
47	Speed 40 m A TI			52,848	52,560	99.46	0.252	0.000	1.007	0.096
48	Speed 40 m B TI			52,848	0	0.00				
49	Synthesized 80 m WPD	W/m²		52,848	52,848	100.00	94	0	2,616	142
50	Speed 60 m A WPD	W/m²		52,848	52,560	99.46	62	0	1,428	89
51	Speed 60 m B WPD	W/m²		52,848	52,560	99.46	66	0	1,768	98
52	Speed 50 m A WPD	W/m²		52,848	52,560	99.46	47	0	1,161	69
53	Speed 50 m B WPD	W/m²		52,848	52,560	99.46	49	0	1,397	76

Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
54	Speed 40 m A WPD	W/m²		52,848	52,560	99.46	36	0	1,072	57
55	Speed 40 m B WPD	W/m²		52,848	0	0.00				

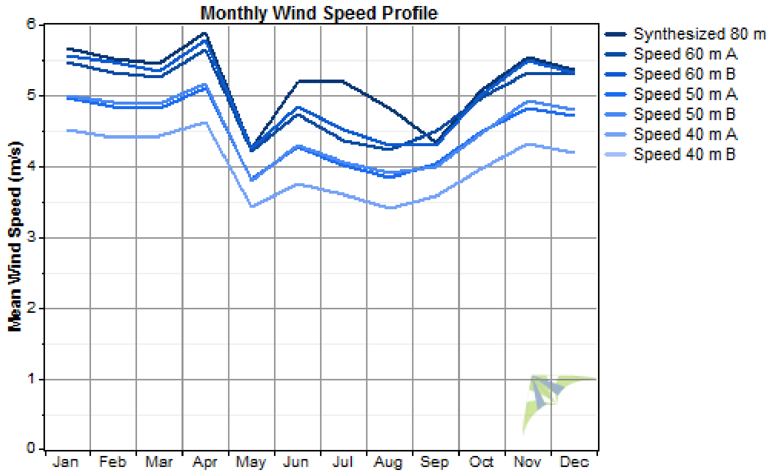
Data Set Properties

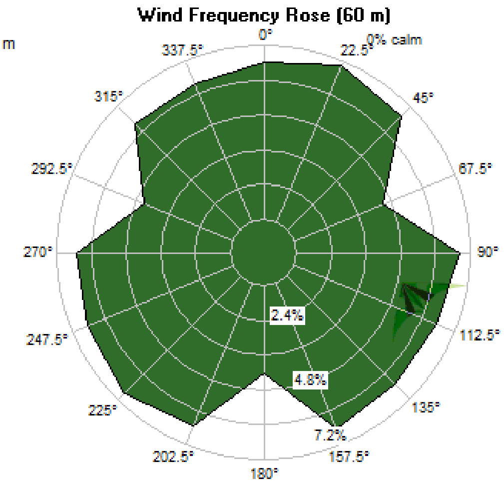
Report Created: 10/24/2012 13:09 using Windographer 2.4.7
Filter Settings: <Unflagged data>, Synthesized

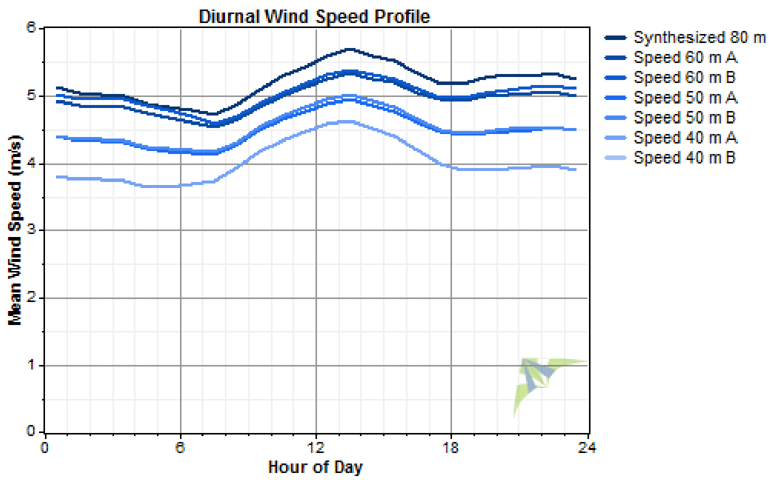
Variable	Value
Latitude	N 49° 9' 0.000"
Longitude	W 71° 47' 0.000"
Elevation	300 m
Start date	8/26/2011 00:00
End date	8/27/2012 00:00
Duration	12 months
Length of time step	10 minutes
Calm threshold	0 m/s
Mean temperature	11.7 °C
Mean pressure	651.5 mbar
Mean air density	0.799 kg/m³
Power density at 50m	45 W/m²
Wind power class	1 (Poor)
Power law exponent	n/a
Surface roughness	n/a
Roughness class	n/a
Roughness description	n/a

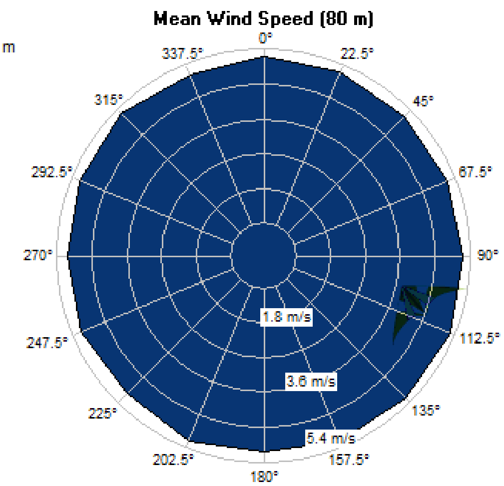


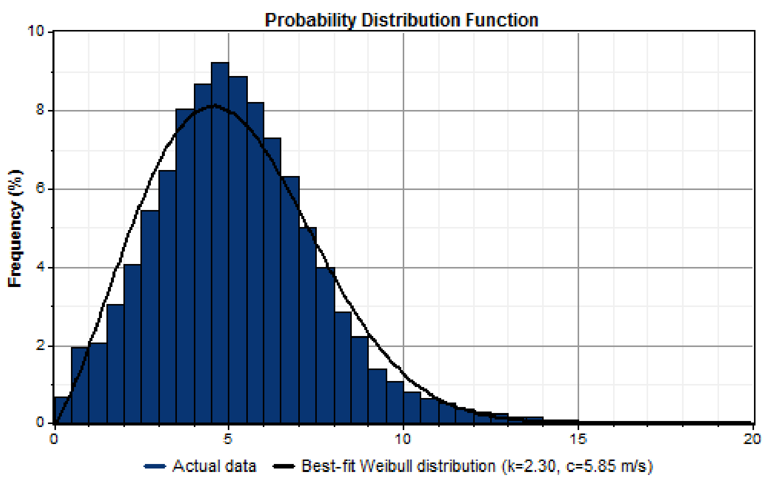
Wind Speed and Direction

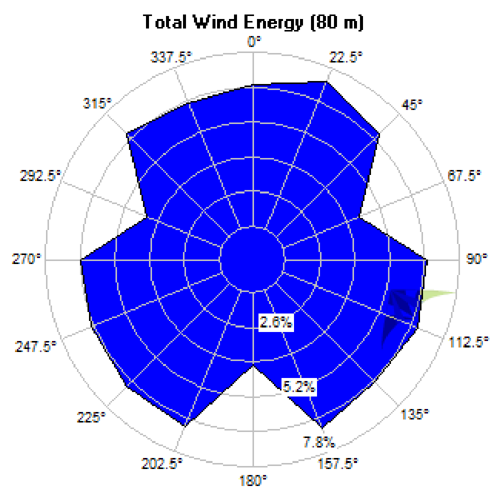




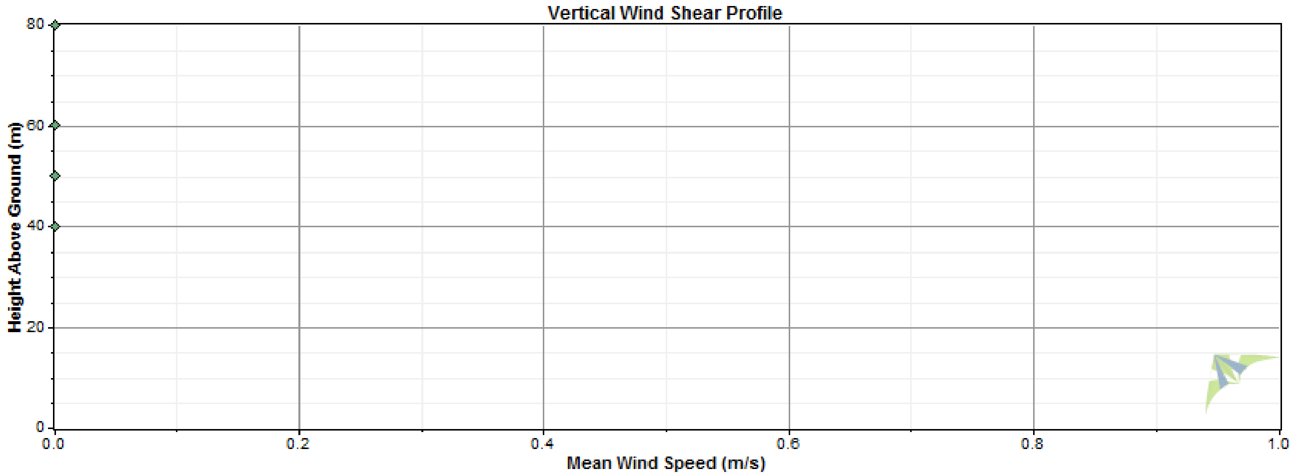


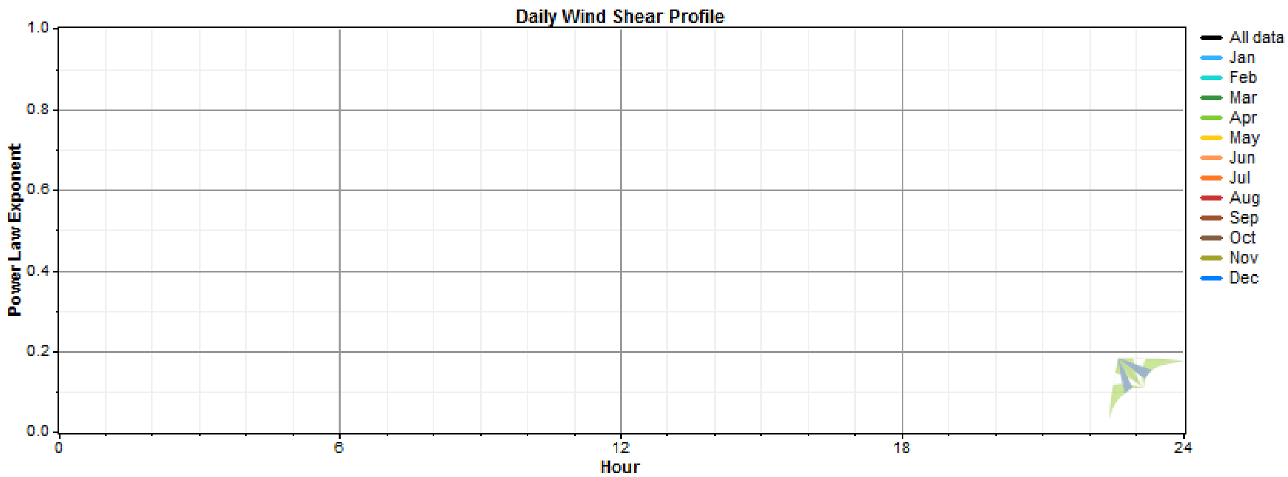


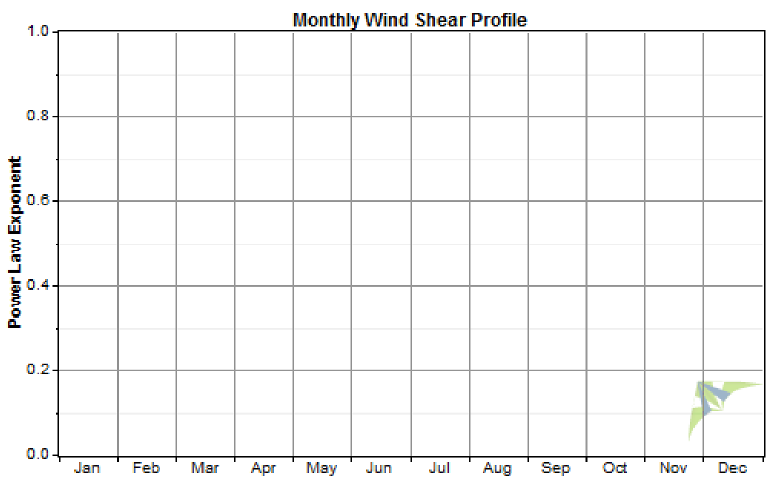


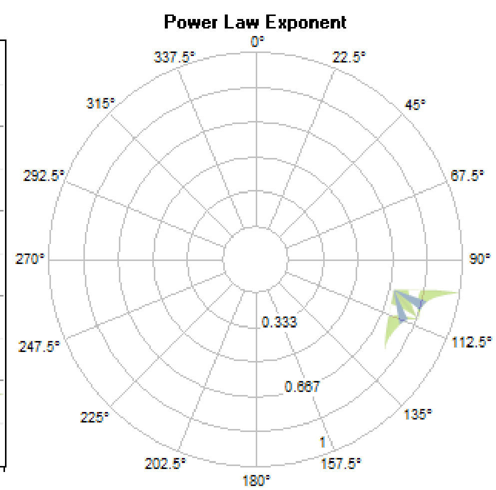


Wind Shear

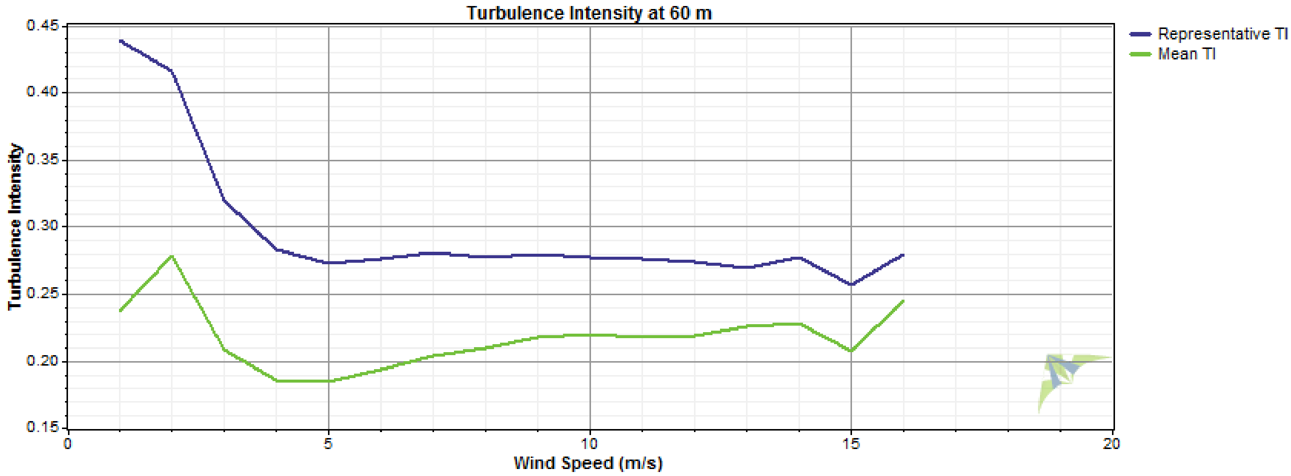

Vertical Wind Shear Profile
Height Above Ground (m)
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
Mean Wind Speed (m/s)

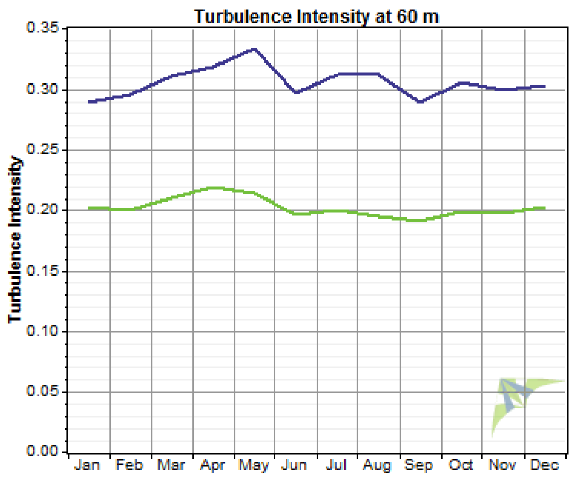

Daily Wind Shear Profile
Power Law Exponent
1.0
0.8
0.6
0.4
0.2
0.0
0
6
12
18
24
Hour
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

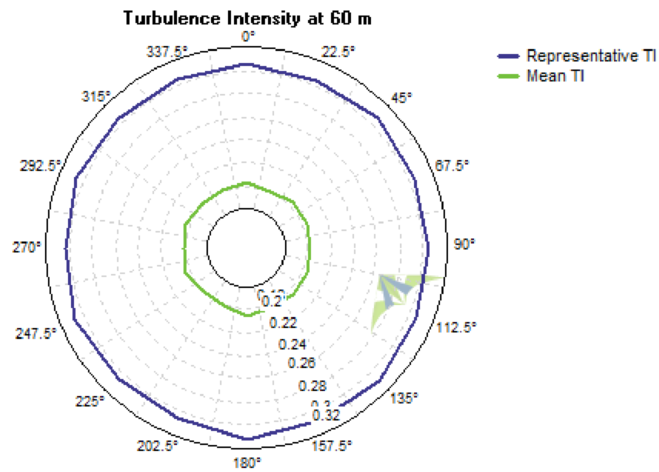

Monthly Wind Shear Profile
Power Law Exponent
1.0
0.8
0.6
0.4
0.2
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

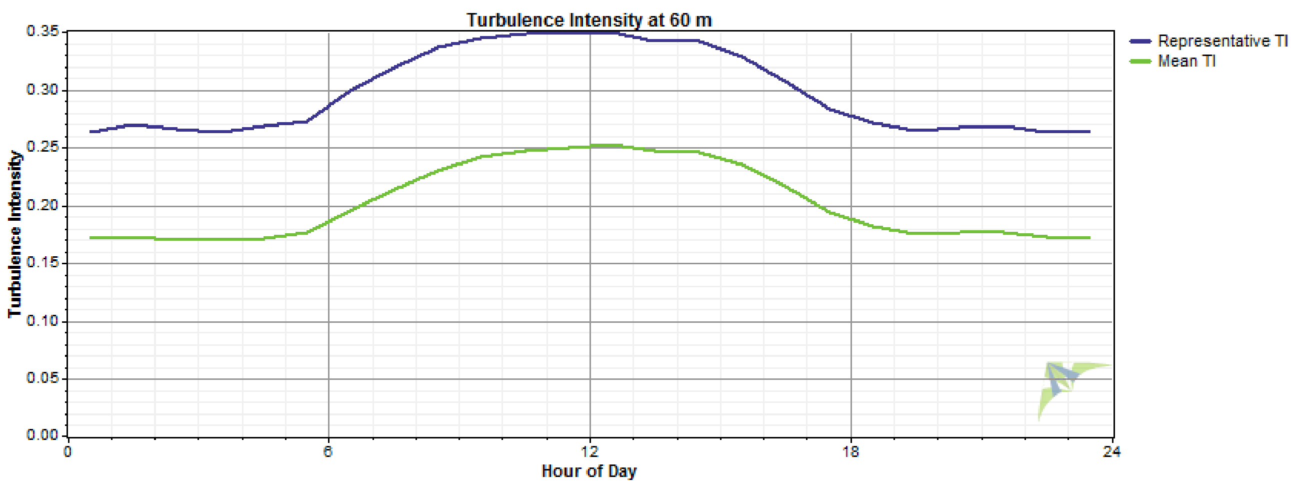

Power Law Exponent
0°
22.5°
45°
67.5°
90°
112.5°
135°
157.5°
180°
202.5°
225°
247.5°
270°
292.5°
315°
337.5°
0.333
0.667
1

Turbulence Intensity









Data Column Properties

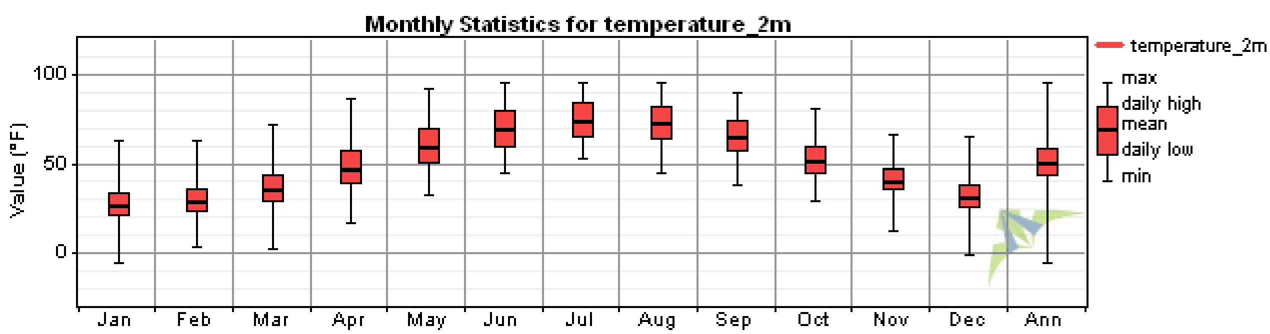
Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	Speed 60 m A	m/s	60 m	52,848	52,560	99.46	4.94	0.83	16.35	2.07
2	Speed 60 m A SD	m/s	60 m	52,848	52,560	99.46	0.986	0.000	5.243	0.552
3	Speed 60 m A Max	m/s	60 m	52,848	52,560	99.46	7.09	0.43	29.64	3.38
4	Speed 60 m A Min	m/s	60 m	52,848	52,560	99.46	2.146	0.428	9.416	1.249
5	Speed 60 m B	m/s	60 m	52,848	52,560	99.46	5.02	0.85	17.43	2.14
6	Speed 60 m B SD	m/s	60 m	52,848	52,560	99.46	0.980	0.000	5.457	0.553
7	Speed 60 m B Max	m/s	60 m	52,848	52,560	99.46	7.11	0.43	31.67	3.40
8	Speed 60 m B Min	m/s	60 m	52,848	52,560	99.46	2.216	0.428	9.737	1.308
9	Speed 50 m A	m/s	50 m	52,848	52,560	99.46	4.48	0.81	15.15	1.90
10	Speed 50 m A SD	m/s	50 m	52,848	52,560	99.46	0.984	0.000	5.029	0.545
11	Speed 50 m A Max	m/s	50 m	52,848	52,560	99.46	6.69	0.43	30.82	3.26
12	Speed 50 m A Min	m/s	50 m	52,848	52,560	99.46	1.783	0.428	8.881	1.095
13	Speed 50 m B	m/s	50 m	52,848	52,560	99.46	4.52	0.81	16.11	1.97
14	Speed 50 m B SD	m/s	50 m	52,848	52,560	99.46	0.994	0.000	5.029	0.546
15	Speed 50 m B Max	m/s	50 m	52,848	52,560	99.46	6.71	0.43	33.28	3.28
16	Speed 50 m B Min	m/s	50 m	52,848	52,560	99.46	1.771	0.428	8.132	1.138
17	Speed 40 m A	m/s	40 m	52,848	52,560	99.46	4.02	0.74	14.76	1.81
18	Speed 40 m A SD	m/s	40 m	52,848	52,560	99.46	0.991	0.000	4.815	0.540
19	Speed 40 m A Max	m/s	40 m	52,848	52,560	99.46	6.26	0.32	33.28	3.18
20	Speed 40 m A Min	m/s	40 m	52,848	52,560	99.46	1.344	0.321	7.276	0.968
21	Speed 40 m B	m/s	40 m	52,848	0	0.00				
22	Speed 40 m B SD	m/s	40 m	52,848	0	0.00				
23	Speed 40 m B Max	m/s	40 m	52,848	0	0.00				
24	Speed 40 m B Min	m/s	40 m	52,848	0	0.00				
25	Direction 60 m	°	60 m	52,848	52,560	99.46	29.9	8.0	360.0	104.3
26	Direction 60 m SD	°	60 m	52,848	52,560	99.46	13.7	0.0	107.0	8.8
27	Direction 60 m Max	°	60 m	52,848	52,560	99.46	134.8	0.0	359.0	109.3
28	Direction 60 m Min	°	60 m	52,848	52,560	99.46	138	138	138	0
29	Direction 40 m	°	40 m	52,848	52,560	99.46	243.7	0.0	359.0	92.3
30	Direction 40 m SD	°	40 m	52,848	52,560	99.46	16.8	0.0	117.0	10.3
31	Direction 40 m Max	°	40 m	52,848	52,560	99.46	198.9	0.0	359.0	93.0
32	Direction 40 m Min	°	40 m	52,848	52,560	99.46	318	318	318	0
33	Temperature	°C		52,848	52,560	99.46	11.73	-15.10	35.30	9.57
34	Temperature SD	°C		52,848	52,560	99.46	0.038	0.000	1.700	0.088
35	Temperature Max	°C		52,848	52,560	99.46	11.99	-15.00	35.60	9.61
36	Temperature Min	°C		52,848	52,560	99.46	11.56	-15.20	35.20	9.55
37	NRG #BP20 Barometric	mbar		52,848	52,560	99.46	651.5	651.1	651.2	0.4
38	NRG #BP20 Barometric SD	mB		52,848	52,560	99.46	0.132	0.000	0.300	0.050
39	NRG #BP20 Barometric Max	mB		52,848	52,560	99.46	651.9	651.1	651.9	0.4
40	NRG #BP20 Barometric Min	mB		52,848	52,560	99.46	650.8	650.7	651.1	0.2
41	Synthesized 80 m	m/s	80 m	52,848	52,848	100.00	5.19	0.40	18.56	2.36
42	Air Density	kg/m³		52,848	52,848	100.00	0.799	0.735	1.190	0.039
43	Speed 60 m A TI			52,848	52,560	99.46	0.202	0.000	0.746	0.081
44	Speed 60 m B TI			52,848	52,560	99.46	0.200	0.000	0.840	0.083
45	Speed 50 m A TI			52,848	52,560	99.46	0.223	0.000	0.849	0.088
46	Speed 50 m B TI			52,848	52,560	99.46	0.224	0.000	0.825	0.088
47	Speed 40 m A TI			52,848	52,560	99.46	0.252	0.000	1.007	0.096
48	Speed 40 m B TI			52,848	0	0.00				
49	Synthesized 80 m WPD	W/m²		52,848	52,848	100.00	94	0	2,616	142
50	Speed 60 m A WPD	W/m²		52,848	52,560	99.46	76	0	1,749	109
51	Speed 60 m B WPD	W/m²		52,848	52,560	99.46	81	0	2,165	120
52	Speed 50 m A WPD	W/m²		52,848	52,560	99.46	57	0	1,422	84
53	Speed 50 m B WPD	W/m²		52,848	52,560	99.46	60	0	1,711	93

Number	Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
54	Speed 40 m A WPD	W/m²		52,848	52,560	99.46	44	0	1,314	70
55	Speed 40 m B WPD	W/m²		52,848	0	0.00				

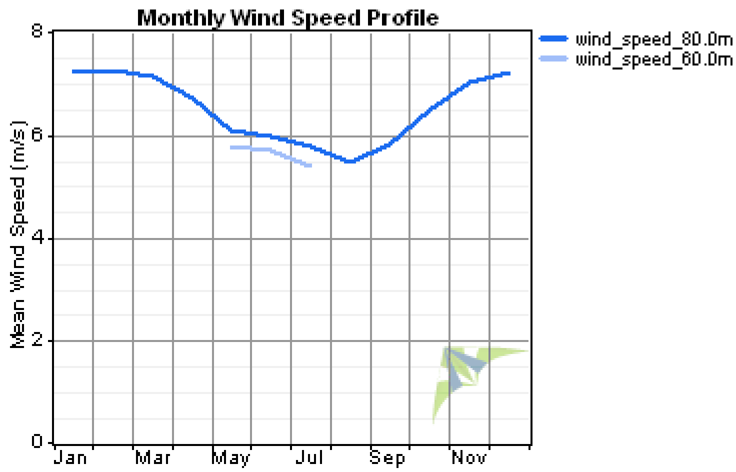
Data Set Properties

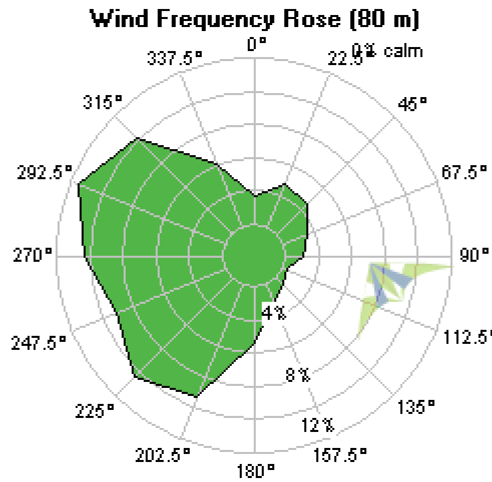
Report Created: 12/10/2010 10:46 using Windographer 2.1.2
Filter Settings: <Unflagged data>

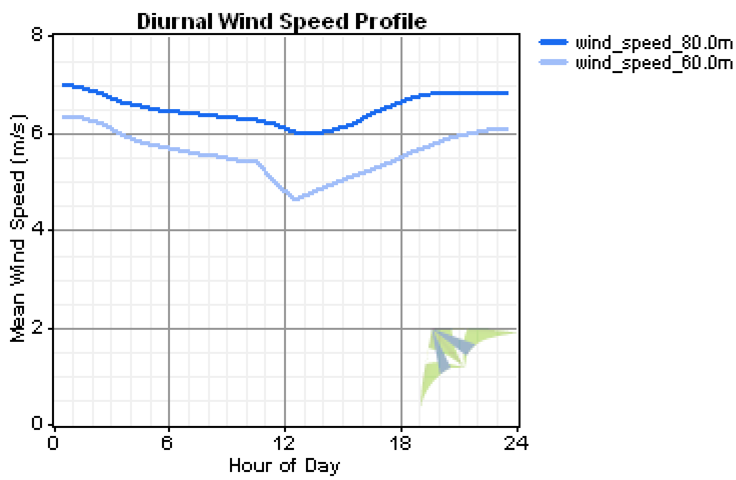
Variable	Value
Latitude	N 42.163527
Longitude	W 71.790695
Elevation	198 m
Start date	1/1/1980 00:00
End date	8/3/2010 00:00
Duration	31 years
Length of time step	60 minutes
Calm threshold	0 m/s
Mean temperature	49.8 °F
Mean pressure	99.36 kPa
Mean air density	1.224 kg/m³
Power density at 50m	111 W/m²
Wind power class	1 (Poor)
Power law exponent	0.15
Surface roughness	0.0864 m
Roughness class	1.88
Roughness description	Few trees

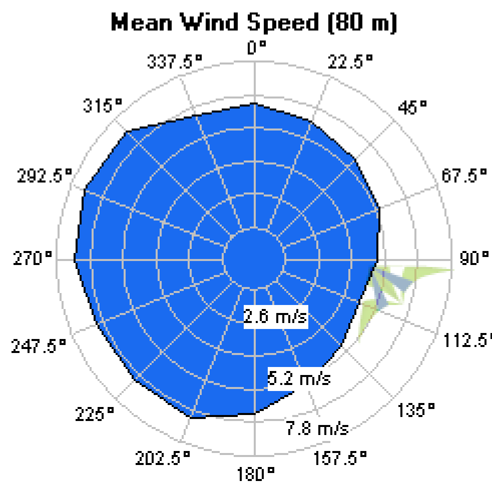


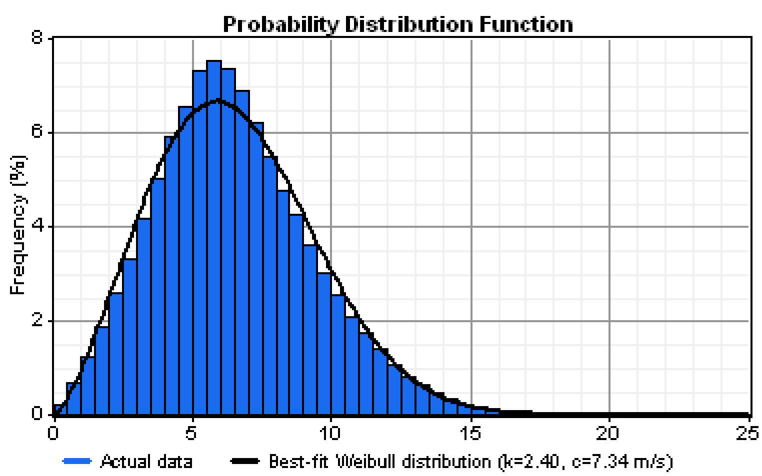
Wind Speed and Direction

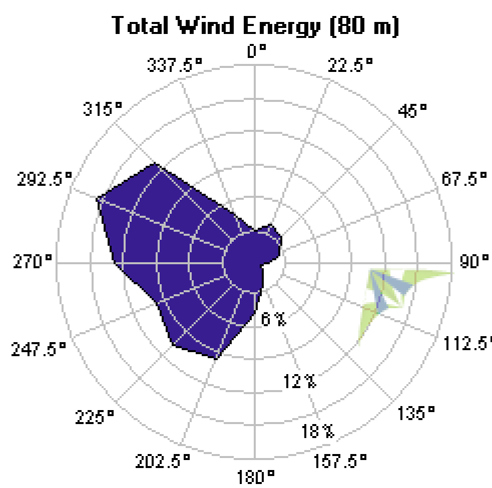




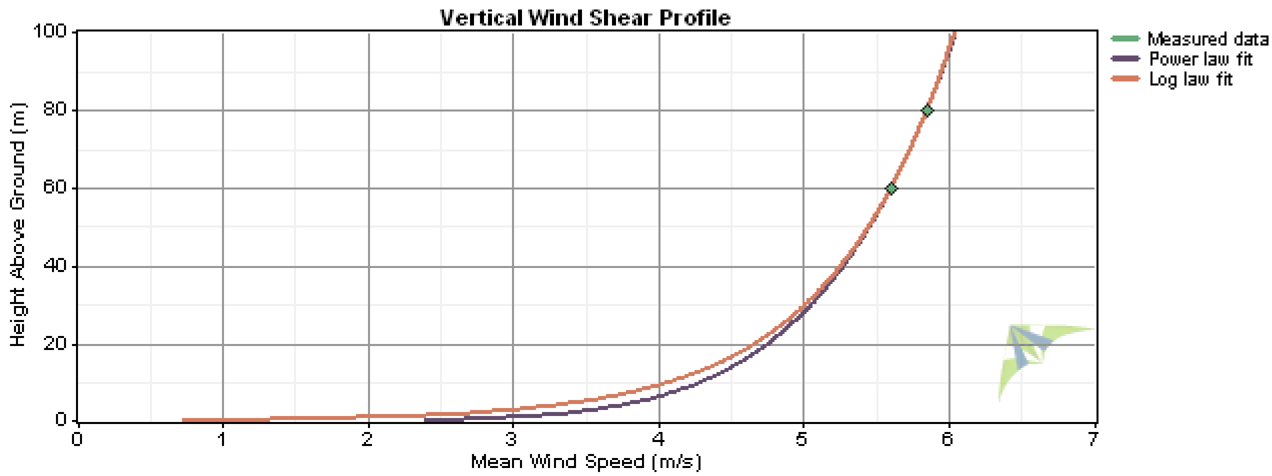


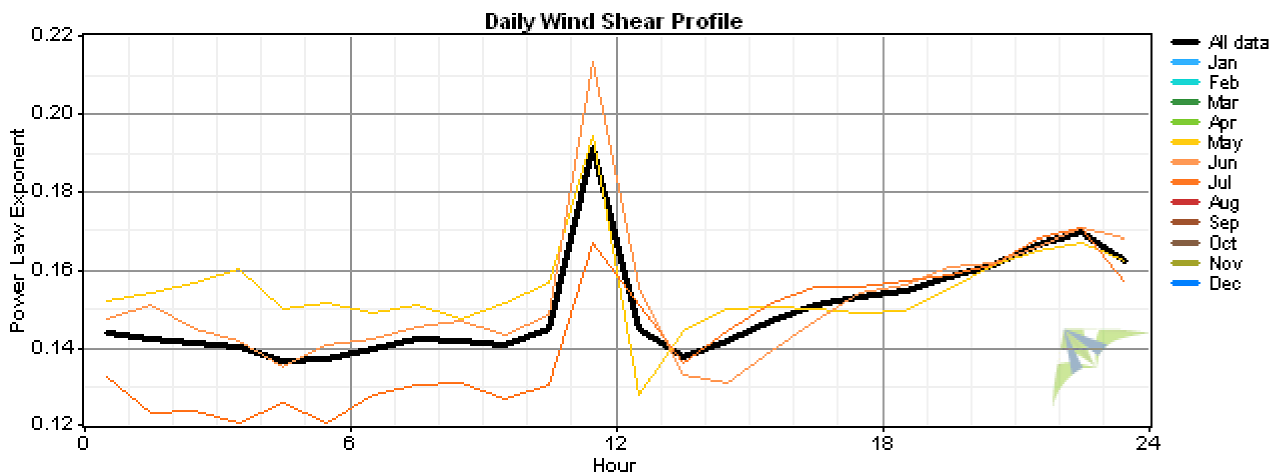


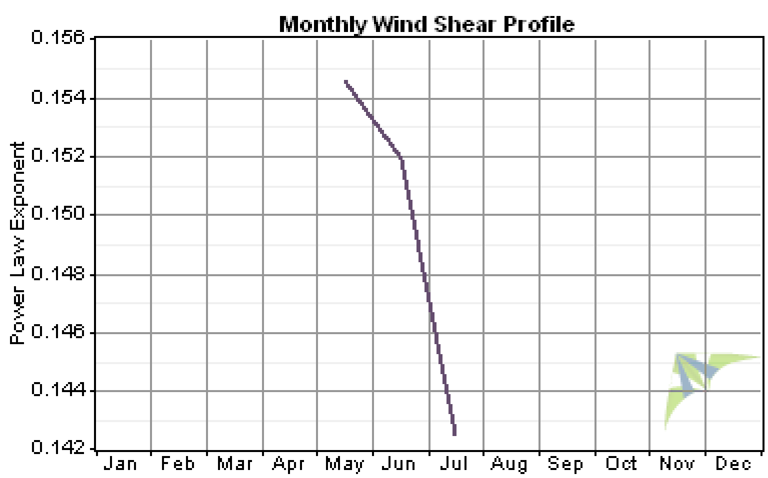


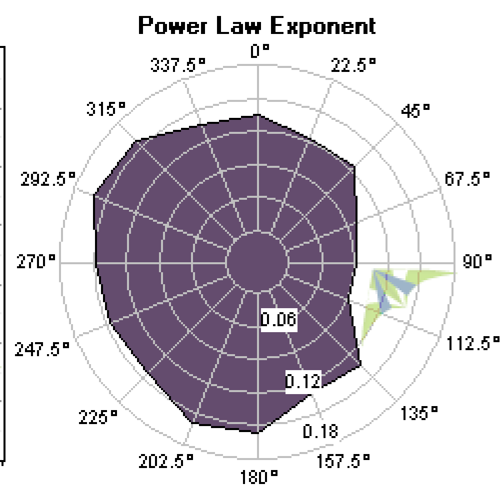


Wind Shear


Vertical Wind Shear Profile
Measured data
Power law fit
Log law fit
Height Above Ground (m)
100
80
60
40
20
0
0
1
2
3
4
5
6
7
Mean Wind Speed (m/s)


Daily Wind Shear Profile
All data
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Power Law Exponent
0.22
0.20
0.18
0.16
0.14
0.12
0
6
12
18
24
Hour


Monthly Wind Shear Profile
Power Law Exponent
0.156
0.154
0.152
0.150
0.148
0.146
0.144
0.142
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Power Law Exponent
0°
22.5°
45°
67.5°
90°
112.5°
135°
157.5°
180°
202.5°
225°
247.5°
270°
292.5°
315°
337.5°
0.06
0.12
0.18

Data Column Properties

Label	Units	Height	Possible Records	Valid Records	Recovery Rate (%)	Mean	Min	Max	Std. Dev
pressure_0m	kPa		268,128	268,080	99.98	99.4	94.3	102.5	0.8
temperature_2m	°F		268,128	268,080	99.98	49.83	-5.80	95.00	19.32
wind_direction_80.0m	°	80 m	268,128	268,080	99.98	270.5	0.0	360.0	95.8
wind_speed_80.0m	m/s	80 m	268,128	268,080	99.98	6.51	0.04	20.51	2.87
wind_direction_60.0m	°	60 m	268,128	2,113	0.79	261.8	1.0	357.0	83.6
wind_speed_60.0m	m/s	60 m	268,128	2,113	0.79	5.60	0.29	14.43	2.30
Vestas V90 - 1.8 MW Power Output	kW		268,128	268,080	99.98	585	0	1,800	578
Air Density	kg/m^3		268,128	268,080	99.98	1.224	1.113	1.386	0.049
wind_speed_80.0m WPD	W/m^2		268,128	268,080	99.98	277	0	5,394	373
wind_speed_60.0m WPD	W/m^2		268,128	2,113	0.79	158	0	1,768	196

Estimated Energy Production
MET Tower Data

100kW
Northern Power 100
37 m hub height

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	4,464	2.93	55.94	0	1.6	1,181	1.6
Feb	4,176	3.04	58.96	0	2.2	1,447	2.2
Mar	4,464	3	57.17	0	1.7	1,263	1.7
Apr	4,320	3	56.99	0	1.3	923	1.3
May	4,464	2.25	82.66	0	0.2	164	0.2
Jun	4,320	2.57	71.69	0	0.5	349	0.5
Jul	4,464	2.44	78.65	0	0.2	159	0.2
Aug	4,608	2.56	76.63	0	1.4	1,006	1.4
Sep	4,320	3.18	48.06	0	1.9	1,365	1.9
Oct	4,464	2.67	66.64	0	0.8	577	0.8
Nov	4,320	2.99	51.46	0	1.5	1,057	1.5
Dec	4,464	2.79	66.13	0	1.3	990	1.3
Overall	52,848	2.78	64.39	0	1.2	10,508	1.2

600kW
RRB Energy PS 600
63.1 m hub height

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	4,464	4.87	26.25	0	49.1	36,554	8.2
Feb	4,176	4.8	25.57	0	45.5	30,592	7.6
Mar	4,464	4.73	27.37	0	41	30,476	6.8
Apr	4,320	5.03	18.94	0	45.3	32,616	7.5
May	4,464	3.72	44.44	0	14.2	10,575	2.4
Jun	4,320	4.28	30.69	0	21.6	15,539	3.6
Jul	4,464	4.08	31.63	0	15.1	11,268	2.5
Aug	4,608	3.93	42.23	0	22.7	16,897	3.8
Sep	4,320	4	38.1	0	20.5	14,736	3.4
Oct	4,464	4.39	31.61	0	29.4	21,909	4.9
Nov	4,320	4.79	25.97	0	41.5	29,895	6.9
Dec	4,464	4.63	27.6	0	40.9	30,439	6.8
Overall	52,848	4.43	30.95	0	32.1	281,591	5.4

Estimated Energy Production
MET Tower Data

1,500 kW
GE 1.5 XLE
80 m hub height

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	4,464	5.68	21.17	0.36	192.4	143,166	12.8
Feb	4,176	5.53	18.99	0.5	166.8	112,082	11.1
Mar	4,464	5.45	22.45	0.38	154.4	114,895	10.3
Apr	4,320	5.89	12.87	0.16	180.9	130,243	12.1
May	4,464	4.26	35.48	0	55.4	41,210	3.7
Jun	4,320	5.19	21.71	0.02	103.7	74,679	6.9
Jul	4,464	5.2	17.79	0	96.2	71,574	6.4
Aug	4,608	4.82	30.47	0.33	102.5	76,255	6.8
Sep	4,320	4.33	33.73	0.25	62	44,671	4.1
Oct	4,464	5.08	23.68	0	116.9	86,961	7.8
Nov	4,320	5.54	21.06	0	158.7	114,282	10.6
Dec	4,464	5.37	20.54	0.63	159.3	118,535	10.6
Overall	52,848	5.19	23.38	0.22	128.9	1,128,825	8.6

1,500 kW
GE 1.5 SLE
80m hub height

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	4,464	5.68	21.01	0	155.5	115,657	10.4
Feb	4,176	5.53	18.68	0	134.6	90,444	9
Mar	4,464	5.45	22.27	0	122.4	91,044	8.2
Apr	4,320	5.89	12.66	0	145.5	104,737	9.7
May	4,464	4.26	34.99	0	41.4	30,782	2.8
Jun	4,320	5.19	21.39	0	77.8	56,002	5.2
Jul	4,464	5.2	17.7	0	71.5	53,216	4.8
Aug	4,608	4.82	30.32	0	81.8	60,830	5.5
Sep	4,320	4.33	33.4	0	47.6	34,254	3.2
Oct	4,464	5.08	23.52	0	90.3	67,215	6
Nov	4,320	5.54	20.88	0	121.6	87,580	8.1
Dec	4,464	5.37	20.41	0	129.8	96,578	8.7
Overall	52,848	5.19	23.16	0	101.4	888,666	6.8

Estimated Energy Production
MET Tower Data

1,800 kW
Vestas V90
80m hub height

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	4,464	5.68	21.1	0.11	281.8	209,640	15.7
Feb	4,176	5.53	18.8	0.36	245.5	164,965	13.6
Mar	4,464	5.45	22.31	0.2	230.5	171,478	12.8
Apr	4,320	5.89	12.69	0.07	267	192,252	14.8
May	4,464	4.26	35.17	0	89	66,188	4.9
Jun	4,320	5.19	21.53	0	163.1	117,453	9.1
Jul	4,464	5.2	17.72	0	152.9	113,746	8.5
Aug	4,608	4.82	30.4	0.22	154.1	114,660	8.6
Sep	4,320	4.33	33.45	0.14	97.7	70,350	5.4
Oct	4,464	5.08	23.57	0	178.7	132,973	9.9
Nov	4,320	5.54	20.93	0	242.3	174,452	13.5
Dec	4,464	5.37	20.43	0.38	232.8	173,171	12.9
Overall	52,848	5.19	23.23	0.12	194.2	1,701,599	10.8

Estimated Energy Production
Long Term Correlated Data

100kW
Northern Power 100
37 m hub height

	Valid	Hub Height	Time At	Time At	Mean Net	Mean Net	Net Capacity
	Data	Wind Speed	Zero Output	Rated Output	Power Output	Energy Output	Factor
Month	Points	(m/s)	(%)	(%)	(kW)	(kWh/yr)	(%)
Jan	4,464	4.47	24.69	0	7.1	5,302	7.1
Feb	4,176	4.39	25	0	6.5	4,366	6.5
Mar	4,464	4.38	24.22	0	6.2	4,579	6.2
Apr	4,320	4.59	18.36	0	6.7	4,815	6.7
May	4,464	3.43	38.93	0	2.5	1,847	2.5
Jun	4,320	3.7	31.92	0	3	2,157	3
Jul	4,464	3.44	34.09	0	1.9	1,401	1.9
Aug	4,608	3.32	45.07	0	2.6	1,906	2.6
Sep	4,320	3.68	34.1	0	3.5	2,491	3.5
Oct	4,464	3.96	30.33	0	4.4	3,268	4.4
Nov	4,320	4.31	27.06	0	6	4,319	6
Dec	4,464	4.2	27.55	0	5.9	4,362	5.9
Overall	52,848	3.98	30.2	0	4.7	40,807	4.7

600kW
RRB Energy PS 600
63.1 m hub height

	Valid	Hub Height	Time At	Time At	Mean Net	Mean Net	Net Capacity
	Data	Wind Speed	Zero Output	Rated Output	Power Output	Energy Output	Factor
Month	Points	(m/s)	(%)	(%)	(kW)	(kWh/yr)	(%)
Jan	4,464	5.37	22.24	0	68.7	51,130	11.5
Feb	4,176	5.25	20.11	0	60.9	40,913	10.1
Mar	4,464	5.19	23.54	0	57.1	42,488	9.5
Apr	4,320	5.56	14.17	0	64.9	46,732	10.8
May	4,464	4.08	37.86	0	22.4	16,632	3.7
Jun	4,320	4.73	24.68	0	33.7	24,276	5.6
Jul	4,464	4.57	23.77	0	27	20,056	4.5
Aug	4,608	4.31	36.02	0	31.1	23,149	5.2
Sep	4,320	4.23	33.75	0	26.4	19,004	4.4
Oct	4,464	4.82	25.58	0	43	31,978	7.2
Nov	4,320	5.25	22.11	0	58.3	42,006	9.7
Dec	4,464	5.11	21.73	0	57.8	42,980	9.6
Overall	52,848	4.87	25.54	0	45.8	401,351	7.6

Estimated Energy Production
Long Term Correlated Data

1,500 kW
GE 1.5 XLE
80 m hub height

	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Month							
Jan	4,464	5.68	21.17	0.36	192.4	143,166	12.8
Feb	4,176	5.53	18.99	0.5	166.8	112,082	11.1
Mar	4,464	5.45	22.45	0.38	154.4	114,895	10.3
Apr	4,320	5.89	12.87	0.16	180.9	130,243	12.1
May	4,464	4.26	35.48	0	55.4	41,210	3.7
Jun	4,320	5.19	21.71	0.02	103.7	74,679	6.9
Jul	4,464	5.2	17.79	0	96.2	71,574	6.4
Aug	4,608	4.82	30.47	0.33	102.5	76,255	6.8
Sep	4,320	4.33	33.73	0.25	62	44,671	4.1
Oct	4,464	5.08	23.68	0	116.9	86,961	7.8
Nov	4,320	5.54	21.06	0	158.7	114,282	10.6
Dec	4,464	5.37	20.54	0.63	159.3	118,535	10.6
Overall	52,848	5.19	23.38	0.22	128.9	1,128,825	8.6

1,500 kW
GE 1.5 SLE
80m hub height

	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Month							
Jan	4,464	5.68	21.01	0	155.5	115,657	10.4
Feb	4,176	5.53	18.68	0	134.6	90,444	9
Mar	4,464	5.45	22.27	0	122.4	91,044	8.2
Apr	4,320	5.89	12.66	0	145.5	104,737	9.7
May	4,464	4.26	34.99	0	41.4	30,782	2.8
Jun	4,320	5.19	21.39	0	77.8	56,002	5.2
Jul	4,464	5.2	17.7	0	71.5	53,216	4.8
Aug	4,608	4.82	30.32	0	81.8	60,830	5.5
Sep	4,320	4.33	33.4	0	47.6	34,254	3.2
Oct	4,464	5.08	23.52	0	90.3	67,215	6
Nov	4,320	5.54	20.88	0	121.6	87,580	8.1
Dec	4,464	5.37	20.41	0	129.8	96,578	8.7
Overall	52,848	5.19	23.16	0	101.4	888,666	6.8

Estimated Energy Production
Long Term Correlated Data

1,800 kW
Vestas V90
80m hub height

Month	Valid Data Points	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Mean Net Power Output (kW)	Mean Net Energy Output (kWh/yr)	Net Capacity Factor (%)
Jan	4,464	5.68	21.1	0.11	281.8	209,640	15.7
Feb	4,176	5.53	18.8	0.36	245.5	164,965	13.6
Mar	4,464	5.45	22.31	0.2	230.5	171,478	12.8
Apr	4,320	5.89	12.69	0.07	267	192,252	14.8
May	4,464	4.26	35.17	0	89	66,188	4.9
Jun	4,320	5.19	21.53	0	163.1	117,453	9.1
Jul	4,464	5.2	17.72	0	152.9	113,746	8.5
Aug	4,608	4.82	30.4	0.22	154.1	114,660	8.6
Sep	4,320	4.33	33.45	0.14	97.7	70,350	5.4
Oct	4,464	5.08	23.57	0	178.7	132,973	9.9
Nov	4,320	5.54	20.93	0	242.3	174,452	13.5
Dec	4,464	5.37	20.43	0.38	232.8	173,171	12.9
Overall	52,848	5.19	23.23	0.12	194.2	1,701,599	10.8

Site Name: Millbury
Installation Date:
Tension Check Date: 9/13/2011
Tower: NRG 60 meter

Ideal Sag*	Guy Level	North Initial	North Final	South Initial	South Final	East Initial	East Final	West Initial	West Final
1.0 - 2.0	1	1	1	2	1.5	1.5	1	1	1
1.5 - 2.5	2	1	1.5	2	2	1.5	1.5	1.5	1.5
2.0 - 3.0	3	2	2	3	2.5	4	2.5	1	2.5
2.5 - 3.5	4	5	3	3	2.5	4	3.5	4.5	2.5
3.0 - 4.5	5	5.5	3	5	3.5	7	4	5	3
3.5 - 5.0	6	3	3.5	6	4	9	5	3	4

* Sag is the number of tube sections as defined by manufacturer installation manual

Orientation:
North: Uphill
South: Downhill (lifting anchors)
West: Trees
East: Farm Buildings

Wind Vane Notes:
1:00pm 245degrees (arm facing south)
2:30pm 263 (west)

Appendix D

Relevant Correspondence

AVIATION SYSTEMS INC.

Date: OCT 06 2010

To: Johanna Nagle
Weston & Sampson Engineers, Inc.
5 Centennial Drive
Peabody, MA 019[illegible]

ASI #: 10-O-0632.004
Client Site ID: Millbury, MA
FAA #:

We are sending you herewith the following via:

☑ **US Mail** ☐ **Overnight** ☐ **Fax** ☑ **Email** ☐ **2nd Day**

☑ ASI FAR Part 77 Airspace Obstruction Report
☐ Search Area Study Report
☑ Copies of our filing(s) with FAA and/or State
☐ Responses from FAA and/or State
☐ ASI Opinion Letter
☑ Quad Chart
☑ See attachments for Airport Runway data and/or AM Stations(s)
☐ Certified Survey

Comments:

Sincerely,

Aviation Systems, Inc.
By: Allen

2510 W. 237th Street • Suite 210 • Torrance, CA 90505
Tel: 310.530.3188 • Fax: 310.530.3850 • email: asi@aviationsystems.com • www.aviationsystems.com

Date: OCT 06 2010

To: Massachusetts Aeronautics Comm.
Aeronautics Commission
10 Park Plaza, Room 6620
Boston, MA 02116-3966

ASI #: 10-O-0632.004
Client Site ID: Millbury, MA
FAA #:

We are sending you herewith the following via:

☑ **US Mail** ☐ **Overnight** ☐ **Fax** ☐ **Email** ☐ **2nd Day**

☑ Copy of Notice of Proposed Construction (7460-1) filed with FAA

☑ Quad Chart depiction and supporting data

Comments:

Thank you.

Sincerely,

Aviation Systems, Inc.
By:

2510 W. 237th Street • Suite 210 • Torrance, CA 90505
Tel: 310.530.3188 • Fax: 310.530.3850 • email: asi@aviationsystems.com • www.aviationsystems.com

Date: OCT 06 2010

To: Air Traffic Division, ANE-530
New England Regional Office
12 New England Executive Park
Burlington, MA 01803-5299

ASI #: 10-O-0632.004
Client Site ID: Millbury, MA
FAA #:

We are sending you herewith the following via:

☐ **US Mail** ☑ **Overnight** ☐ **Fax** ☐ **Email** ☐ **2nd Day**

☑ Copy of Notice of Proposed Construction (7460-1)
☑ Quad Chart depiction and supporting data
☐ Our comments to your Aeronautical Circular or your communication regarding the referenced study number.

Comments:

☐ Side mounted, not to exceed existing structure.
☑ The height requested exceeds the FAR 77 filing requirements.
☐ The height requested does ☐ does not ☑ exceed FAR 77 obstruction standards.
☐ The obstruction standards exceeded, if any, would not be a hazard to air navigation.
☑ If FAA determines that further aeronautical study is required, by this Transmittal we hereby request such study.
☑ Proponent requests dual marking & lighting in compliance with AC 70/7460-1K, Change 1.
☐ Frequency Filing Only

Notes:

Thank you.

Sincerely,

Aviation Systems, Inc.
By: [signature]

2510 W. 237th Street • Suite 210 • Torrance, CA 90505
Tel: 310.530.3188 • Fax: 310.530.3850 • email: asi@aviationsystems.com • www.aviationsystems.com

AVIATION SYSTEMS, INC.
Phone: 310-530-3188 Fax: 310-530-3850
crisj@aviationsystems.com
www.aviationsystems.com

FAR PART 77 AIRSPACE OBSTRUCTION REPORT

To:

Johanna Nagle
Weston & Sampson Engineers, Inc.
5 Centennial Drive
Peabody, MA 01960

Date: October 5, 2010

Location: Millbury, MA
Client Case No: Millbury, MA
ASI Case No: 10-O-0632.004

SUMMARY OF FINDINGS:

At this location any structure over 200 feet AGL will have to be filed with the FAA. A structure up to 500 feet AGL should receive a routine approval. Refer to Findings and Comment Section for additional information.

SITE DATA:

Structure: Wind Turbine

Coordinates: 42°-09'-48.54" / 071°-47'-28.25" **[NAD 27]**
42°-09'-48.88" / 071°-47'-26.50" **[NAD 83]**

Site Ground Elevation: 662 **' [AMSL]**
Studied Structure Height (with Appurtenances): MAX **' [AGL]**
Total Overall Height: **' [AMSL]**

SEARCH RESULTS:

- The nearest public use or military air facility subject to FAR Part 77 is Worcester Rgnl. Airport.
- The studied structure is located 6.83 NM / 41,513 feet SouthEast (150 ° True) of the Worcester Rgnl. Airport Runway 33.
- Other public or private airports or heliports within 3 NM: ☐ None ☑ Printout attached
- AM radio station(s) within 3NM: ☑ None ☐ Printout attached

Highlighted AM stations on printout require notice under FCC Rules and Policy (Ref.: 47 CFR 73.1692).

ASI Case No: 10-O-0632.004

FINDINGS

- **FAA Notice (Ref.: FAR 77.13 (a)(1); FAR 77.13 (a)(2) i, ii, iii)**

☐ Not required at studied height

☐ Required at studied height

☒ The No Notice Maximum height is 200 feet AGL.

IMPORTANT: Our report is intended as a planning tool. If notice is required, actual site construction activities are not advisable until an FAA Final Determination is issued.

- **Obstruction Standards of FAR Part 77 (Ref.: FAR 77.23 (a)(1),(2),(3),(4),(5)):**

☐ Not exceeded at studied height.

☐ Exceeded at studied height.

☒ Maximum nonexceedance height is 500 feet AGL.

- **Marking and Lighting (Ref: AC 70/7460-1K,Change 1):**

☐ Will not be required at studied height

☒ Will be required at studied height, structure exceeds:

  ☒ 200 feet AGL

  ☐ Obstruction Standards

- **Operational Procedures (Ref.: FAR 77.23 (a) (3),(4); FAA Order 7400.2; FAA Order 8260.3B)**

☐ Not affected at studied height *(FAA should issue a Determination of No Hazard.)*

☐ Affected at studied height and the FAA will consider the studied structure to be a Hazard to Air Navigation.

☒ Maximum height that would not affect operational procedures is 500 feet AGL/ 1162 feet AMSL.

Conclusions/Comments:

- This proposed site does not fall within the airspace defined by MGL Regulation Chapter 90 Section 35B.

- For your planning purposes, this site has been evaluated to a height up to and including 500' AGL. Proposed structures that would exceed 500' AGL require the FAA to conduct detailed extended studies and circularize the proposal for industry comment. Structures above 500' AGL may be impacted by helicopter low-level routes, fixed-wing aircraft flyways, minimum vectoring altitudes, minimum enroute altitudes and other operational procedures. ASI studies for structures above 500' AGL should be separately requested.

Per conversation with Johanna Nagle ASI filed with the FAA for a 410' turbine height.

-Impact to Air Defense and Homeland Security radars is likely. Further radar study may be advisable.

-Impact likely to WSR-88D weather radar operations. Turbines likely in radar line of sight. Further radar impact study may be advisable.

Actions:

ASI will file with ANE FAA Region and State ☒ Yes ☐ No

Federal Aviation Administration

« OE/AA/

Notice of Proposed Construction or Alteration - Off Airport

Project Name: WESTO-000157105-10 **Sponsor:** Weston & Sampson Engineers, Inc.

Details for Case : Millbury, MA 10-O-0632.004

Show Project Summary

Case Status

ASN: 2010-WTE-14470-OE

Status: Accepted

Date Accepted: 10/06/2010

Date Determined:

Letters: None

Documents: None

Construction / Alteration Information

Notice Of: Construction

Duration: Permanent

***if Temporary* :** Months: Days:

Work Schedule - Start:

Work Schedule - End:

State Filing: Filed with State

Structure Summary

Structure Type: Wind Turbine

Structure Name: Millbury, MA 10-O-0632.(

NOTAM Number:

FCC Number:

Prior ASN:

Structure Details

Latitude: 42° 9' 48.88" N

Longitude: 71° 47' 26.50" W

Horizontal Datum: NAD83

Site Elevation (SE): 662 (nearest foot)

Structure Height (AGL): 410 (nearest foot)
**** If the entered AGL is a proposed change to an existing structure's height include the current AGL in the Description of Proposal.***

Requested Marking/Lighting: Dual-red and medium intensity

***Other* :**

Recommended Marking/Lighting:

Current Marking/Lighting: N/A New Structure

***Other* :**

Nearest City: Millbury

Nearest State: Massachusetts

Description of Location:
On the Project Summary page upload any certified survey. Wind Turbine 1 of 1. All Structures are white.

Description of Proposal: 410' ASL Wind Turbine to be constructed west of Forrest Hill Dr and south of Main Street in Millbury, MA

Common Frequency Bands

Low Freq	High Freq	Freq Unit	ERP	ERP l

Specific Frequencies

massDOT
Massachusetts Department of Transportation
Aeronautics Division

Airspace Review Form

Sponsor Information

Sponsor First Name:	Johanna
Sponsor Last Name:	Nagle
Sponsor Suffix:	
Sponsor Address:	5 Centennial Drive
Sponsor City:	Peabody
Sponsor State:	MA
Sponsor Zip:	01960
Sponsor Telephone:	978.532.1900
Sponsor Email:	naglej@wseinc.com

Sponsor's Representative

☐ Same as Sponsor

Sponsor's Rep. First Name:	Cris
Sponsor's Rep. Last Name:	Justis
Sponsor's Rep. Suffix:	
Sponsor's Rep. Address:	2510 W. 237th St Ste 200
Sponsor's Rep. City:	Torrance
Sponsor's Rep. State:	CA
Sponsor's Rep. Zip:	90505
Sponsor's Rep. Telephone:	310.530.3188
Sponsor's Rep. Email:	crisj@aviationsystems.com

Project Description

Wind Turbine 1 of 1. 410' AGL Wind Turbine to be constructed west of Forrest Hill Dr. and south of Main Street in Millbury, MA.

Location, Height & Elevation Data

Nearest Aviation Facility: Worcester Regional Airport

City: Worchester

Datum: NAD 83

	Degrees	Minutes	Seconds
Latitude:	42	09	44.88
Longitude:	071	47	26.50

Site Elevation above MSL (ft.):	662
Maximum Height Above Ground (ft.):	410
Maximum elevation above MSL (ft.):	1072

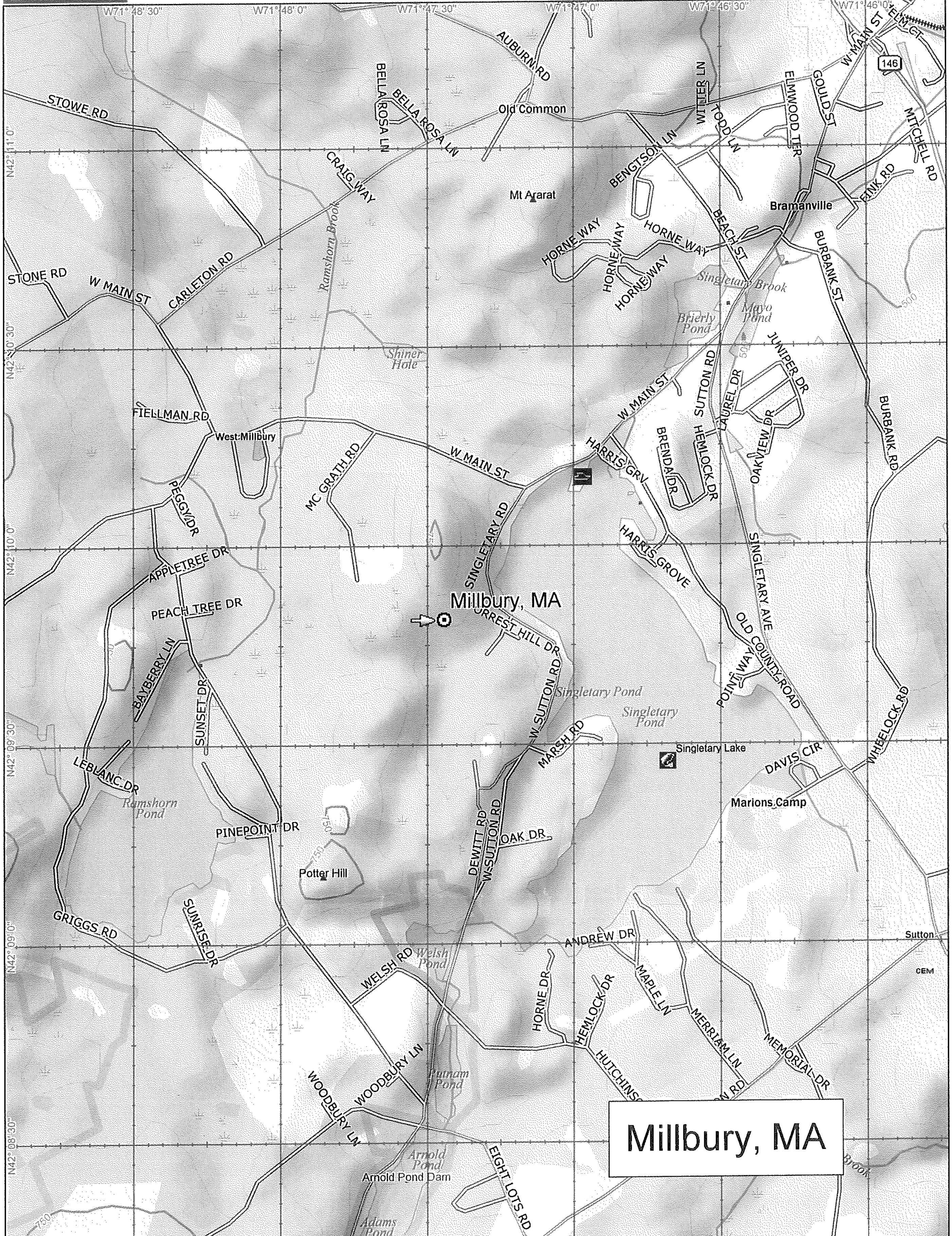
USGS Quad Sheet Showing Project Location

Please browse for the file to attach to this submission using the file control below.

Choose File 10-O-0632.004 Map.pdf

Cancel Submit

DeLorme XMap® 7



Data use subject to license.

www.delorme.com

TN

MN (14.6°W)

Scale 1 : 24,000

1" = 2,000.0 ft

Data Zoom 13-0

Airports with Runways

Search Latitude: 42-09-49 **Search Radius:** 3

Search Longitude: 071-47-27 **Height (MSL):**

ID	Name	City	State	ARP Lat	ARP Long	Type	Rways	Primary	RwyLat	RwyLong	Elev.	Dist/NM	Dist/feet	Bear
4MA3	MILLBURY SAVINGS/WEST	MILLBURY	MA	42-11-30.3400N	071-46-10.2530W	PR						1.93	11,750	29.50

The Commonwealth of Massachusetts
AERONAUTICS COMMISSION
REQUEST FOR AIRSPACE REVIEW

For Office Use Only

☐ Airspace Analysis ________ Initials
☐ Comments Received
☐ AIMS Updated

MAC File No.: ____________________ FAA File No.: ____________________ (For reference only)

Notice is required by 780 CMR (Code of Massachusetts Regulations) 111.7, *Hazards to air navigation.* Pursuant to Massachusetts General Laws (MGL) Chapter 90, Section 35B, the Massachusetts Aeronautics Commission (MAC) agrees to perform an AIRSPACE ANALYSIS and render a determination for the project listed below. **IMPORTANT: All shaded areas must be completed.**

Sponsor (include name, address & telephone number):

Johanna Nagle
Weston & Sampson Engineers, Inc.
5 Centennial Drive
Peabody, MA 01960
(978)532-1900

Sponsor's Representative (same data if applicable):

Gary M. Allen
Aviation Systems, Inc.
2510 W. 237th Street, Suite 210
Torrance, CA 90505
(310) 530-3188 Fax (310) 530-3850

Project Description (please type or print clearly):

Per conversation with Johanna Nagle, ASI filed with the FAA for a 410 foot AGL turbine height.

☒ REQUIRED: Attach 8½ x 11 inch map (e.g. USGS Quad sheet) showing location of project

Location, Height & Elevation Data:

Nearest City, State: Millbury, MA

	Degrees	Minutes	Seconds
Latitude	42	09	48.88
Longitude	071	47	26.50

Datum ☑ NAD 83 or ☐ NAD 27

Site elevation above MSL (ft.): 662 MSL
Maximum height above ground (ft.): MAX AGL
Maximum elevation above MSL (ft.): ______ MSL

Nearest Public-Use Aviation Facility: Worcester Rgnl. Airport

Print or type, below, the name of person filing this request for review	Signature	Date
Gary M. Allen, Director of Regulatory Affairs Aviation Systems, Inc.		

*************** **DO NOT WRITE BELOW THIS LINE - FOR MAC OFFICE USE ONLY** ***************

MAC's AIRSPACE ANALYSIS concludes the following:

Closest Runway: __________ Distance from RW end: __________ Offset from RW CL: __________ ☐ Left ☐ Right

☐ Project violates MGL Ch. 90, §35B by ______ ft. [Runway Horizontal Plane - 3,000' x 2 Statute Miles]
☐ Project violates MGL Ch. 90, §35B by ______ ft. [Runway Approach Plane - 3,000' x 3,000' @ 20:1 slope]
☐ Project violates 702 CMR, §5.03(1)(a) by ______ ft. [Runway Approach Plane / Land - 500' x 10,000' @ 20:1 slope]
☐ Project violates 702 CMR, §5.03(2)(a) by ______ ft. [Runway Approach Plane / Water - 500' x 10,000' @ 20:1 slope]

☐ Project does not violate MAC Airspace Laws or Regs.

MAC hereby issues the following DETERMINATION:

☐ Permit is required* pursuant to MGL Ch.90, §35B, for: ☐ Runway Horizontal Plane ☐ Runway Approach Plane

* Sponsor must submit a separate written request for a MAC Airspace Permit. Request should be addressed to MAC Chief Legal Counsel, Massachusetts Aeronautics Commission, 10 Park Plaza, Room 6620, Boston, MA 02116-3966

☐ Permit is not required pursuant to MGL Ch.90, §35B ☐ No violation of Laws or Regs ☐ Ch.90 Violation $\leq$ 30' agl

☐ MAC has the following additional concerns:

☐ FAA Standards ☐ Noise
☐ Traffic Pattern ☐ Wildlife
☐ VFR Route ☐ Other

This determination is based on the foregoing description of the proposed project including the location, height and elevation data provided by the Sponsor. Any change in the data provided to the MAC from that which is shown herein will render this determination null and void and will necessitate a new request for review.

Mgr. of Airport Engineering, Massachusetts Aeronautics Commission ____________ Date ____________

Appendix E

Selected Millbury Electric Bills

nationalgrid

www.nationalgrid.com

SERVICE FOR
TOWN OF MILLBURY SCHOOL
ELMWOOD ST OFC OFF POLE 19
MILLBURY MA 01527

BILLING PERIOD
May 21, 2009 to Jun 23, 2009

ACCOUNT NUMBER 15570-23007
PLEASE PAY BY Aug 17, 2009
AMOUNT DUE $ 10,227.40

CUSTOMER SERVICE
1-800-322-3223

CREDIT DEPARTMENT
1-888-211-1313

POWER OUTAGE OR DOWNED LINE
1-800-465-1212

EMAIL BILLING INQUIRES
customerservice@us.ngrid.com

ADDRESS
PO Box 960
Northborough, MA 01532-0960

DATE BILL ISSUED
Jun 23, 2009

ACCOUNT BALANCE

	National Grid Services	Other Supplier Service	Adjustments	Total
Previous Balance	3,392.73	8,217.09	0.00	11,609.82
Payment(s) Received	- 1,928.21	- 4,676.36	- 0.00	- 6,604.57
Amount Past Due	1,464.52	3,540.73	0.00	5,005.25
Current Charges	1,527.75	3,693.52	0.88	5,222.15
Amount Due Now ▶	$ 2,992.27	$ 7,234.25	$ 0.88	$ 10,227.40

To avoid late payment charges of 0.95%, your "Amount Due Now" must be received by Aug 17 2009.

➢ **PLANTING A TREE? PLANNING OUTDOOR PROJECTS?:** Prevent personal injury, property damage and service interruptions caused by accidentally digging into electric, gas, telephone, water, sewer or cable facilities. **Call 811 before you dig!**.

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone WCMA
Acct No: 15570-23007 **Cycle:** 16, TOWN

Electric Usage History

Month	kWh	Month	kWh
Jun 08	33520	Jan 09	46080
Jul 08	21840	Feb 09	42080
Aug 08	23600	Mar 09	41440
Sep 08	33760	Apr 09	38720
Oct 08	36160	May 09	28080
Nov 08	37360	Jun 09	30080
Dec 08	35680		

Billed Demand Last 12 months

Minimum	86.4
Maximum	168.8
Average	152.2

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	-	Previous Reading	=	Difference	x	Meter Multiplier	=	Total Usage
Energy	24090 *Actual*		23714 *Actual*		376		80		30080 kWh
							Total Energy		**30080 kWh**

Demand-kW	Demand-kVA
143.2 kW	145.6 kVA

Billed Demand **143.2 kW**

METER NUMBER 98720974 NEXT SCHEDULED READ DATE Jul 23
SERVICE PERIOD May 21 - Jun 23 NUMBER OF DAYS IN PERIOD 33
RATE General Service - Demand G-2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

JUN 2 6 [illegible]

KEEP THIS PORTION FOR YOUR RECORDS.

nationalgrid

SERVICE FOR
TOWN OF MILLBURY SCHOOL
ELMWOOD ST OFC OFF POLE 19
MILLBURY MA 01527

BILLING PERIOD
May 21, 2009 to Jun 23, 2009

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
15570-23007	Aug 17, 2009	**$ 10,227.40**

Customer Charge				16.56
Distribution Charge	0.00089	x	30080 kWh	26.77
Transition Charge	0.00123	x	30080 kWh	36.99
Transmission Charge	0.01408	x	30080 kWh	423.53
Distribution Demand Chg	6.41	x	143.2 kW	917.91
Dem Side Mgmt Chg	0.0025	x	30080 kWh	75.20
Transition Demand Chg	0.11	x	143.2 kW	15.75
Renewable Energy Chg	0.0005	x	30080 kWh	15.04
	Total Delivery Services			**$ 1,527.75**

Explanation of General Billing Terms

KWH: Kilowatt-hour, a basic unit of electricity used.
Off-Peak: Period of time when the need or demand for electricity on the Company's system is low, such as late evenings, weekends and holidays.
Peak: Period of time when the need or demand for electricity on the Company's system is high, normally during the day, Monday through Friday, excluding holidays.
Estimated Bill: A bill which is calculated based on your typical monthly usage rather than on an actual meter reading. It is usually rendered when we are unable to read your meter.
Meter Multiplier: A number by which the usage on certain meters must be multiplied by to obtain the total usage.
Demand Charge: The cost of providing electrical transmission and distribution equipment to accommodate your largest electrical load.

Supplier Service Charges are comprised of:

Generation Charge: The charge(s) to provide electricity and other services to the customer by a supplier.

Delivery Service Charges are comprised of:

Customer Charge: The cost of providing customer related service such as metering, meter reading and billing. These fixed costs are unaffected by the actual amount of electricity you use.
Distribution Charge: The cost of delivering electricity from the beginning of the Company's distribution system to your home or business.
Transition Charge: Company payments to its wholesale supplier for terminating its wholesale arrangements.
Transmission Charge: The cost of delivering electricity from the generation company to the beginning of the Company's distribution system.

Demand Side Management: The cost of demand side management programs offered by the Company.
Renewable Energy Charge: A charge to fund initiatives for communicating the benefits of renewable energy and fostering formation, growth, expansion and retention of renewable energy and related enterprises.

nationalgrid

www.nationalgrid.com

SERVICE FOR
TOWN OF MILLBURY
123 ELM ST
MILLBURY MA 01527

BILLING PERIOD
May 21, 2009 to Jun 23, 2009

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
28002-42006	Aug 17, 2009	$ 256.22

CUSTOMER SERVICE
1-800-322-3223

CREDIT DEPARTMENT
1-888-211-1313

POWER OUTAGE OR DOWNED LINE
1-800-465-1212

EMAIL BILLING INQUIRES
customerservice@us.ngrid.com

ADDRESS
PO Box 960
Northborough, MA 01532-0960

DATE BILL ISSUED
Jun 23, 2009

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone WCMA
Acct No: 28002-42006 **Cycle:** 16, TOWN

Electric Usage History

Month	kWh	Month	kWh
Jun 08	1435	Jan 09	3398
Jul 08	1730	Feb 09	2059
Aug 08	1787	Mar 09	1959
Sep 08	1501	Apr 09	1291
Oct 08	1820	May 09	1242
Nov 08	1605	Jun 09	1355
Dec 08	2743		

ACCOUNT BALANCE

	National Grid Services	Other Supplier Service	Total
Previous Balance	83.08	152.51	235.59
Payment(s) Received	- 83.08	- 152.51	- 235.59
Current Charges	89.84	166.38	256.22
Amount Due Now ▶	$ 89.84	$ 166.38	$ 256.22

To avoid late payment charges of 0.95%, your "Amount Due Now" must be received by Aug 17 2009.

➤ **PLANTING A TREE? PLANNING OUTDOOR PROJECTS?:** Prevent personal injury, property damage and service interruptions caused by accidentally digging into electric, gas, telephone, water, sewer or cable facilities. **Call 811 before you dig!**.

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	-	Previous Reading	=	Difference	x	Meter Multiplier	=	Total Usage
Energy	34751 *Actual*		33396 *Actual*		1355		1		1355 kWh
							Total Energy		**1355 kWh**

METER NUMBER 16620183 **NEXT SCHEDULED READ DATE** Jul 23
SERVICE PERIOD May 21 - Jun 23 **NUMBER OF DAYS IN PERIOD** 33
RATE General Service - Small C/I G-1 **VOLTAGE DELIVERY LEVEL** 0 - 2.2 kv

Customer Charge				9.03
Distribution Charge	0.04094	x	1355 kWh	55.48
Transition Charge	0.00116	x	1355 kWh	1.57
Transmission Charge	0.01453	x	1355 kWh	19.69
Dem Side Mgmt Chg	0.0025	x	1355 kWh	3.39
Renewable Energy Chg	0.0005	x	1355 kWh	0.68
			Total Delivery Services	**$ 89.84**

KEEP THIS PORTION FOR YOUR RECORDS.

Supply Services

SUPPLIER Suez Energy Resources NA
3 Barker Ave
White Plains, NY 10601

PHONE 866-999-8374 **ACCOUNT NO** TESMA0400165135

Electricity Supply	0.12279 x 1355 kWh	166.38
	Total Supply Services	**$ 166.38**

Explanation of General Billing Terms

KWH: Kilowatt-hour, a basic unit of electricity used.
Off-Peak: Period of time when the need or demand for electricity on the Company's system is low, such as late evenings, weekends and holidays.
Peak: Period of time when the need or demand for electricity on the Company's system is high, normally during the day, Monday through Friday, excluding holidays.
Estimated Bill: A bill which is calculated based on your typical monthly usage rather than on an actual meter reading. It is usually rendered when we are unable to read your meter.
Meter Multiplier: A number by which the usage on certain meters must be multiplied by to obtain the total usage.
Demand Charge: The cost of providing electrical transmission and distribution equipment to accommodate your largest electrical load.

Supplier Service Charges are comprised of:

Generation Charge: The charge(s) to provide electricity and other services to the customer by a supplier.

Delivery Service Charges are comprised of:

Customer Charge: The cost of providing customer related service such as metering, meter reading and billing. These fixed costs are unaffected by the actual amount of electricity you use.
Distribution Charge: The cost of delivering electricity from the beginning of the Company's distribution system to your home or business.
Transition Charge: Company payments to its wholesale supplier for terminating its wholesale arrangements.
Transmission Charge: The cost of delivering electricity from the generation company to the beginning of the Company's distribution system.

Demand Side Management: The cost of demand side management programs offered by the Company.
Renewable Energy Charge: A charge to fund initiatives for communicating the benefits of renewable energy and fostering formation, growth, expansion and retention of renewable energy and related enterprises.

145

Appendix F

USFWS Impact Evaluation Criteria

USFWS Impact Evaluation Criteria

The United States Fish and Wildlife Service has developed general impact evaluation criteria used in this preliminary assessment. These eight criteria, listed below, serve to highlight the critical information needed to make an accurate impact assessment on the avian community. Assessment of each of the evaluation criteria was conducted included in conjunction with consultation with federal and state agencies, landscape analysis, GIS screening, species listings and reviewing special site considerations were employed to gather the necessary information to address each of the impact evaluation criteria presented in this section and are addressed individually below:

1. Are the potential locations of turbines located within one mile of documented locations of any rare species of wildlife or plants?

In total, there are fifty-two federal and state listed species present in the area near the Town of Millbury. Site layout and natural community buffering appears to preclude the frequent presence of rare species on the developed portion of the site, but more detailed survey would be required to confirm.

2. Are the potential turbine locations in known local bird migratory pathways or in areas where birds are highly concentrated (e.g. wetlands, wildlife refuges, landfills, rookeries, etc…)?

The site is located within the path of a documented North Atlantic Flyway. In general the flyway concept is often misconstrued and must be viewed with a certain degree of skepticism when applied directly to real-life applications. There are a number of limitations within the flyway concept. Most notably birds migrate in general north-south direction, but with an equally important east-west component (Bakken et al, 2003). Birds therefore migrate over a broad range, and as such this element is not always well captured in the traditional flyway models.

3. Are potential turbine locations in known daily movement flyways (e.g. nesting and feeding/foraging areas) and areas with a high incidence of fog, mist, or low visibility?

Although a more detailed survey would be required to accurately assess the daily movement patterns of wildlife in the area, the presence of NHESP priority habitats surrounding the facility make the daily migration to feeding/foraging areas likely. However, birds moving in a localized manner between feeding points are not likely to fly into the swept area of a wind turbine.

4. Are potential turbine locations in areas or features of the landscape known to attract raptors?

There is the potential for forest raptors to nest in the forested areas near the site.

5. Are potential turbine locations near known bat hibernation, breeding, and maternity/nursery colonies, in migration corridors, or in flight paths between colonies and feeding areas?

Accurate assessment of the bat population would require a more detailed study of the project area. At this time there are no known bat hibernacula in the area of the proposed turbine location. Further assessment would be required to determine bat populations, since landscape features or site development does not avert the presence of significant bat populations.

6. Do potential turbine locations fragment large, contiguous tracts of wildlife habitat?

No, habitat fragmentation is considered negligible.

7. Are turbines being proposed in habitat known to be occupied by species that exhibit extreme avoidance of vertical features and/or structural habitat fragmentation?

There are no species in the proposed area of the project that have been known to exhibit extreme avoidance to vertical features. The extent of structural habitat fragmentation existing currently on the site implies that further developmental effects would be negligible.

8. Do any significant ecological events occur in the region associated with the proposed development?

The occurrence of significant ecological events in the area of the site is unknown. However; a more detailed review of the conditions and observation of the avian community during the annual migration period would be required to determine if there are any significant ecological effects that would interrupted by construction of a wind turbine.

Research by the National Wind Coordinating Committee has determined that roughly 200 to 500 million-bird collisions occur annually. Of these, roughly 0.1 to 0.2 percent of the collisions are attributed to wind turbines in comparison to the 1 to 2 percent from communication towers, 25 to 50 percent from windows/buildings, and 15 to 30 percent from vehicle collision incidents. Therefore, avian impacts from the construction of one wind turbine in an area that is already developed would likely be minimal in comparison to annual bird mortality rates.

Research conducted at the Massachusetts Maritime Academy, located in Bourne, MA where a 660 kW wind turbine was installed, indicates that during a post-construction mortality survey, no bird kills were attributed to the wind turbine. Research has demonstrated that frequency of bird sightings in the vicinity of the turbine actually decreases when the wind turbine is operating. This suggests that birds may actually alter their flight patterns making it even less likely for them to pass through the rotors swept area.

If a wind turbine is to be installed, monitoring for avian mortality could be included as part of the normal operation and maintenance of the wind turbine. This would add valuable data to monitor actual affects of wind turbines on avian species.

Most conservation groups generally support the development of wind energy in the United States as an alternative to fossil and nuclear-fueled power plants to meet growing demand for electrical energy. However, concerns have surfaced over the potential threat to birds, bats, and other wildlife from the construction and operation of wind turbine facilities, as well as other "Not In My Back Yard" or NIMBY-related issues, due to the sight and sounds produced by a wind turbine.

In 2003, representatives of the wind industry, environmental community, and biological research community agreed that it would be useful to convene a meeting to examine the most current and best data on wind energy impacts to birds and bats; and examine the measures that are and could be employed to minimize or prevent such impacts. The *Proceedings of the Wind Energy and Birds/Bats Workshop: Understanding and Resolving Bird and Bat Impacts* held in Washington, DC on May 18-19, 2004, were reviewed investigating the potential impacts on birds and bats as part of this feasibility study. The event was co-sponsored by The American Wind Energy Association and The American Bird Conservancy.

In summary, the workshop proceedings provided an overview of the current state of the wind industry regarding technology, siting considerations, and environmental assessment standards, and also included background on research methods and results of bird and bat impacts, and wind energy regulation. Excerpts of the aforementioned proceedings are included by reference herein.

A wide variety of bird species have been killed at wind turbine sites. Fatality searches at various wind projects have yielded fatalities of a number of USFWS Birds of Conservation Concern, including particular species of owls, hawks, and other raptors, sparrows, wrens, warblers, and others. At communication towers (*not* wind turbines) over 90% of all bird species killed are neo-tropical migrants, with 230 species documented as being killed at such towers. Sixty-four of those neo-tropical migrant species are on the USFWS Birds of Management Concern List. Without management measures they may be listed under the Endangered Species Act in the future. In addition, some endangered bird species have been killed.

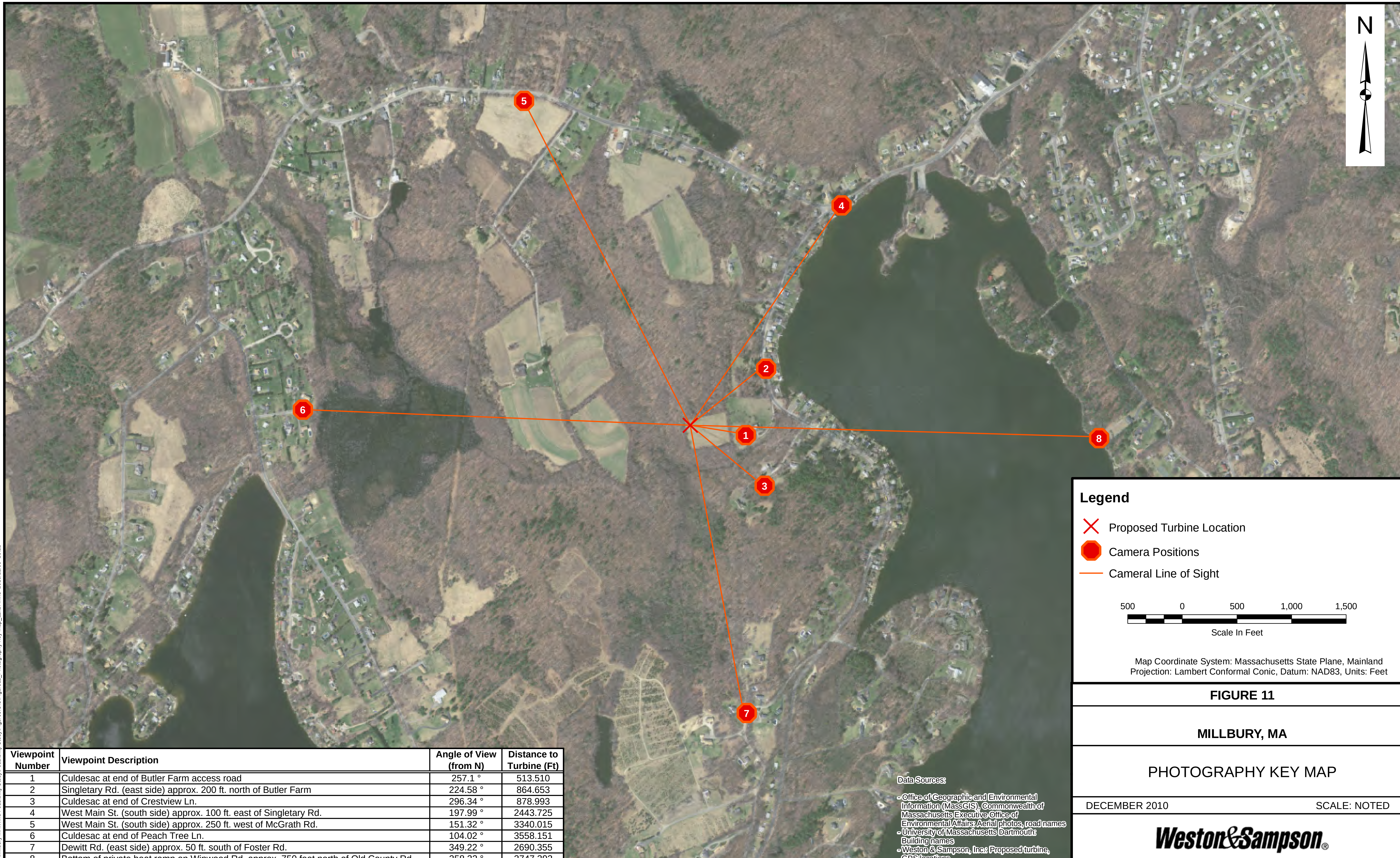
Wind energy production may affect birds in three ways: First and the most widely noted, are fatalities resulting from collisions with rotors, towers, power lines, or with other related structures. Electrocution on power lines is also possible. Second, birds may avoid wind turbines and the habitat surrounding them. Third, the direct impacts on bird habitat from the footprint of turbines, roads, power lines, and auxiliary buildings.

Annual per-turbine mortality rates average 1.825 outside the State of California (and the highest recorded per turbine mortality was 7.5 at Buffalo Mountain, Tennessee). There are a number of environmental concerns. One of the key concerns is mortality or other effects on ESA-listed species or Birds of Conservation Concern. Cumulative impacts on species at national and regional scales as well around individual projects, especially large ones, are of concern. One concern regarding research to date is that most of the wind projects that have been monitored for bird impacts are in the West. In the eastern US, locating wind turbines along ridge tops and potentially off-shore are both of concern. Finally, growth in the number of wind turbines and their increasing height, have the potential for more avian impacts.

According to Mr. Gerald Winegrad, with the American Bird Conservancy, the use of guy wires should be avoided, if possible. Transmission lines should be placed underground to minimize project footprint and lighting should be minimized. Implementation of these techniques shall be utilized to minimize the number of avian deaths. Bird deaths at the sites shall also be monitored, to add to the database of bird deaths at wind turbine sites, using scientifically rigorous methods. The number of bird mortalities, species, date and prevailing weather conditions shall be recorded as part of the operations and maintenance plan for the proposed wind turbine facility.

Appendix G

Visual Simulations



Viewpoint Number	Viewpoint Description	Angle of View (from N)	Distance to Turbine (Ft)
1	Culdesac at end of Butler Farm access road	257.1 °	513.510
2	Singletary Rd. (east side) approx. 200 ft. north of Butler Farm	224.58 °	864.653
3	Culdesac at end of Crestview Ln.	296.34 °	878.993
4	West Main St. (south side) approx. 100 ft. east of Singletary Rd.	197.99 °	2443.725
5	West Main St. (south side) approx. 250 ft. west of McGrath Rd.	151.32 °	3340.015
6	Culdesac at end of Peach Tree Ln.	104.02 °	3558.151
7	Dewitt Rd. (east side) approx. 50 ft. south of Foster Rd.	349.22 °	2690.355
8	Bottom of private boat ramp on Winwood Rd. approx. 750 feet north of Old County Rd.	258.22 °	3747.393

FIGURE 11

MILLBURY, MA

PHOTOGRAPHY KEY MAP

DECEMBER 2010 SCALE: NOTED

Weston&Sampson®

O:\Millbury MA\Wind Feasibility Study\Feasibility Study\Figures\GIS\Figure11_Photography Key Map_11x17.mxd 2010/12/09 16:12

Weston&Sampson®

ENVIRONMENTAL/INFRASTRUCTURE CONSULTANTS
1899 ESTABLISHED

5 Centennial Drive
Peabody, MA 01960
978-532-1900
978-977-0100 (fax)
www.westonandsampson.com

Photo Simulation of Millbury, MA Wind Energy Project

About the Project:

Owner: Town of Millbury, MA
Project Site: Butler Farm, 44 Singletary Road, Millbury, MA
Turbine(s): Vestas V90, 1.8 MW
Rotor Diameter: 90 m (295 ft.)
Hub Height: 80 m (262 ft.)
Structure Height: 125 m (410 ft.)
Location: 42.1635272° N; 71.7906949° W

About the Photo:

Viewpoint Number: 1
Viewpoint Description: Culdesac at end of Butler Farm access roa
Angle of View: 257.1 °
Location: 42.1632755° N; 71.7888319° W
Distance to Nearest Turbine: 513.510
Apparent size and location of this turbine from this viewpoint
is determined geometrically using EMD WindPro Software

Weston&Sampson®

ENVIRONMENTAL/INFRASTRUCTURE CONSULTANTS
1899 ESTABLISHED

5 Centennial Drive
Peabody, MA 01960
978-532-1900
978-977-0100 (fax)
www.westonandsampson.com

Photo Simulation of Millbury, MA Wind Energy Project

About the Project:

Owner: Town of Millbury, MA
Project Site: Butler Farm, 44 Singletary Road, Millbury, MA
Turbine(s): Vestas V90, 1.8 MW
Rotor Diameter: 90 m (295 ft.)
Hub Height: 80 m (262 ft.)
Structure Height: 125 m (410 ft.)
Location: 42.1635272° N; 71.7906949° W

About the Photo:

Viewpoint Number: 2
Viewpoint Description: Singletary Rd. 200 ft. north of Butler Farm
Angle of View: 224.58 °
Location: 42.1649493° N; 71.7881428° W
Distance to Nearest Turbine: 0.164 Miles (864.653 Feet)
Apparent size and location of this turbine from this viewpoint
is determined geometrically using EMD WindPro Software

Weston&Sampson®
ENVIRONMENTAL/INFRASTRUCTURE CONSULTANTS
1899 ESTABLISHED
5 Centennial Drive
Peabody, MA 01960
978-532-1900
978-977-0100 (fax)
www.westonandsampson.com

Photo Simulation of Millbury, MA Wind Energy Project

About the Project:

Owner: Town of Millbury, MA
Project Site: Butler Farm, 44 Singletary Road, Millbury, MA
Turbine(s): Vestas V90, 1.8 MW
Rotor Diameter: 90 m (295 ft.)
Hub Height: 80 m (262 ft.)
Structure Height: 125 m (410 ft.)
Location: 42.1635272° N; 71.7906949° W

About the Photo:

Viewpoint Number: 3
Viewpoint Description: Culdesac at end of Crestview Ln.
Angle of View: 296.34 °
Location: 42.1620036° N; 71.7881829° W
Distance to Nearest Turbine: 0.166 Miles (878.993 Feet)
Apparent size and location of this turbine from this viewpoint is determined geometrically using EMD WindPro Software

Weston&Sampson®

ENVIRONMENTAL/INFRASTRUCTURE CONSULTANTS 1899 ESTABLISHED

5 Centennial Drive
Peabody, MA 01960
978-532-1900
978-977-0100 (fax)
www.westonandsampson.com

Photo Simulation of Millbury, MA Wind Energy Project

About the Project:

Owner: Town of Millbury, MA
Project Site: Butler Farm, 44 Singletary Road, Millbury, MA
Turbine(s): Vestas V90, 1.8 MW
Rotor Diameter: 90 m (295 ft.)
Hub Height: 80 m (262 ft.)
Structure Height: 125 m (410 ft.)
Location: 42.1635272° N; 71.7906949° W

About the Photo:

Viewpoint Number: 4
Viewpoint Description: West Main St. 100 ft. east of Singletary Rd.
Angle of View: 197.99 °
Location: 42.1690634° N; 71.785612° W
Distance to Nearest Turbine: 0.463 Miles (2443.725 Feet)
Apparent size and location of this turbine from this viewpoint
is determined geometrically using EMD WindPro Software

Weston&Sampson®
ENVIRONMENTAL/INFRASTRUCTURE CONSULTANTS
1899 ESTABLISHED
5 Centennial Drive
Peabody, MA 01960
978-532-1900
978-977-0100 (fax)
www.westonandsampson.com

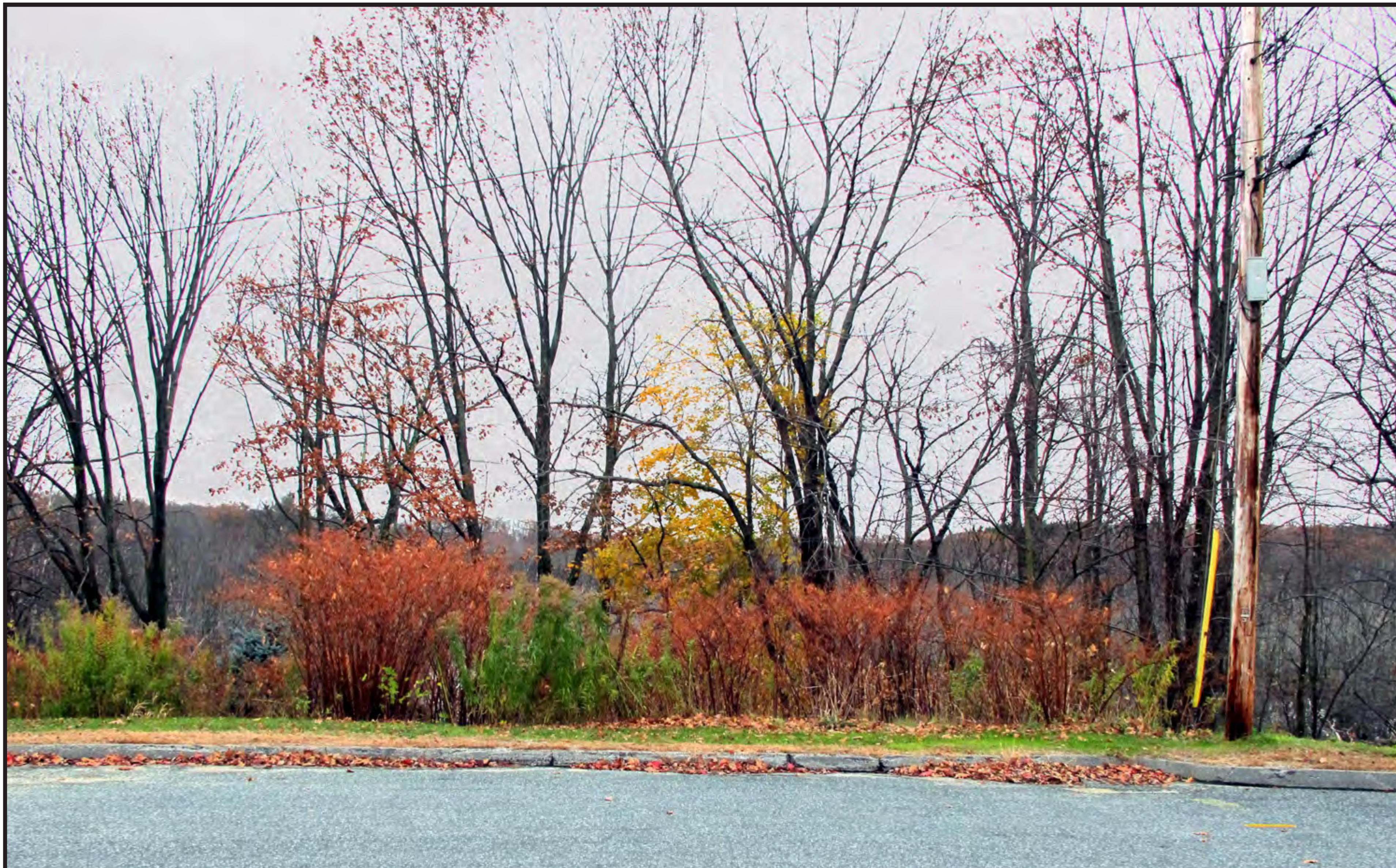
Photo Simulation of Millbury, MA Wind Energy Project

About the Project:

Owner: Town of Millbury, MA
Project Site: Butler Farm, 44 Singletary Road, Millbury, MA
Turbine(s): Vestas V90, 1.8 MW
Rotor Diameter: 90 m (295 ft.)
Hub Height: 80 m (262 ft.)
Structure Height: 125 m (410 ft.)
Location: 42.1635272° N; 71.7906949° W

About the Photo:

Viewpoint Number: 4
Viewpoint Description: West Main St. 100 ft. east of Singletary Rd.
Angle of View: 197.99 °
Location: 42.1690634° N; 71.785612° W
Distance to Nearest Turbine: 0.463 Miles (2443.725 Feet)
Apparent size and location of this turbine from this viewpoint
is determined geometrically using EMD WindPro Software



Weston&Sampson®

ENVIRONMENTAL/INFRASTRUCTURE CONSULTANTS ESTABLISHED 1899

5 Centennial Drive
Peabody, MA 01960
978-532-1900
978-977-0100 (fax)
www.westonandsampson.com

Photo Simulation of Millbury, MA Wind Energy Project

About the Project:

Owner: Town of Millbury, MA
Project Site: Butler Farm, 44 Singletary Road, Millbury, MA
Turbine(s): Vestas V90, 1.8 MW
Rotor Diameter: 90 m (295 ft.)
Hub Height: 80 m (262 ft.)
Structure Height: 125 m (410 ft.)
Location: 42.1635272° N; 71.7906949° W

About the Photo:

Viewpoint Number: 6
Viewpoint Description: Culdesac at end of Peach Tree Ln.
Angle of View: 104.02 °
Location: 42.1638726° N; 71.8038071° W
Distance to Nearest Turbine: 0.674 Miles (3558.151 Feet)
Apparent size and location of this turbine from this viewpoint
is determined geometrically using EMD WindPro Software

Weston&Sampson®

ENVIRONMENTAL/INFRASTRUCTURE CONSULTANTS
1899
ESTABLISHED

5 Centennial Drive
Peabody, MA 01960
978-532-1900
978-977-0100 (fax)
www.westonandsampson.com

Photo Simulation of Millbury, MA Wind Energy Project

About the Project:

Owner: Town of Millbury, MA
Project Site: Butler Farm, 44 Singletary Road, Millbury, MA
Turbine(s): Vestas V90, 1.8 MW
Rotor Diameter: 90 m (295 ft.)
Hub Height: 80 m (262 ft.)
Structure Height: 125 m (410 ft.)
Location: 42.1635272° N; 71.7906949° W

About the Photo:

Viewpoint Number: 7
Viewpoint Description: Dewitt Rd. 50 ft. south of Foster Rd.
Angle of View: 349.22 °
Location: 42.1562892° N; 71.7887548° W
Distance to Nearest Turbine: 0.51 Miles (2690.355 Feet)
Apparent size and location of this turbine from this viewpoint
is determined geometrically using EMD WindPro Software

Weston&Sampson®

1899 ESTABLISHED ENVIRONMENTAL/INFRASTRUCTURE CONSULTANTS

5 Centennial Drive
Peabody, MA 01960
978-532-1900
978-977-0100 (fax)
www.westonandsampson.com

Photo Simulation of Millbury, MA Wind Energy Project

About the Project:

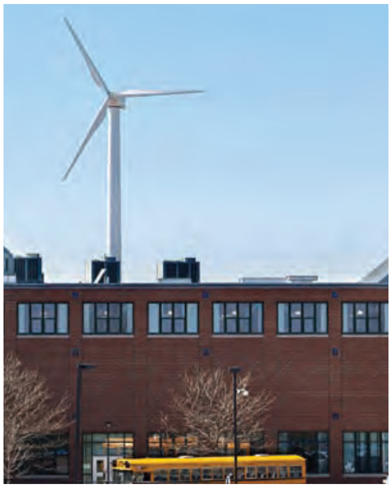
Owner: Town of Millbury, MA
Project Site: Butler Farm, 44 Singletary Road, Millbury, MA
Turbine(s): Vestas V90, 1.8 MW
Rotor Diameter: 90 m (295 ft.)
Hub Height: 80 m (262 ft.)
Structure Height: 125 m (410 ft.)
Location: 42.1635272° N; 71.7906949° W

About the Photo:

Viewpoint Number: 8
Viewpoint Description: Bottom of boat ramp on Winwood Rd.
Angle of View: 258.22 °
Location: 42.1632243° N; 71.7768826° W
Distance to Nearest Turbine: 0.71 Miles (3747.393 Feet)
Apparent size and location of this turbine from this viewpoint
is determined geometrically using EMD WindPro Software

Appendix H

Selected Wind Turbine Specifications

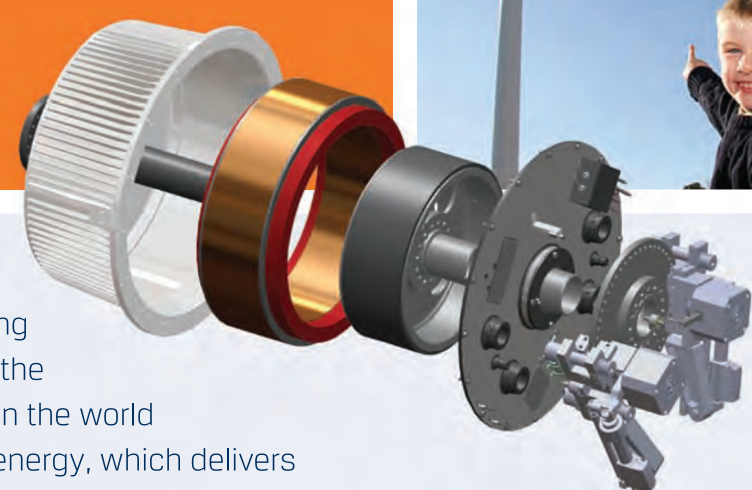


Northwind® 100

Community Scale Wind Turbine

Direct.

To Communities Everywhere.



All turbines capture wind.
The **Northwind** 100 is designed to do it better.

Around the world, turbines are sprouting out of the ground making wind one of the fastest growing sources of electricity in the world today. Wind provides clean domestic energy, which delivers clear economic environmental and social benefits. Wind farms are not the only answer. The space and investment required for utlity-scale development precludes many from participating in the wind power revolution. Thus the growing demand for community wind projects…and our drive to meet our customers where they live and work.

The Right Fit For Your Community

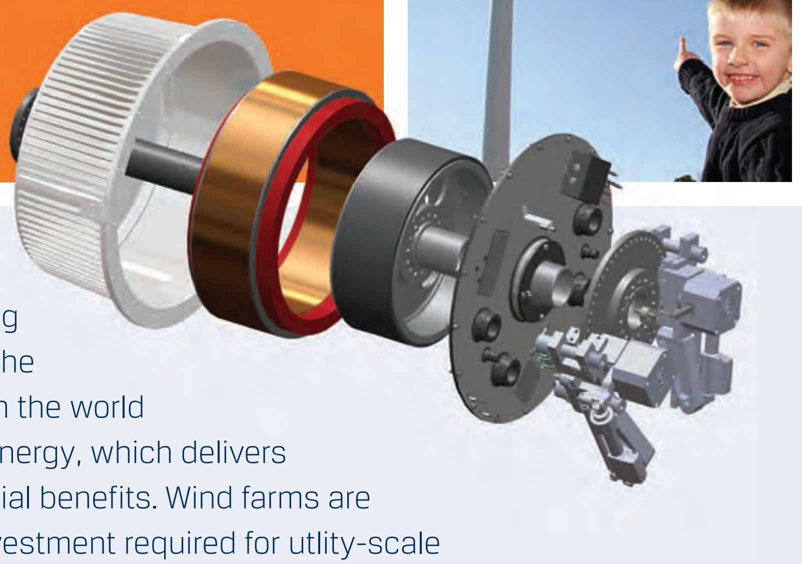
At 100 kilowatts of rated power, the Northwind 100 can match the power needs of many local applications, whether they are municipalities, schools and universities, commercial farms, or business campuses. Its physical size fits within most constraints inherent in highly populated areas and the low-maintenance design ensures that you can "fly it and forget it." Discover the Northwind 100 and harness the most advanced technology, in its simplest form, for your clean energy solution.

Public Schools • Small Businesses • Farms & Dairies • Municipal Buildings

Greenhouses • Universities • Corporations • Hotels & Resorts • Libraries

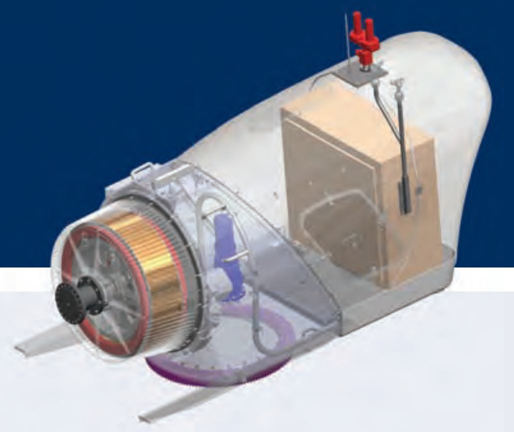
Direct.

To Communities Everywhere.



Around the world, turbines are sprouting out of the ground making wind one of the fastest growing sources of electricity in the world today. Wind provides clean domestic energy, which delivers clear economic environmental and social benefits. Wind farms are not the only answer. The space and investment required for utlity-scale development precludes many from participating in the wind power revolution. Thus the growing demand for community wind projects...and our drive to meet our customers where they live and work.

Our Design



The Northwind 100 is a technological masterpiece with its innovative gearless design and best in class reliability. What this means for your application is more energy and less maintenance.

Originally developed with a NASA grant and designed for remote and isolated sites, the Northwind 100 put reliability at a premium. Regular and costly maintenance was not an option for applications located at the South Pole or in the Indian Ocean—let alone your farm, school, or business.

›› Our Northwind 100 is **optimized for low winds,** so you don't have to live in a wind tunnel to benefit from wind power. Our turbines can begin making power at wind speeds as low as 3 meters per second (6 mph) and can provide clear economic benefits in all kinds of wind regimes.

›› An engineering advancement in simplicity and precision, **our gearless direct drive technology** maximizes energy capture and outperforms conventional gearbox designs.

›› Our **state of the art power converter** design provides smooth, clean power to local grids which simplifies grid interconnect and adds to grid stability, making the Northwind 100 the best choice for a variety of applications.

›› Our **advanced blades** are fiberglass reinforced and use a unique aerodynamic design created by our talented engineers specifically for the Northwind 100.

Your Solution

The Northwind 100 is the ideal choice for community applications that favor a low height profile, easy utility connect, low noise and cost effectiveness.

›› **The Northwind 100 makes economic sense:** Even at modest speeds, the Northwind 100 can produce enough electricity to represent significant savings in utility costs. Given its 20 year design life, you can be sure that the Northwind 100 will provide long term benefits and more than pay for itself over time.

›› **The right amount of power:** One 100 kW turbine—or a cluster of two or three—meets all the energy needs for most municipalities, schools and small industrial sites.

›› **Turn it on and go back to work:** Our turbine is designed for ultimate reliability, so you don't have to be in the utility business or hire a team of full time professionals to reap all the benefits of wind power.

›› **Ready for utility interconnect:** With an easy grid connect and no complicated approvals or expensive interconnection requirements, it makes for an ideal choice.

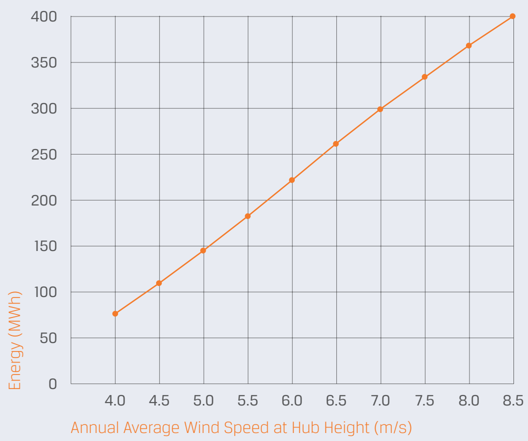
›› **Low height profile, sleek design:** Sitting on a standard 37 meter tower, the elegantly designed Northwind 100 fits neatly into community settings

›› **Quiet operation:** Our gearless design, advanced blades and harmonically engineered towers all contribute to our impressively low apparent noise levels which resemble the sound of normal conversations or soft music.

Public Schools • Small Businesses • Farms & Dairies • Municipal Buildings Malls • Island Communities • Ski Resorts • Churches • Town Offices • Rural Utilities Manufacturing Facilities • Remote Villages • Hospitals • Sports Facilities

Annual Energy Production*: 21-Meter Rotor

Standard Air Density, Rayleigh Wind Speed Distribution



Specifications

Model	Northwind 100
Design Class	IEC IIA (air density 1.225 kg/m^3, average annual wind below 8.5 m/s, 50-yr peak gust below 59.5 m/s)
Design Life	20 years
Hub Height	37 m (121 ft)
Rotor Diameter	21 m (69 ft)
Rated Electrical Power	100 kW, 3 Phase, 480 VAC, 60 Hz
Cut-In Wind Speed	3.5 m/s (7.8 mph)
Gearbox Type	No gearbox (direct drive)
Generator Type	Permanent magnet, passively cooled
Apparent Noise Level	55 dBA at 40m (131 ft)

For more detailed information, see the Northwind 100 Specifications Sheet. All Specifications subject to change without notice.

Northern POWER SYSTEMS
29 Pitman Road, Barre, VT 05641
1 877 90 NORTH +01 802 461 2955
WWW.NORTHERNPOWER.COM

Northern Power Systems has over 30 years of experience in developing advanced, innovative wind turbines. The company's next generation wind turbine technology is based on a vastly simplified architecture that utilizes a unique combination of permanent magnet generators and direct-drive design. This revolutionary new approach delivers higher energy capture, eliminates drive-train noise, and significantly reduces maintenance and downtime costs. Northern Power Systems is a fully integrated company that designs, manufactures, and sells wind turbines into the global marketplace from its headquarters in Vermont, USA.

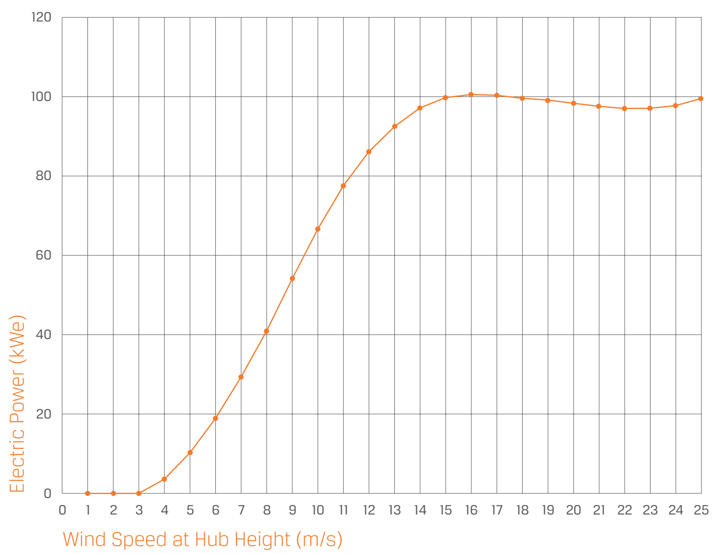
Printed in the USA with soy based inks on recycled paper containing post consumer fiber.
Printed by Phoenix Press, proud owner of a Northwind 100 wind turbine.

NW-0409-01

Specifications

Northwind® 100

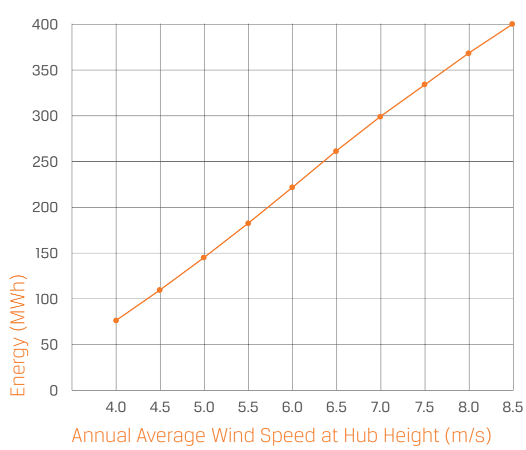
Power Curve: 21-Meter Rotor Standard Air Density (1.225 kg/m³)



Wind Speed (m/s)	Power (kWe)	Wind Speed (m/s)	Power (kWe)
1	0	14	97.3
2	0	15	100.0
3	0	16	100.8
4	3.7	17	100.6
5	10.5	18	99.8
6	19.0	19	99.4
7	29.4	20	98.6
8	41.0	21	97.8
9	54.3	22	97.3
10	66.8	23	97.3
11	77.7	24	98.0
12	86.4	25	99.7
13	92.8		

1 m/s = 2.24 mph

Annual Energy Production*: 21-Meter Rotor Standard Air Density, Rayleigh Wind Speed Distribution



Average Annual Wind Speed (mph)	Average Annual Wind Speed (m/s)	Annual Energy Output (MWh/yr)
8.9	4.0	77
10	4.5	110
11	5.0	145
12	5.5	183
13	6.0	222
15	6.5	260
16	7.0	298
17	7.5	334
18	8.0	368
19	8.5	400

*Annual energy production estimates assume standard conditions, 100% availability and no losses.

Northern
POWER SYSTEMS

Specifications

GENERAL CONFIGURATION	DESCRIPTION
Model	Northwind 100
Design Class	IEC IIA (air density 1.225 kg/m^3, average annual wind below 8.5 m/s, 50-yr peak gust below 59.5 m/s)
Design Life	20 years
Hub Height	37 m (121 ft) / 30 m (98 ft)
Tower Type	Tubular steel monopole
Orientation	Upwind
Rotor Diameter	21 m (69 ft)
Power Regulation	Variable speed, stall control
Certifications	UL1741, UL1004-4, CSA C22.2 No.107.1-01, CSA C22.2 No. 100.04, and CE compliant

PERFORMANCE	DESCRIPTION (standard conditions: air density of 1.225 kg/m^3, equivalent to 15°C (59°F) at sea level)
Rated Electrical Power	100 kW, 3 Phase, 480 VAC, 60/50 Hz
Rated Wind Speed	14.5 m/s (32.4 mph)
Maximum Rotation Speed	59 rpm
Cut-In Wind Speed	3.5 m/s (7.8 mph)
Cut-Out Wind Speed	25 m/s (56 mph)
Extreme Wind Speed	59.5 m/s (133 mph)

WEIGHT	DESCRIPTION
Rotor (21-meter)	1,400 kg (3,100 lbs)
Nacelle (standard)	5,800 kg (13,000 lbs)
Tower (37-meter)	13,800 kg (30,000 lbs)

DRIVE TRAIN	DESCRIPTION
Gearbox Type	No gearbox (direct drive)
Generator Type	Permanent magnet, passively cooled

BRAKING SYSTEM	DESCRIPTION
Service Brake Type	Two motor-controlled calipers
Normal Shutdown Brake	Generator dynamic brake and two motor-controlled calipers
Emergency Shutdown Brake	Generator dynamic brake and two spring-applied calipers

YAW SYSTEM	DESCRIPTION
Controls	Active, electromechanically driven with wind direction/speed sensors and automatic cable unwind

CONTROL/ELECTRICAL SYSTEM	DESCRIPTION
Controller Type	DSP-based multiprocessor embedded platform
Converter Type	Pulse-width modulated IGBT frequency converter
Monitoring System	SmartView remote monitoring system, ModBus TCP over ethernet
Power Factor	Set point adjustable between 0.9 lagging and 0.9 leading
Reactive Power	+/- 45 kVAR

NOISE	DESCRIPTION
Apparent Noise Level	Less than 55 dBA at the base of the tower

ENVIRONMENTAL SPECIFICATIONS	DESCRIPTION
Temperature Range: Operational	-20°C to 50°C (-4°F to 122°F)
Temperature Range: Storage	-40°C to 55°C (-40°F to 131°F)
IP Class: Generator/Nacelle	IP55/IP54
Lightning Protection	Receptors in blades, nacelle lightning rod and electrical surge protection
Icing Protection	Turbine designed in accordance with Germanischer Lloyd Wind Guidelines Edition 2003

All Specifications subject to change without notice.

SS-090901-01

SV0933 nZ

Proven Performance

Dw#UUE#Hqhuj|#Olp lwhg#+UUEHO,#z h#vshqg#d#orw#ri#wlp h#rq#whvwlqj#dqg#grfxp hqwlqj#wkh# shuirup dqfh#ri#rxu#Z lqg#Hohfwulf#Jhqhudwruv#+Z HJv,#lq#rughu#wr#hqvxuh#wkdw#rxu#Z HJv# p hhw#wkh#yhu|#kljkhvw#uhtxluhp hqw#z lwk#uhjdug#wr#hqhuj|#surgxfwlrq/#dydlodelolw|#idfwru/# srz hu#txdolw|#dqg#vrxqg#ohyhov1

We prove what we claim

UUEHO#kdv#uhshdwhgo|#ghp rqvwudwhg#wkdw#lwv#z lqg#wxuelqhv#duh#p dwfkohvv#dqg#duh#lq#d# fodvv#ri#wkhlu#rz q1#UUEHO#wxuelqhv#duh#edvhg#rq#wkh#z ruogÑ#ehvw/#p rvw#p rghuq#dqg# suryhq#whfkqrorj|#lq#wkh#ilhog#ri#Z lqg#Hqhuj|1#Uhshdw#rughuv#ri#fxvwrp huv/#edvhg#rq# rxu#suryhq#shuirup dqfh/#hvsrxvhv#wkhlu#frqilghqfh#lq#xv1#Z khq#|rx#ex|#d#UUEHO#Z lqg# Wxuelqh#|rx#vxuho|#ihho#surxg#wr#rz q#rqh#ri#wkh#Z ruogÑ#ehvw#hqjlqhhuhg#Z lqg#Hohfwulf# Jhqhudwru1

IHDWXUHV) EHQHILWV

Optimal Pitch with optitip

Doo#UUEHO#Z HJv#duh#htxlsshg#z lwk#p lfursurfhvvru0frqwuroohg#R swlwls#slwfk#uhjxodwlrq/#hqvxulqj#frqwlqxrxv#dqg# rswlp do#dgmxvwp hqw#ri#wkh#dqjohv#ri#wkh#eodghv#lq#uhodwlrq#wr#wkh#suhydlolqj#z lqg1#Wkh#R swlwls#v|vwhp #lv#wkh#ehvw# vroxwlrq#wr#wkh#riwhq#frqwudglfwru|#uhtxluhp hqw#iru#kljk#rxwsxw#dqg#orz #vrxqg#ohyhov/#ghshqglqj#rq#wkh#orfdwlrq1

Lightning protection

R xu#wxuelqhv#duh#dovr#htxlsshg#z lwk#d#vwdwh#ri#wkh#duw#Oljkwqlqj#Surwhfwlrq#v|vwhp 1#Wklv#surwhfwv#wkh#hqwluh#wxuelqh# iurp #wkh#wlsv#ri#wkh#eodghv#wr#wkh#irxqgdwlrq1#Wkh#v|vwhp #frqgxfwv#doo rvw#doo#oljkwqlqj#vwulnhv#kdup ohvvo|#sdvw#wkh# vhqvlwlyh#sduwv#ri#wkh#qdfhooh#dqg#grz q#lqwr#wkh#hduwk1#Dv#dq#h{wud#vdihw|#p hdvxuh/#wkh#ghglfdwh#frqwuro#xqlw#dqg# surfhvvruv#lq#wkh#Z lqg#Wxuelqh#duh#dovr#surwhfwhg#e|#dq#hiilflhqw#vklhoglqj#v|vwhp 1

WHFKQLFDO GDWD

PS-600 kW

Overall Data

Rated Power	600 kW
Cut in wind speed	4.0 m/s
Cut out wind speed	25 m/s
Rated wind speed	15 m/s
Tip speed	64 m/s

SURGXFWV

- Y5:0558nZ
- Y6<0833nZ #z lwk#7:p #Urwru#gldp hwhu
- SV0933#nZ
- SV04;33#nZ
- Fdvkdq#Ghyhorsp hqw#P hfkdqlvp
- hOFdwdorjxh

SKRWR JDOOHU\

Vhh#doo »   Vhh#rxu#Ylghr#Jdoohu|#»

FRQWDFW XV

Qdp h

Frp sdq|#Qdp h

Hp dlo

Rotor speed	26.2 rpm
Hub height	50 m (Lattice) and 65 m (Tubular)
Nacelle tilt angle	5°
Power Regulation	Pitch regulated

Gearbox

Type	Planetary / Helical
Gear Ratio	1: 58.2
No. of Steps	3

Generator

Type	Single Winding Asynchronous
Voltage	690 V
Rated Speed	1527 rpm
Frequency	50 Hz / 60 Hz

Tower

Type	Lattice and Tubular
Height	48.1 m (Lattice) and 63.1 m (Tubular)
Material	Steel
Sections	6/9

Rotor

No.of blades	3
Diameter	47 m
Swept area	1735 m2
Power Regulation	Pitch regulated

Brake System

Aerodynamics	Full feathering of blade
Mechanical (Parking)	Disc Brake

Yaw System

Yaw Mechanism	Slewing system with geared motors for yawing

Control System	Microprocessor based

Due to continuous improvement & upgrades, technical specifications & other information are subject to change without notice.

EXLOW+LQ VDIHW\ IHDWXUHV

VWUXFWXUH

SRZHU FXUYH

Txhvwlrq#2#Frpphqw

Submit

About us

Frpsdq|#SurilOh
K lvwru|
Sklorvrsk|
FPGÑ#Eulhi#Elrjudsk|
FPGÑ#Ghvn
Dzdugv
Ylvlrq
Uhidnfwlrqv
Vwuhqjwkv
Fhuwlilfdwhv
Jrdo

Wind Energy

Frqfhsw#Sulqflsdo#) #Phfkdqlvp
Dgydqwdjhv
Orqj#Whup#Hqhuj|#Vxvwdlqdelolw|#) #Vhfxulw|
Z lqg#Srzhu#Ghyhorsphqw#lq#Lqgld
Z lqg#Uhvrxufhv#) #Srwhqwldo#lq#Lqgld

Products

Y5:0558nZ
Y6<0833nZ #zlwk#7:p#Urwru#gldphwhu
SV0933#nZ
SV04;33#nZ
Fdvdq#Ghyhorsphqw#Phfkdqlvp
h0Fdwdorjxh

Projects

Sxusrvh
Remhfwlyh
Surfhgxuh#iru#hvwdeolvklqj#d#Z lqg#Idup
Surmhfw#Sodqqlqj
Surmhfw#H{hfxwlrq#dv#shu#vwdqgdug#vshflilfdwlrqv

Download **RRB in News**

Srdflhv
Z doosdshuv

Ł#5345 UUE#Hqhuj|1#Doo#uljkw#uhvhuyhg#

Wordpress Customization by ITSYS Solutions

GE Power & Water
Renewable Energy

1.5 MW
Wind Turbine Series

imagination at work

a product of
ecomagination

1996
First 1.5 MW installed ... still operating today

2002
GE enters wind industry

2003
LVRT introduced; 1,000th unit shipped

2004
First 1.5-77 installed; First GE designed 37 meter blade

2005
First 1.5-82.5 installed; GE introduces HALT testing

CONTINUAL 1.5 MW

GE's 1.5 MW Wind Turbine Series

Changing and growing energy needs are driving new opportunities for a more reliable, affordable and efficient supply of electric power with zero greenhouse gas emissions. That is why GE continues to drive investments in cutting-edge wind turbine technology. GE's strategy is built around differentiating ourselves with leading technology in production, efficiency and reliability. Trusting in our deep, rich heritage in power generation, GE pulls in expertise from our core business to drive product strategy, product leadership and product value. Every initiative we pursue bears our uncompromising commitment to quality and product innovation.

Building on a strong power generation heritage spanning more than a century, our 1.5 MW wind turbine series—known as the industry workhorse—delivers proven performance and reliability, creating more value for our customers. Our reputation for excellence can be seen in everything we do. GE's commitment to customer value and technology evolution is demonstrated in our ongoing investment in product development. Since entering the wind business in 2002, GE has invested more than $1 billion in driving reliable and efficient renewable energy technology.

2006
GE designed pitch system introduced; 5,000th unit shipped

2007
First GE designed 40 meter blade; GE launches Mark* VIe controller for wind

2008
10,000th unit shipped

2009
First 1.6-82.5 uprate in TC II

2010
1.6-82.5 100 meter tower for TC I; 13,000+ units shipped

2011
On schedule for 15,000th unit shipped

SERIES INVESTMENT

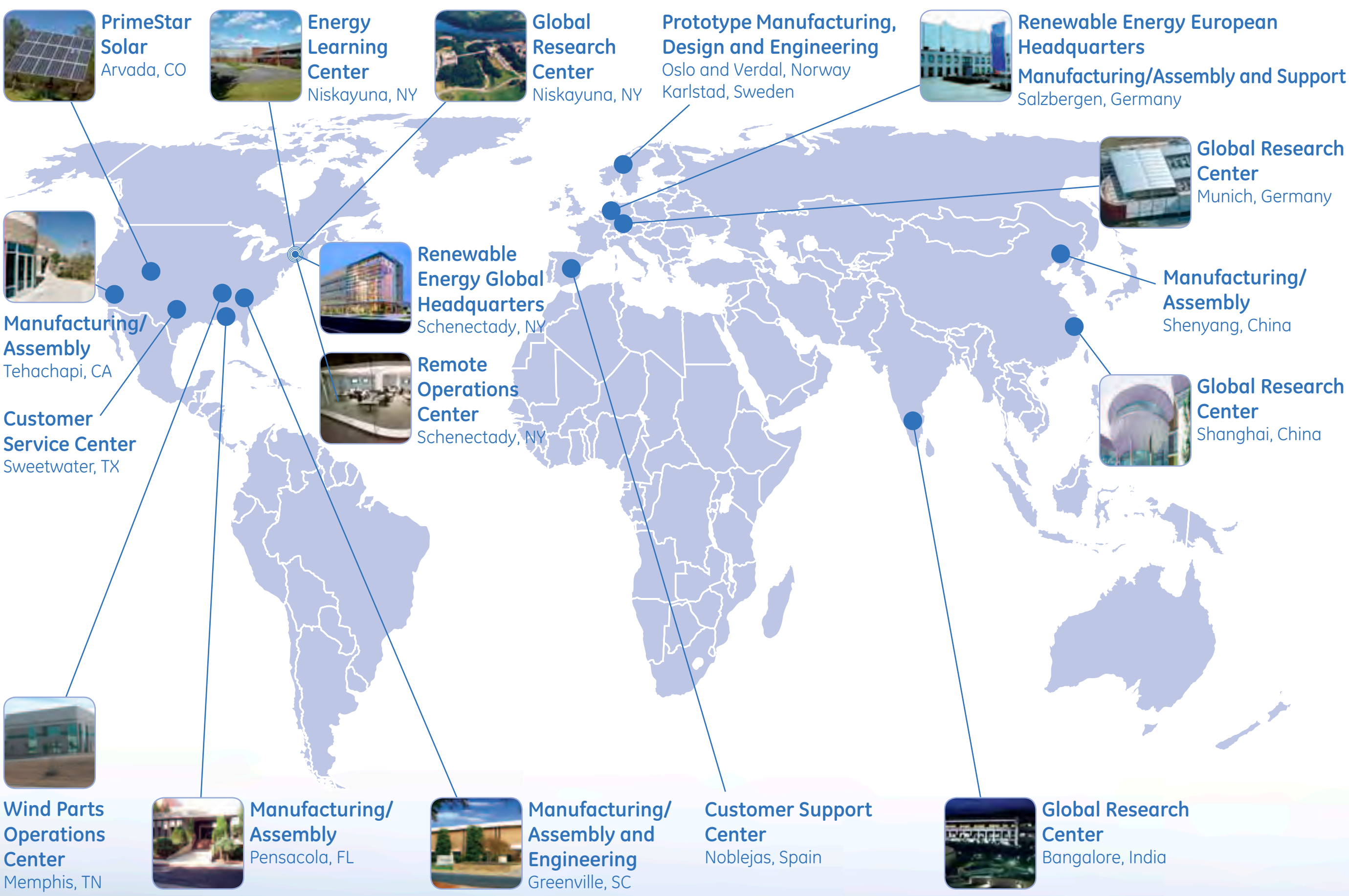
The Industry Workhorse

- Continual investment …
  focused on increasing customer value
- Product evolution…
  world's best running fleet
- Provide portfolio flexibility …
  value where you need it

Global Footprint

GE Energy is one of the world's leading suppliers of power generation and energy delivery technologies—providing comprehensive solutions for coal, oil, natural gas and nuclear energy; renewable resources such as wind, solar and biogas, and other alternative fuels. As a part of GE Energy—which includes the Power & Water, Oil & Gas, and Energy Services businesses—we have the worldwide resources and experience to help customers meet their needs for cleaner, more reliable and efficient energy.

GE has 11 global locations specifically devoted to wind technology. Our facilities are registered to ISO 9001:2000 and our Quality Management System, which incorporates our rigorous Six Sigma methodologies, provides our customers with quality assurance backed by the strength of GE. We believe wind power will be an integral part of the world energy mix throughout the 21st century and we are committed to helping our customers design and implement energy solutions for their unique energy needs.



Advancing Wind Capture Performance

As a leading global provider of energy products and services, GE continues to invest in advancing its 1.5 MW wind turbine series with a core focus on enhancing efficiency, reliability and site flexibility. GE understands what customers value and responds with technology enhancements aimed at capturing maximum wind energy for greater return on investment.

Launched in 2004, the 1.5-77 model has earned the reputation for being the industry workhorse and delivers exceptional turbine performance and reliability. Relying on proven technology and experience, GE continues to differentiate its product leadership with evolutionary advancements in blade, drive train and controls technology.

With the use of advanced load controls the 1.5-77 can now be sited in IEC Class I wind regimes. GE advanced its original Class I wind turbine, the 1.5-70.5, with increased rotor length and controls technology resulting in a greater annual energy production. GE's 1.5-77 wind turbine is available in both 50 and 60 Hz for use in IEC Class I environments.

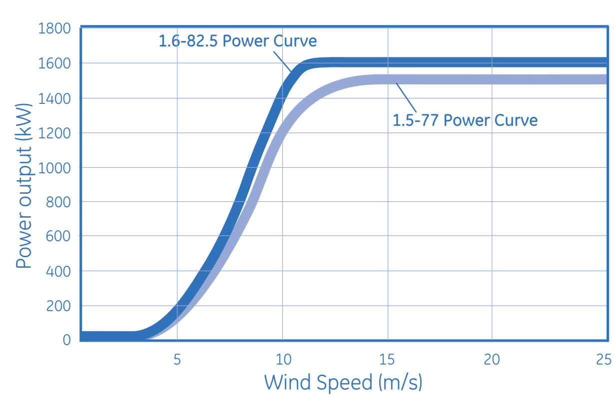
Advancing the Industry Workhorse

GE's 1.6-82.5 model was designed and built on the success of the 1.5-77, changing only what was required to increase customer value. The 1.6-82.5 model provides a 15% increase in swept area relative to the 1.5-77 and greater energy capture providing a strong return on investment. With the use of advanced load controls, the 1.6-82.5 can be sited in IEC Class II wind regimes.

Enhancements to GE's 1.6-82.5 wind turbine include an improved gearbox design and an upgraded pitch system. GE's 1.6-82.5 wind turbine utilizes GE Energy's proven Mark* VIe controller and advanced diagnostic capability to increase troubleshooting efficiency.

1.5 MW	2002	2009
Rotor Diameter (m)	70	82.5 +12.5 m
Capacity Factor (%)	39	52 +13 pts
Reliability (%)	85	98 +13 pts

Improving the 1.5-77... 1.6-82.5



GE's 1.5 MW wind turbine series models are designed to maximize customer value by providing proven performance and reliability. Our commitment to customer satisfaction drives our continuous investment in the evolution of the 1.5 MW wind turbine series. The models described below provide flexibility for customer wind site conditions and optimization of wind turbine placement.

1.5 MW Wind Turbine Series Models

	1.6–82.5	1.5–77
Rotor Diameter (m)	82.5	77
Hub Heights (m)	80/100	65/80
Frequency (Hz)	50/60	50/60
Vavg (m/s)	8.5	10.0
Vref (m/s)	40.0	45.0
Ve50 (m/s)	56.0	70.0
Cut-In (m/s)	3.5	3.5
Cut-Out (m/s)	25	25
IEC Wind Class	IEC TC IIB	IEC TC IB

Improved Flexibility

Reinforced Tower

GE's investment in a reinforced tower design opens up new potential wind sites for our customers, enabling us to deliver reliable and safe products that meet product and regulatory compliance expectations. GE's reinforced tower sections have the same length and external diameter as the standard GE North American modular system, but are specially built to handle seismic loads.

- Allows wind farms to be located in designated seismic prone areas with good wind resources
- GE provides an evaluation to determine if the site requires reinforced tower due to seismic activity

Increased Reliability

Condition Based Maintenance (CBM)

GE Energy's integrated Condition Based Maintenance (CBM) offering proactively detects potential drive train issues, enabling increased performance and decreased maintenance expenses. Factory or field installed and tested, the CBM solution can improve reliability on a single wind farm or multiple wind farms. GE's CBM allows operators to understand an issue weeks in advance.

The CBM offering could allow wind farm operators to:

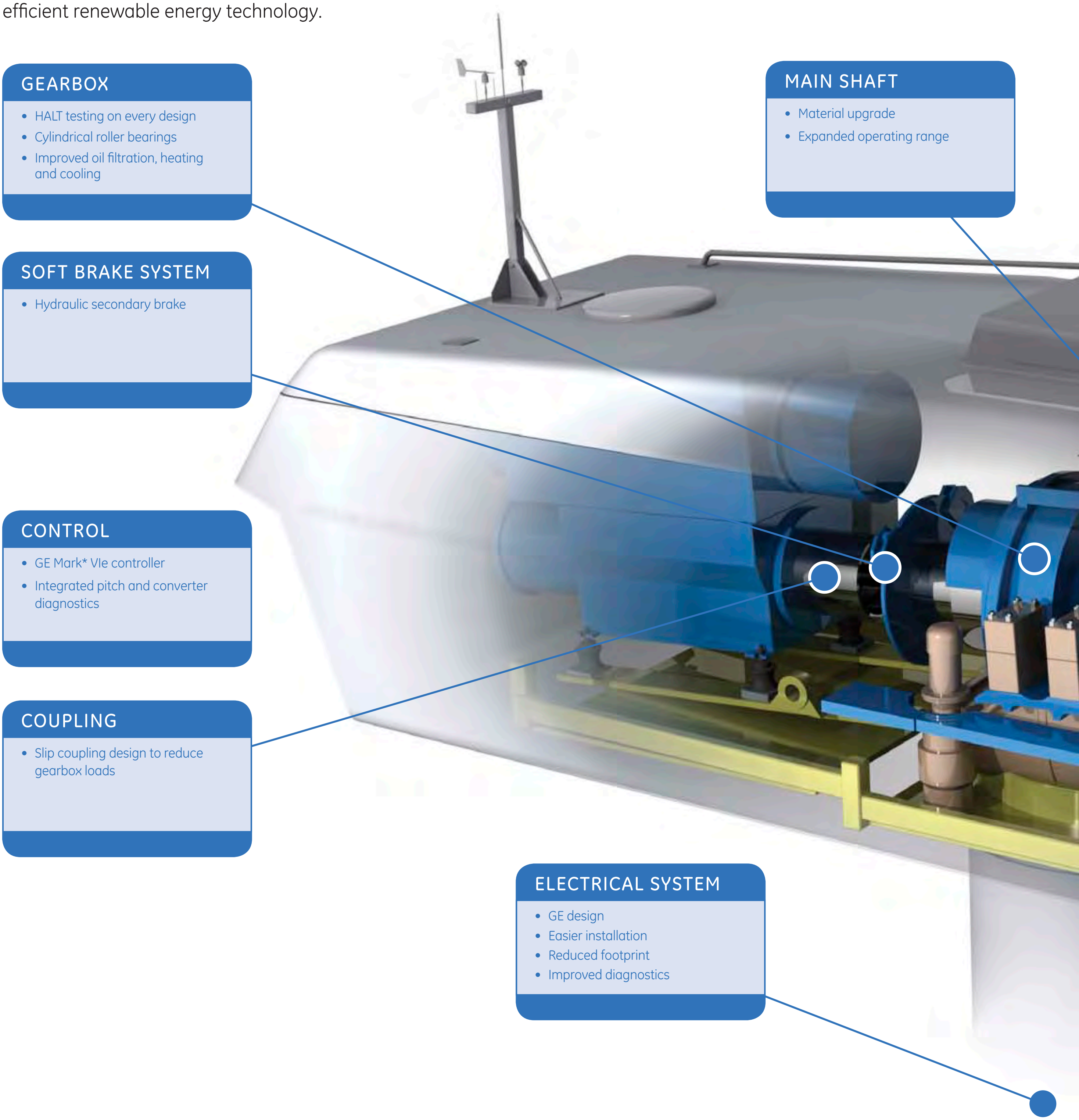
- Continue to produce power while parts, crane, and labor are resourced
- Plan multiple maintenance events with the same resources
- Reduce or limit the extent of damage to the drive train and reduce repair costs

Coupling our design expertise and Mark* VIe control technology, based on GE Bently world leading vibration monitoring technology, enables all these system offerings.

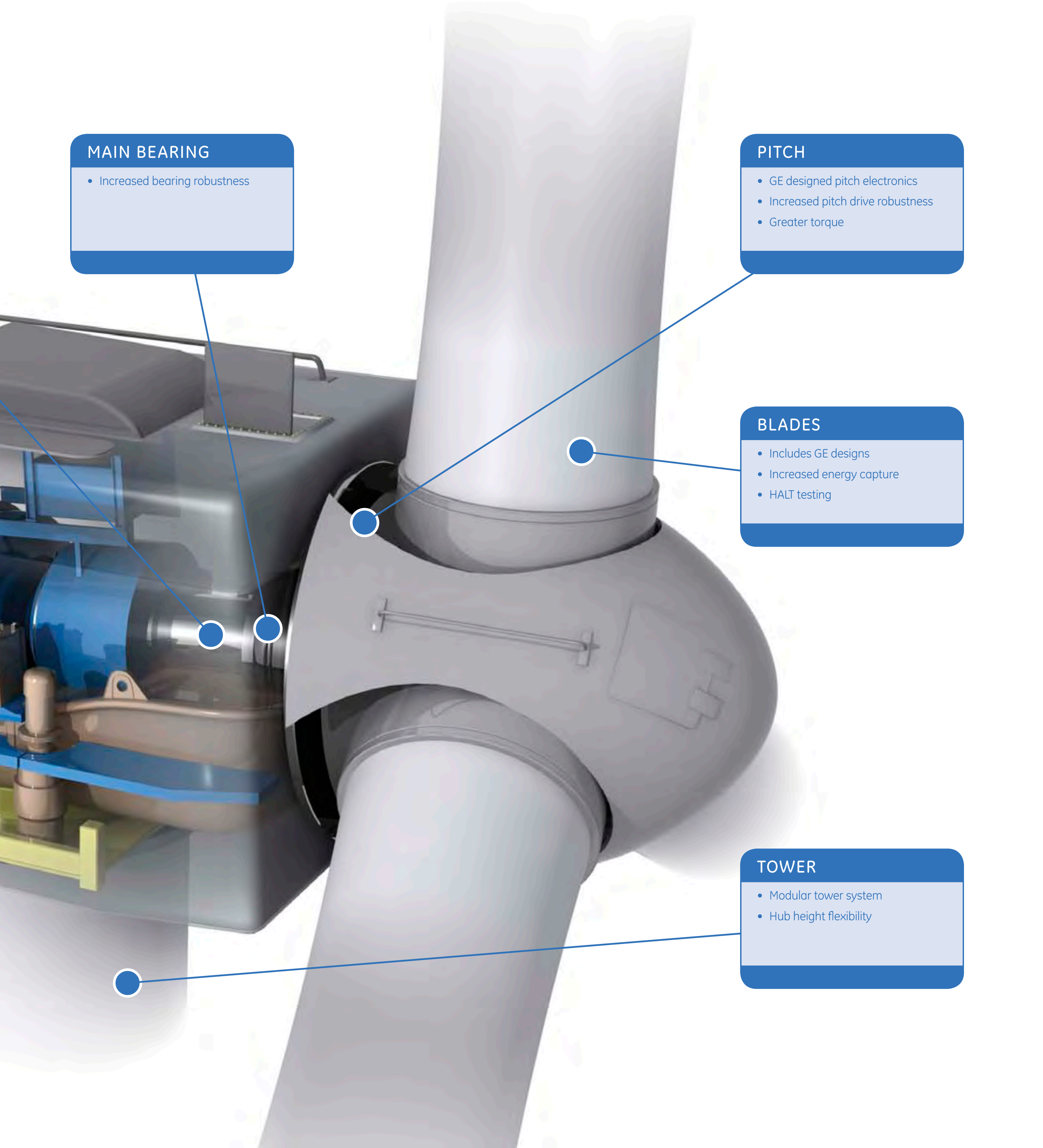
Inside the Industry Workhorse

With technology centers of excellence in the United States, Europe, India and China, our teams of engineers and scientists use Six Sigma methodology, coupled with the latest computational modeling and power electronic analysis tools to manufacture wind turbines with the reliability, efficiency and maintainability necessary to meet the challenges our customers face in today's energy environment.

GE's commitment to customer value and technology evolution is demonstrated by our ongoing investment in product development. Since entering the wind business in 2002, GE has invested more than $1 billion in driving reliable and efficient renewable energy technology.



To optimize turbine reliability and availability, GE focuses on reducing the number of downtime faults, and providing faster Return-to-Service (RTS). Our rigorous design and testing process—including specialized 20-year fatigue testing and Highly Accelerated Life Testing (HALT)—reflects our ongoing investment in key turbine components.



Reliability by Design

The 1.5 MW wind turbine is designed according to our Design for Reliability (DFR) methodology. DFR starts with the definition of reliability goals and the environmental conditions in which the wind turbine components must operate. The reliability targets are applied to component level models that are developed to predict reliability.

A key step in the DFR process is validating design assumptions on both component levels and system levels. GE conducts extensive product validation, including climate chamber testing, compliance testing and Highly Accelerated Life Testing (HALT). In the test, components are subjected to loads of the entire design life in a very short time frame.

The last step of the DFR methodology is production auditing. While validation is focused on ensuring that the design is free of flaws, the production audit is focused on ensuring that each unit is delivered with consistent quality by understanding the impact of manufacturing variability.

DFR COMMON STEPS	TESTING & EVALUATION
1 GOAL SETTING	SHOP TESTING
2 SYSTEM MODELING	FIELD TESTING
3 DESIGN AND PREDICTION	ACCELERATED TESTING
4 TESTING AND EVALUATION	COMPLIANCE TESTING
5 PRODUCT AUDIT	

Combined Strength

GE's 1.5 MW wind turbine series utilizes expertise from many areas of GE as well as from our four global research centers. The result of this combined strength is a reliable and efficient product line that is based on proven technology.

GE Energy

GE Energy Financial Services

GE Oil & Gas

GE Transportation

GE Aviation

GE Global Research Centers

$1 Billion and Growing Renewable Energy Technology Investment

Blade Innovation

- Aero elastic sweep – bend twist
- Advanced materials-carbon

Power Conversion

- Increased power density and reliability with higher voltage
- Control for integration with weak grids

Drive Train

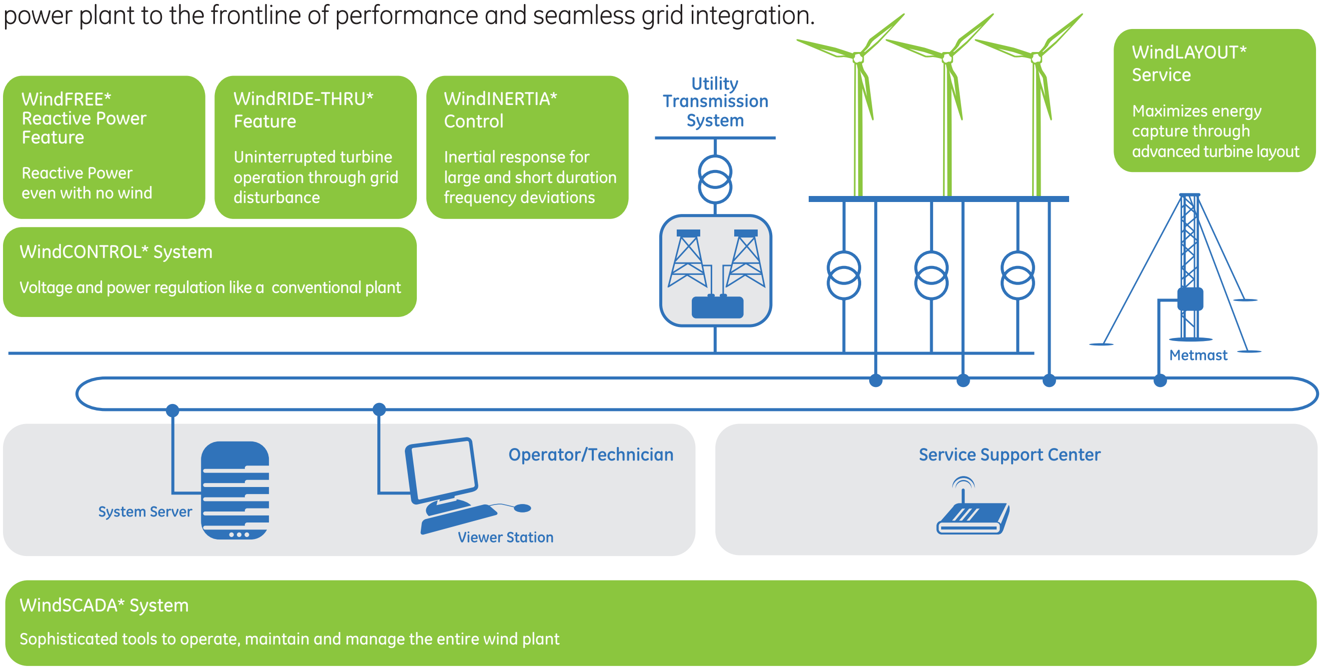
- Direct drive ... 50% greater output at the same weight
- Compact drive ... 25% less weight

Solar

- Thin film technology leadership through PrimeStar
- Differentiated utility-scale Brilliance* inverter

Optimized Wind Power Plant Performance

Wind turbine performance is a critical issue in light of increasingly stringent grid requirements. Our unrivaled experience in power generation makes us the industry leader in grid connection. By providing a sophisticated set of grid-friendly offerings similar to conventional power plants, GE's patented integrated suite of controls and electronics take your wind power plant to the frontline of performance and seamless grid integration.



Feature	Description	Benefits
WindCONTROL* System	Voltage and power regulation like a conventional power plant	Ability to supply and regulate reactive and active power to the grid Additional features include power frequency droop, power ramp rate limiters and integrated capacitor/reactor bank control
WindFREE* Reactive Power Feature	Provides reactive power even with no wind	Provides smooth fast voltage regulation by delivering controlled reactive power through all operating conditions Eliminates the need for grid reinforcements specifically designed for no-wind conditions
WindRIDE-THRU* Feature	Low voltage, zero voltage and high voltage ride-through of grid disturbances	Uninterrupted turbine operation through grid disturbances Meets present and emerging transmission reliability standards
WindINERTIA* Control	Provides temporary boost in power for under-frequency grid events	Provides inertial response capability to wind turbines that is similar to conventional synchronous generators without additional hardware
WindLAYOUT* Service	Service to optimize turbine layout for a site	Opportunity to increase annual energy production for a site
WindSCADA System	Tools to operate, maintain and manage wind power plant	Real-time data visualization, reporting on historical data, alarm management and secure user access

Flexible Wind Service Solutions

Global Resources, Local Support ...

GE's wind turbine fleet is one of the fastest growing and best-run fleets in the world. GE provides state-of-the-art solutions built from our extensive global resources, expertise, and regional capability, helping to ensure that your wind turbine assets are operating at peak performance.

24/7 Remote Monitoring and Troubleshooting:
GE's customer support and remote operations centers in Schenectady, New York, and Salzbergen, Germany provide continuous monitoring and diagnostics services 24 hours a day, 365 days a year. These centers offer capabilities developed using our in-depth product knowledge, service engineering expertise and years of successful fleet operation, helping us to respond quickly and accurately to your needs.

Dedicated Regional Support:
GE-trained regional technicians are available to ensure a timely resolution—whenever and wherever you need us. GE's technicians are equipped to perform procedures such as fault inspections and technical advisory services and manual resets in a timely and efficient manner. If an issue is detected, you can rely on our top-of-the-line repair and replacement capabilities and our highly skilled team to fix the issue immediately.

Wind Parts Center of Excellence:
Availability of parts is critical to wind power plant operations. GE's Wind Parts Center of Excellence provides a full range of offerings for all parts and refurbishment needs from routine maintenance kits, wear and tear, and flow parts, to vital capital parts such as gearboxes and blades.

With the launch of our 24/7 parts call center (877-956-3778), and the development of online ordering tools, we are increasing the channels that our wind plant operators can utilize to order required wind turbine parts, including emergency requests for down-turbine needs.

GE's Wind Service Packages

MONITORING AND REMOTE OPERATIONS | **EXTENDED PARTS AND SERVICES** | **FULL SERVICE AGREEMENT**

PLANNED

Remote Monitoring and Troubleshooting:
Turbine monitoring & rapid fault response increase equipment availability and reduce downtime.

Routine Services:
6 and 12 month maintenance according to GE's O&M manual and work procedures.

Preventative Maintenance:
Replacement parts and maintenance for both break-in procedures and tasks with periodicities over one year.

On-Site Support:
On-site operations including troubleshooting and technical advisory services.

Parts Package:
Forecasting, warehouse stocking and replenishment recommendations, maintenance kits, flow and capital parts.

Availability Guarantee:
Customers who elect this level of support qualify for an availability guarantee from GE.

UNPLANNED

Unplanned Maintenance Coverage:
Unplanned maintenance including uptower inspection and repair options for reducing repair costs and downtime.

Condition Monitoring:
Advanced vibration equipment and analysis proactively detects impending drive train issues.

Turbine Performance and Life Extension:
Fault forecasting, advanced inspection technologies and system upgrades.

Monitoring and Remote Operations (MRO):
This package brings GE's technical expertise to provide a defined scope of planned maintenance, including routine inspections, consumable parts replacement, and labor required in the replacement of wear and tear parts—as well as improved availability and reliability with remote operation services including 24/7 remote monitoring (with remote reset capability).

Extended Parts and Services Agreement (EPSA):
Adding coverage for manual resets, initial trouble shooting, competitive parts pricing and inventory management, and a limited availability guarantee together with performance analysis reports, the EPSA ensures the highest standards of operation for the project while offering customers competitive solutions to unplanned service events.

Full Service Agreement (FSA):
Maximize turbine operating performance and life by adding predictive Condition Monitoring services, unplanned maintenance with advanced services and uptower repairs, as well as options for turbine performance and life extension enhancement. Under this comprehensive package GE provides the customer with worry-free operation and maintenance with the highest level of performance.

Project Execution

GE understands that grid compatibility, site flexibility, and on-time delivery are critical to the economics of a wind project. That's why the 1.5 MW wind turbine series has been engineered for ease of integration and delivery to a wide range of locations, including those with challenging site conditions.

Our global project management and fulfillment expertise offer customers on-time delivery and schedule certainty. Regardless of where wind turbine components are delivered, GE's integrated logistics team retains ownership and responsibility for this critical step. Utilizing the GE Energy Power Answer Center, our engineering and supply chain teams are ready to respond to any technical, mechanical or electrical questions that may arise.

As one of the world's largest power plant system providers, GE is uniquely positioned to provide customers with full-service project management solutions. With offices in North America, Europe, and Asia, our world class Global Projects Organization utilizes decades of fulfillment expertise in project management, logistics, plant start-up and integration from Gas Turbine, Combined Cycle, Hydro, and Aero plants.

Here are some examples of how GE has worked with customers to solve project challenges and maximize their value through on-time delivery and advanced logistic capabilities:

Challenge:
Site with late grid availability due to project location change

GE's solution:
Pre-commissioning service: GE can utilize portable generators on site and pre-commission turbines even without back feed power

Customer benefit:
Faster commissioning once grid became available

Challenge:
Project site with difficult geographic access

GE's solution:
Well-choreographed team with challenging terrain transportation expertise

Customer benefit:
More site flexibility; schedule target met

Environmental Health and Safety, a GE commitment

Maintaining high Environmental Health and Safety (EHS) standards is more than simply a good business practice; it is a fundamental responsibility to our employees, customers, contractors, and the environment we all share.

GE is committed to maintaining a safe work environment. We incorporate these values into every product, service and process, driving EHS processes to the highest standards.

Powering the world…responsibly.

For more information please visit www.ge-energy.com/wind.

GEA14954D (05/2010)

GE Energy

Search SEARCH PRODUCTS & SERVICES ONLINE TOOLS OUR COMMITMENT ABOUT US CONTACT US

1.5 MW Wind Turbine Technical Specifications

Home
Products & Services
Products
Wind Turbines
1.5 MW Wind Turbine
2.X MW Wind Turbine
3.6 MW Wind Turbine
Services
Lifecycle Services

1.5 MW Wind Turbine Technical Specifications

		TC3+			TC2		TCI
		1.5xle	**1.6xle**	**1.6sle**	**1.5sle**	**1.5xle**	**1.5se**
Rotor Diameter	m	82.5	82.5	77	77	82.5	70.5
Hub Heights	M	80/100	80/100	80	64.7, 80	80	64.7
Frequency	Hz	50/60	60	50/60	50/60	60	60
	Vavg; m/s	8.0	8.0	8.0	8.5	8.5	10.0
	Vref; m/s	37.1	40.0	39.1	39.1	40.0	50.0
	Ve50; m/s	52.5	56.0	55.0	55.0	56.0	70.0
	Cut-In; m/s	3.5	3.5	3.5	3.5	3.5	4.0
	Cut-Out; m/s	20	25	25	25	25	25
	IEC Wind Class	IEC TC III+	IEC TC III+	IEC TC III+	IEC TC IIA	IEC TC IIB	IEC TC Ib

GE Energy Home | Products | Services | Lifecycle Services | Online Tools | Our Commitment | About Us | GE Careers | Customer Advocate | Site Map

GE Corporate Home | Investor Information | Privacy Policy | Terms of Use

V90-1.8 MW

Maximum output at medium-wind sites
in North America

vestas.com

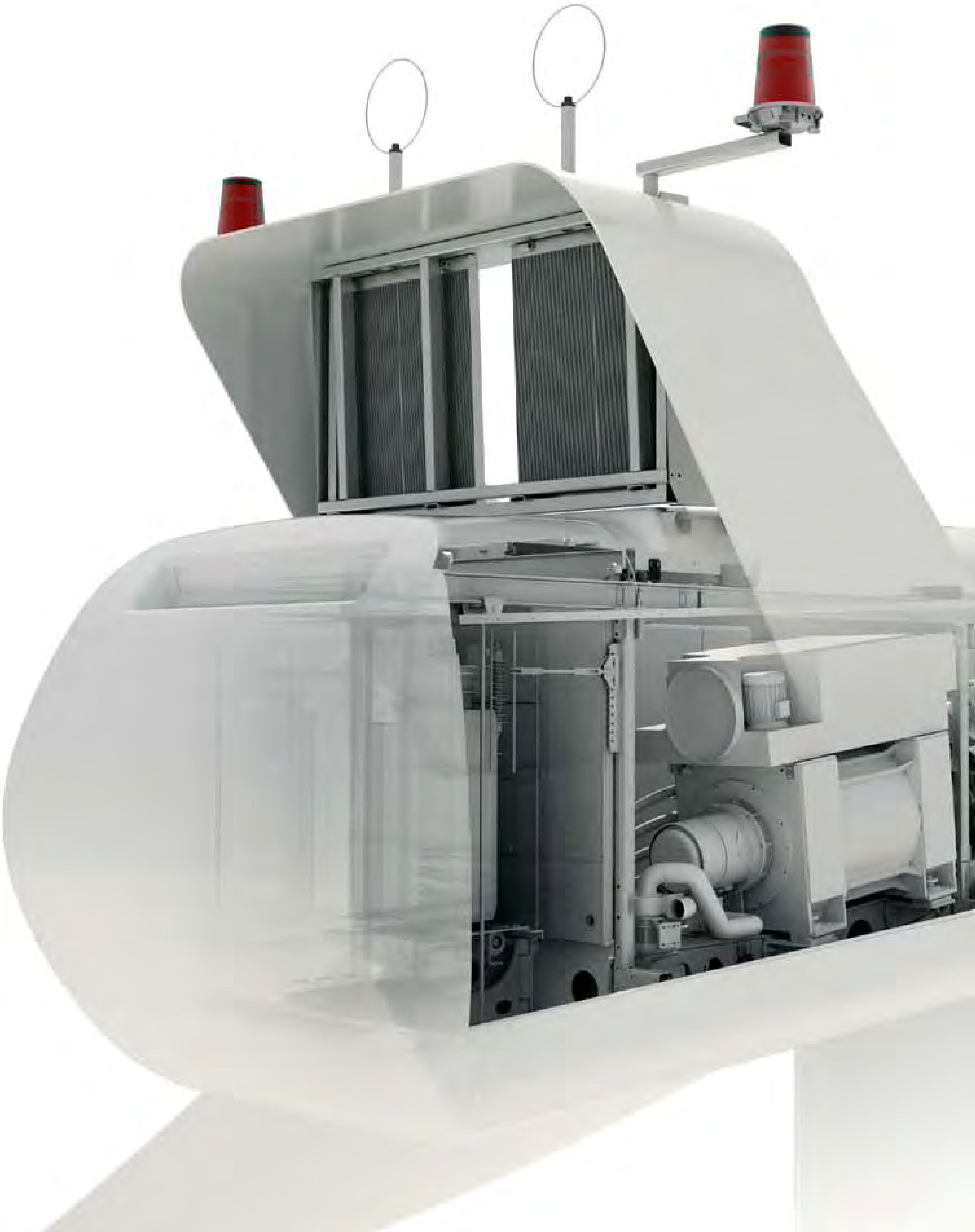
Vestas


WE DELIVER
ON THE PROMISE
OF WIND POWER

SUPERIOR YIELD AT MEDIUM-WIND SITES

Built on experience
The V90-1.8 MW is designed to deliver optimal yield at medium-wind sites (IEC IIA) and builds on decades of experience with existing Vestas turbines. We started with the nacelle from the V80-2.0 MW workhorse. Then we added the revolutionary blades used on the V90-3.0 MW high-wind turbine. Finally, all components were tuned to operate in harmony and take advantage of the special characteristics of medium-wind sites.

Documented high availability and production
Vestas has installed more than 1,500 V90-2 MW class turbines, since the first one was launched in Europe in 2004. If you count the entire 2 MW class, that number climbs to 5,000. All these turbines offer documented high availability and production. The V90-1.8 MW delivers low cost of energy, thanks to documented reliability and the highest yield in its class.

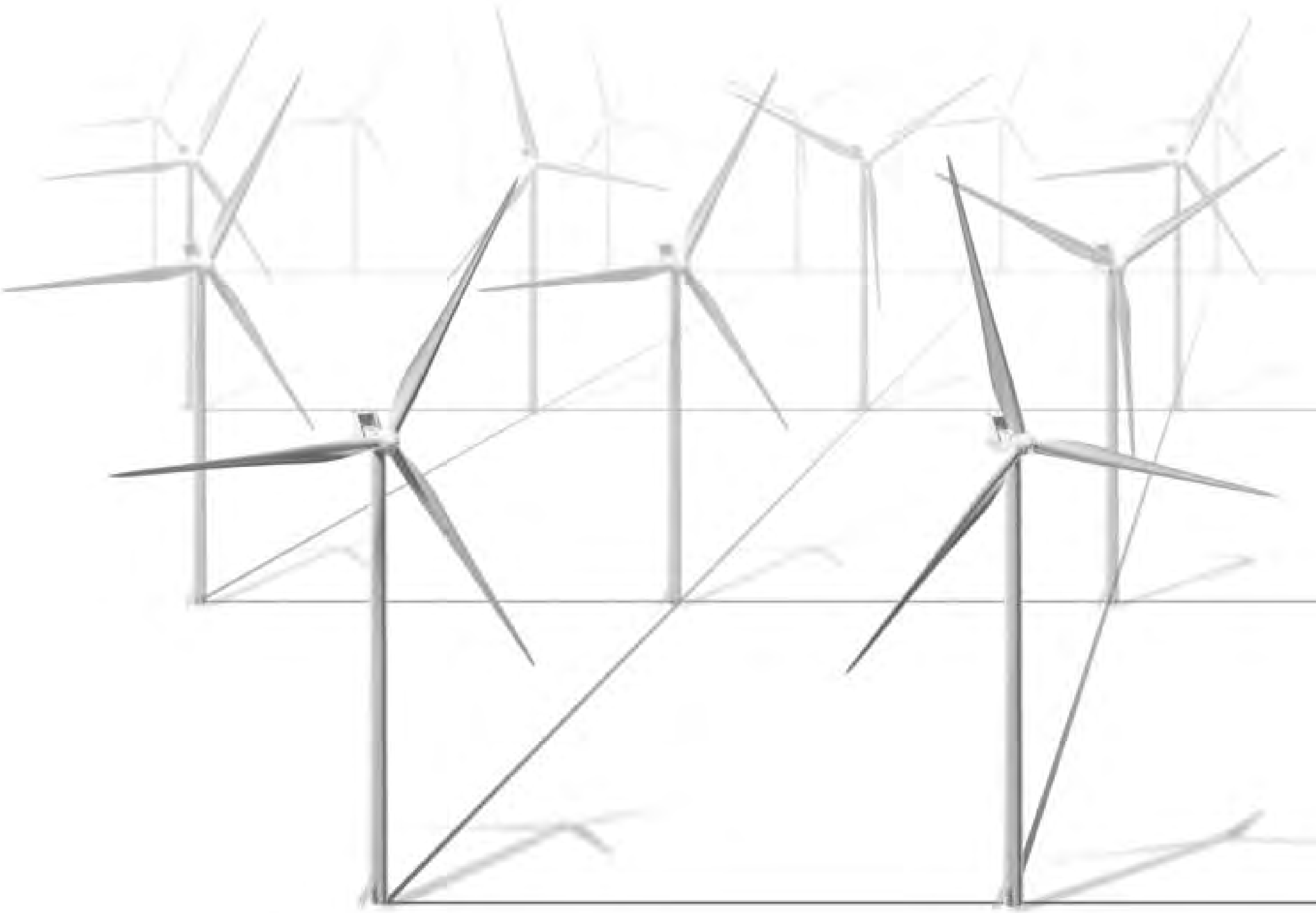


A NEW STANDARD FOR RELIABILITY

Mature technology ensures stable revenue
The many V90-1.8 MW turbines already in operation provide Vestas with invaluable knowledge on which to base further development. This means the V90-1.8 MW is built on a mature, reliable design platform, with several turbines sharing innovative, high-performance technology. The turbine features a rugged 6-gear yaw system, a proven, conventional drive train concept, a 60 Hz 6-pole generator and a transformer, which is integrated with the nacelle to minimize power losses. Finally, the V90-1.8 MW is designed around a large number of standard components that several suppliers can provide, improving overall reliability and availability of the turbine.

Next-generation control system
The V90-1.8 MW is equipped with the latest turbine control and operation software, a state-of-the-art modular software platform developed to run the next generation of Vestas turbines. This software ensures reliable, automatic management of the V90-1.8 MW around the clock. Furthermore the software supports the service organization in monitoring and troubleshooting the wind turbines on site and remotely.

Innovative solutions for lubrication
The V90-1.8 MW offers a number of features that boost reliability and serviceability, including innovative solutions for lubricating key components such as the blade-bearing system and the yaw system.

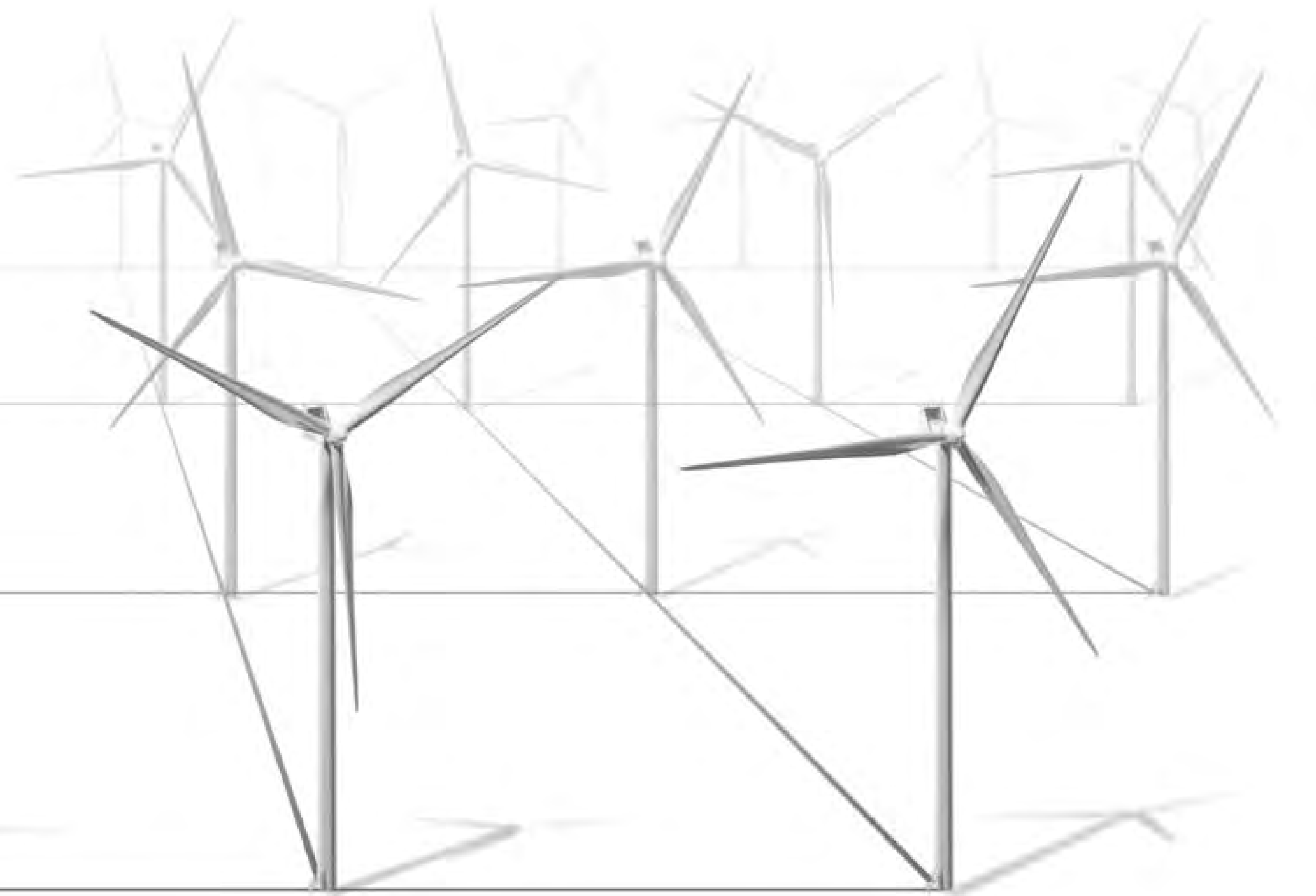


GROUNDBREAKING DESIGN AND EASY MAINTENANCE

Advanced grid operation and stable output
The V90-1.8 MW is equipped with VCUS™ (Vestas Converter Unity System), which ensures a constant and consistent output to the grid. Along with the turbine's pitch control, VCUS™ also ensures energy optimization, low-noise operation and reduced load on the gearbox and other key components. Other VCUS™ advantages include effective fault ride through and complete variable speed capability.

Safety first and easy maintenance
Like all Vestas turbines, the V90-1.8 MW is designed for safe, convenient maintenance. Rotating parts are shielded, and all components are positioned to minimize service time and manpower.

3x44 meters of cutting edge
The revolutionary blades are made from carbon fiber and other lightweight materials. Even though V90s sweep a 27% greater area than V80s, the blade weight is almost the same. What's more, the shape of the blades has been refined to deliver the greatest possible output while minimizing the load on the turbine. The shape also makes these blades less sensitive to dirt, providing better performance at sites affected by salt, insects or other particles in the air.



Can be installed almost anywhere

The V90-1.8 MW is designed for fast, easy transport by truck and rail to virtually any site in the world. The weight, height and width of all parts and main components are designed in consideration of local and international limits for standard transport. Installation, service and maintenance can be carried out using standard tools and equipment.

Special options

The V90-1.8 MW is available with a number of special options that can be provided at the customer's request. These options include:

· Condition monitoring system
· VestasOnline®, Compact or Business
· Switchgear
· Aviation markings on the blades
· Aviation lights
· Company logo
· Ice detection system
· Low temperature package allowing operation in temperatures as low as -30°C.

INNOVATIVE TECHNOLOGY FOR QUIET AND COOL OPERATION

CoolerTop™ saves energy and reduces sound levels
The environmentally friendly CoolerTop™ cools the water used in the turbine's cooling system by channeling wind into the heat exchanger. This boosts reliability, not least by reducing the number of moving parts and electrical components in the cooling system. CoolerTop™ also reduces the turbine's own energy consumption and it keeps sound levels low.

Low sound levels, high productivity
The V90-1.8 MW is a quiet turbine throughout its power curve, but it is even quieter during low-noise operation. The turbine can be operated in configurable modes that keep within defined noise levels, without having a significant effect on production. This makes the V90-1.8 MW ideally suited for sites where sound levels are a concern.


Vestas®

VESTAS TAKES CARE OF YOUR INVESTMENT ROUND THE CLOCK

Verified component lifetime
At the Vestas Testing Centre and Technology R&D, engineering experts and technicians use state-of-the-art testing methods to ensure that the turbine meets our standards for safety, performance and reliability throughout the 20-year service life. These tests push the components beyond their specifications. One method is known as Highly Accelerated Life Testing, which is performed in a HALT chamber. Extreme fluctuations in temperatures combined with heavy vibrations are just some of the stress tests the components are subjected to here. This enables Vestas to address design flaws before a turbine is introduced to the market.

Surveillance 24/7/365
Our surveillance services are manned 24/7 all year round to provide real-time surveillance, remote troubleshooting and other services. These services can also detect potential errors and disruptions before they occur, as data from your turbines is gathered and analyzed. This enables us to prepare a plan for preventative maintenance, in an effort to minimize unexpected production stops and costly downtime.

Service and maintenance
Vestas has service centers around the globe and we are able to cover your every need, from simple cleaning and planned maintenance to emergency call-outs and on-site inventories customized for your turbines.

Asset management and operation risk mitigation

Your wind turbines have to be maintained with great care to avoid exposing your investment to unnecessary risks. And that is exactly what Active Output Management is designed to ensure – that you get the greatest possible return on your investment in a Vestas wind turbine. AOM provides a number of advantages, such as detailed plans for service and maintenance, online monitoring, optimization and troubleshooting, and a competitive insurance scheme. We even offer a full availability guarantee, where Vestas pays compensation if the turbine fails to meet the agreed availability targets.

Project management for effective plants

The better your turbines fit your wind site, the more profitable your plant will be. That's why Vestas offers to take on project management from the initial wind measurements to complete installation of the wind power plant. More than 30 years of international experience and local expertise enable us to complete:

· Wind and site studies
· Designing the wind power project
· Selecting wind turbine types
· Installing the wind farm
· Servicing and maintenance throughout the turbine's service life
· Monitoring and remote troubleshooting.

TECHNICAL DATA FOR V90-1.8 MV

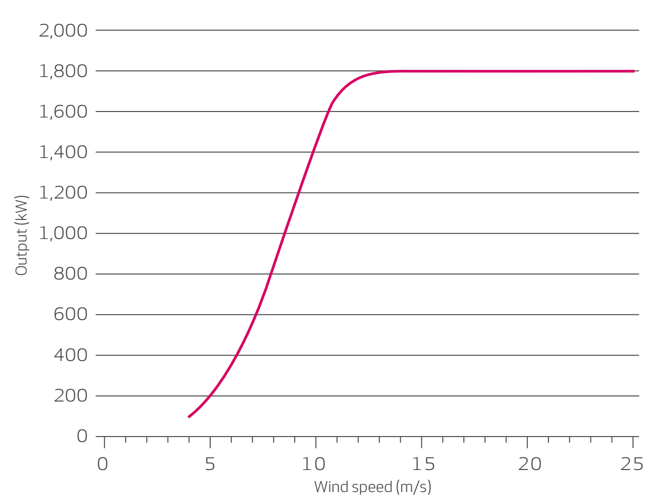
Power regulation	pitch regulated with variable speed
Operating data	
Rated power	1,800 kW
Cut-in wind speed	4 m/s
Rated wind speed	12 m/s
Cut-out wind speed	25 m/s
Wind Class	IEC IIA
Operating temperature	standard range -20°C to 40°C low temperature option -30°C to 40°C
Sound power	
(10 m above ground, hub height 80 m, standard air density 1,225 kg/m3)	
4 m/s	95.6 dB(A)
5 m/s	99.4 dB(A)
6 m/s	102.3 dB(A)
7 m/s	103.1 dB(A)
> 8 m/s	103.5 dB(A)
Rotor	
Rotor diameter	90 m
Swept area	6,362 m^2
Nominal revolutions	14.5 rpm
Operational interval	9.3 - 16.6 rpm
Air brake	full blade feathering with 3 pitch cylinders
Tower	
Type	tubular steel tower
Hub heights	80 m and 95 m
Generator	
Type	6-pole asynchronous with variable speed
Nominal output	1,800 kW
Operational data	60 Hz 690 V
Gearbox	
Type	3-stage planetary/helical

All specifications are for informational purposes and are subject to change without notice. Vestas does not make any representations or extend any warranties, expressed or implied, as to the adequacy or accuracy of this information.

Main dimensions

Blade	
Length	44 m
Max. chord	3.5 m
Weight	6,700 kg
Nacelle	
Height for transport	4 m
Height installed (including CoolerTop):	5.4 m
Length	10.4 m
Width	3.4 m
Weight	70 metric tonnes
Hub	
Max diameter	3.3 m
Max. width	4 m
Length	4.2 m
Weight	18 metric tonnes
Tower	
80 m	
Weight	155 metric tonnes
95 m	
Weight	205 metric tonnes

Power curve V90-1.8 MW



Noise reduced sound power modes are available.

No. 1 in Modern Energy

The world needs ever-greater supplies of clean, sustainable energy. Modern energy that promotes sustainable development and greater prosperity for all our planet's inhabitants. Vestas wind turbines are already generating more than 60 million MWh of electricity every year – enough to power all of Spain, for example – and we are ready to go even further. After more than 30 years in business, Vestas continues to pioneer the wind energy business, achieving breakthroughs that transform our entire industry.

No. 1 in Modern Energy

Vestas Americas Inc.

1881 SW Naito Parkway, Suite 100
Portland, Oregon 97201
USA

Tel: +1 503 327 2000
Fax: +1 503 327 2001

vestas-americas@vestas.com

04/2009-EN

vestas.com

Appendix I

WindPro Model Output Data

Project:
MillburyMA_WP27-Windog-R2

Printed/Page
12/10/2010 1:50 PM / 1

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:39 PM/2.7.473

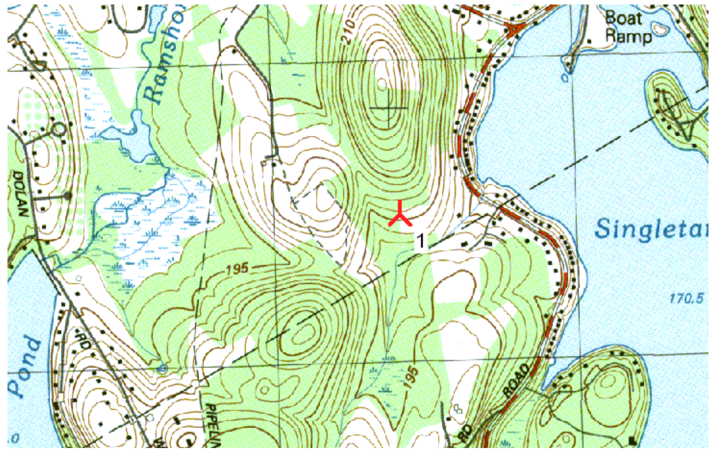
Loss&Uncertainty - Main result

Calculation: 30yr 3Tier Data - NorthWind0.1

Main data for PARK

PARK calculation 2.7.473: NorthWind0.1 - 30yr 3Tier Data - Wiebell

Count	1
Rated power	0.1 MW
Mean wind speed	5.8 m/s at hub height
Sensitivity	2.1 %AEP / %Mean Wind Speed
Expected lifetime	20 Years



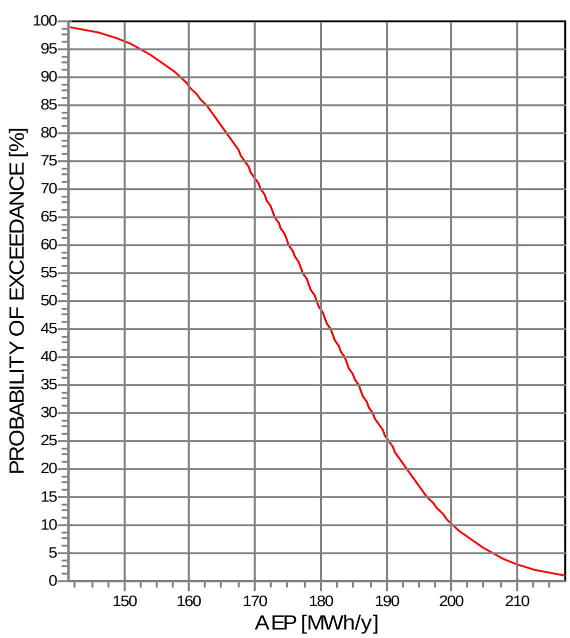
Scale: 25,000

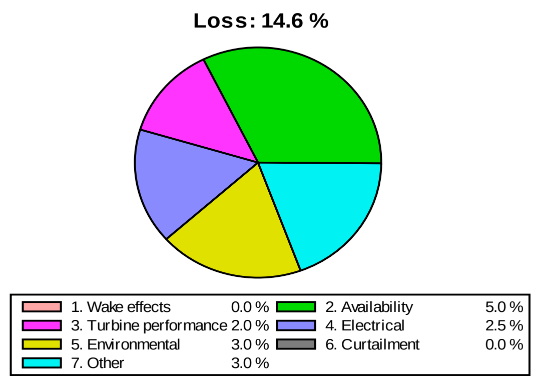
RESULTS

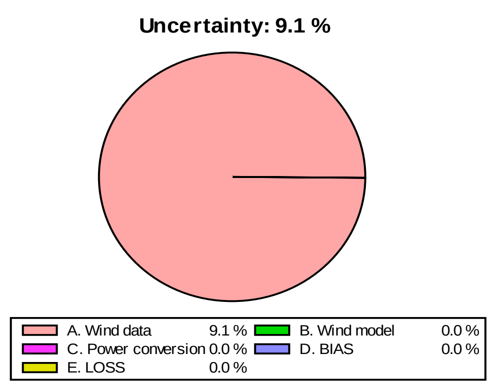
		P50	P84	P90
NET AEP	**[MWh/y]**	**179**	**163**	**159**
Capacity factor	[%]	20.5	18.6	18.1
Full load hours	[h/y]	1,794	1,633	1,586

Result details

	P50		Uncertainty
GROSS AEP *)	210 MWh/y		9.1 %
Bias correction	0 MWh/y	0.0 %	0.0 %
Loss correction	-31 MWh/y	-14.6 %	0.0 %
Wake loss		*0.0 %*	
Other losses		*-14.6 %*	
NET AEP	**179 MWh/y**		**9.1 %**







*) Calculated Annual Energy Production before any bias or loss corrections
Assumptions: Uncertainty and percentiles (PXX values) are calculated for the expected lifetime

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:39 PM/2.7.473

Loss&Uncertainty - Assumptions and results

Calculation: 30yr 3Tier Data - NorthWind0.1

ASSUMPTIONS

LOSS

		Method *)	Loss [%]	Loss [MWh/y]	Std dev**) [%]	Comment
1.	Wake effects					
	Wake effects, all WTGs	Calculation	0.0	0	0.0	
2.	Availability					
	Turbine availability	Estimate	5.0	11	0.0	
3.	Turbine performance					
	Power curve	Estimate	2.0	4	0.0	
4.	Electrical					
	Electrical losses	Estimate	2.5	5	0.0	
5.	Environmental					
	Performance degradation not due to icing	Estimate	1.0	2	0.0	
	Performance degradation due to icing	Estimate	1.0	2	0.0	
	Shutdown due to icing, lightning, hail, etc.	Estimate	1.0	2	0.0	
6.	Curtailment					No input
7.	Other					
	Other loss	Estimate	3.0	6	0.0	
	LOSS, total		**14.6**	**31**	**0.0**	

UNCERTAINTY

		Method *)	Std dev, wind speed [%]	Std dev, AEP [%]	Comment
A.	Wind data				
	Wind measurement/Wind data	Estimate	3.0	6.4	
	Long term correction	Estimate	2.0	4.2	
	Year-to-year variability	Estimate	5.0	10.6	
	Future climate	Estimate	2.0	4.2	
	Other wind related				
B.	Wind model				
	Vertical extrapolation				
	Horizontal extrapolation				
	Other wind model related				
C.	Power conversion				
	Power curve uncertainty				
	Metering uncertainty				
	Other AEP related uncertainties				
D.	BIAS, total uncertainty			0.0	
E.	LOSS, total uncertainty			0.0	
	UNCERTAINTY, total (1y average)			13.8	
	UNCERTAINTY, total (20y average)			**9.1**	

VARIABILITY

Years	Variability (std dev)	Total std dev
1	10.61	13.8
5	4.75	10.0
10	3.36	9.4
20	2.37	**9.1**

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Loss&Uncertainty - Assumptions and results

Calculation: 30yr 3Tier Data - NorthWind0.1

RESULTS

AEP versus exceedance level / time horizon

PXX [%]	1 y [MWh/y]	5 y [MWh/y]	10 y [MWh/y]	20 y [MWh/y]
50	179	179	179	179
75	163	167	168	168
84	155	162	163	163
90	148	157	158	159
95	139	150	152	153

**) Calculation means that a calculation method available in the WindPRO software is used. This still typically involve a user judgement and user data where the quality of those decides the accuracy. If calculation method is used, the values will often be different from turbine to turbine, here the average is shown, but at page "WTG results" the individual turbine results are shown.*
***) For totals the std dev refers to the full AEP, otherwise std dev refers to the bias or loss component which is a fraction of the total AEP.*

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:39 PM/2.7.473

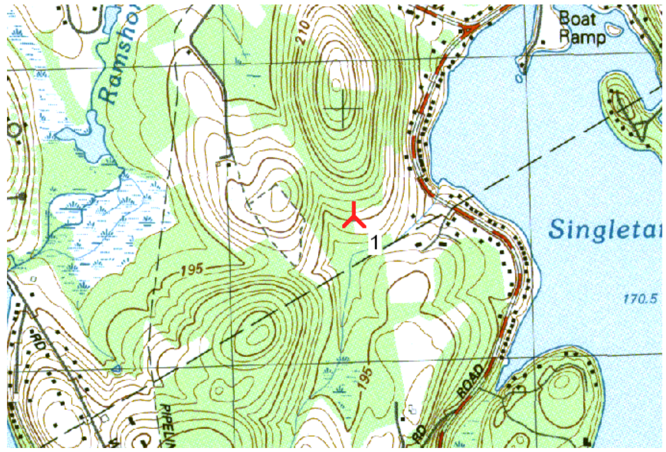
Loss&Uncertainty - WTG results

Calculation: 30yr 3Tier Data - NorthWind0.1

Main data for PARK

PARK calculation 2.7.473: NorthWind0.1 - 30yr 3Tier Data - Wiebell

Count	1
Rated power	0.1 MW
Mean wind speed	5.8 m/s at hub height
Sensitivity	2.1 %AEP / %Mean Wind Speed
Expected lifetime	20 Years



Scale: 25,000

Expected AEP per WTG including bias, loss and uncertainty evaluation

	Description	User label	Calculated GROSS*) [MWh/y]	Bias [%]	Loss [%]	Unc. [%]	20 years averaging P50 [MWh/y]	P84 [MWh/y]	P90 [MWh/y]
1	Northern Power Northwind 100 100 21.0 !O! hub: 37.0 m (1)	WTG4	210.0	0.0	14.6	9.1	179.4	163.3	158.6
	PARK		**210.0**	**0.0**	**14.6**	**9.1**	**179.4**	**163.3**	**158.6**

Project:
MillburyMA_WP27-Windog-R2

Printed/Page
12/10/2010 1:47 PM / 1

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:37 PM/2.7.473

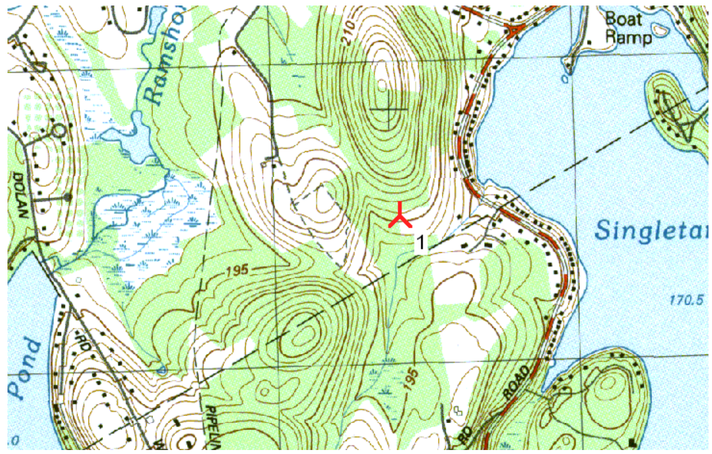
Loss&Uncertainty - Main result

Calculation: 30yr 3Tier Data - Elecon0.6

Main data for PARK

PARK calculation 2.7.473: Elecon0.6 - 30yr 3Tier Data - Wiebell

Count	1
Rated power	0.6 MW
Mean wind speed	6.0 m/s at hub height
Sensitivity	2.2 %AEP / %Mean Wind Speed
Expected lifetime	20 Years



Scale: 25,000

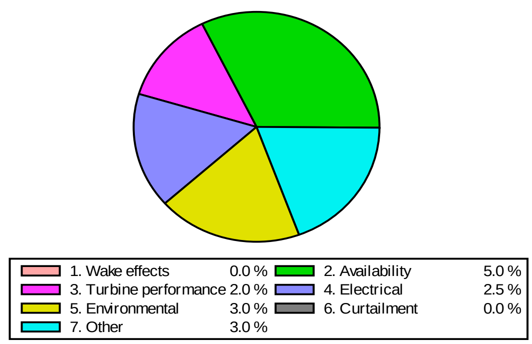
RESULTS

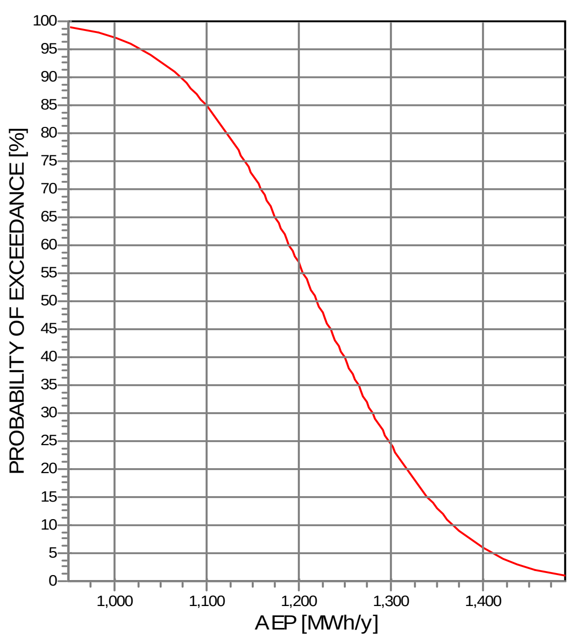
		P50	P84	P90
NET AEP	**[MWh/y]**	**1,219**	**1,104**	**1,071**
Capacity factor	[%]	23.2	21.0	20.4
Full load hours	[h/y]	2,032	1,840	1,785

Result details

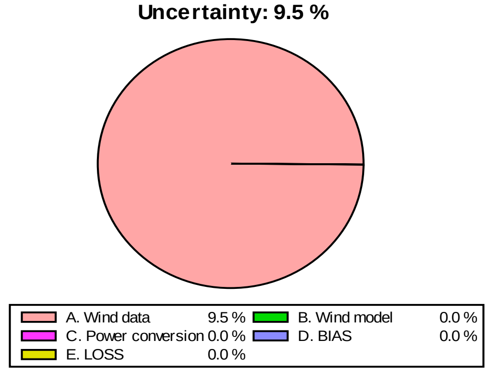
	P50		Uncertainty
GROSS AEP *)	1,427 MWh/y		9.5 %
Bias correction	0 MWh/y	0.0 %	0.0 %
Loss correction	-208 MWh/y	-14.6 %	0.0 %
Wake loss		*0.0 %*	
Other losses		*-14.6 %*	
NET AEP	**1,219 MWh/y**		**9.5 %**

Loss: 14.6 %





Uncertainty: 9.5 %



*) Calculated Annual Energy Production before any bias or loss corrections
Assumptions: Uncertainty and percentiles (PXX values) are calculated for the expected lifetime

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:37 PM/2.7.473

Loss&Uncertainty - Assumptions and results

Calculation: 30yr 3Tier Data - Elecon0.6

ASSUMPTIONS

LOSS

		Method *)	Loss [%]	Loss [MWh/y]	Std dev**) [%]	Comment
1.	Wake effects					
	Wake effects, all WTGs	Calculation	0.0	0	0.0	
2.	Availability					
	Turbine availability	Estimate	5.0	71	0.0	
3.	Turbine performance					
	Power curve	Estimate	2.0	29	0.0	
4.	Electrical					
	Electrical losses	Estimate	2.5	36	0.0	
5.	Environmental					
	Performance degradation not due to icing	Estimate	1.0	14	0.0	
	Performance degradation due to icing	Estimate	1.0	14	0.0	
	Shutdown due to icing, lightning, hail, etc.	Estimate	1.0	14	0.0	
6.	Curtailment					No input
7.	Other					
	Other loss	Estimate	3.0	43	0.0	
	LOSS, total		**14.6**	**208**	**0.0**	

UNCERTAINTY

		Method *)	Std dev, wind speed [%]	Std dev, AEP [%]	Comment
A.	Wind data				
	Wind measurement/Wind data	Estimate	3.0	6.7	
	Long term correction	Estimate	2.0	4.4	
	Year-to-year variability	Estimate	5.0	11.1	
	Future climate	Estimate	2.0	4.4	
	Other wind related				
B.	Wind model				
	Vertical extrapolation				
	Horizontal extrapolation				
	Other wind model related				
C.	Power conversion				
	Power curve uncertainty				
	Metering uncertainty				
	Other AEP related uncertainties				
D.	BIAS, total uncertainty			0.0	
E.	LOSS, total uncertainty			0.0	
	UNCERTAINTY, total (1y average)			14.4	
	UNCERTAINTY, total (20y average)			**9.5**	

VARIABILITY

Years	Variability (std dev)	Total std dev
1	11.09	14.4
5	4.96	10.4
10	3.51	9.8
20	2.48	**9.5**

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:37 PM/2.7.473

Loss&Uncertainty - Assumptions and results

Calculation: 30yr 3Tier Data - Elecon0.6

RESULTS

AEP versus exceedance level / time horizon

PXX	1 y	5 y	10 y	20 y
[%]	[MWh/y]	[MWh/y]	[MWh/y]	[MWh/y]
50	1,219	1,219	1,219	1,219
75	1,101	1,134	1,139	1,141
84	1,045	1,093	1,100	1,104
90	994	1,057	1,066	1,071
95	931	1,010	1,023	1,029

**) Calculation means that a calculation method available in the WindPRO software is used. This still typically involve a user judgement and user data where the quality of those decides the accuracy. If calculation method is used, the values will often be different from turbine to turbine, here the average is shown, but at page "WTG results" the individual turbine results are shown.*
***) For totals the std dev refers to the full AEP, otherwise std dev refers to the bias or loss component which is a fraction of the total AEP.*

Project:
MillburyMA_WP27-Windog-R2

Printed/Page
12/10/2010 1:47 PM / 4

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:37 PM/2.7.473

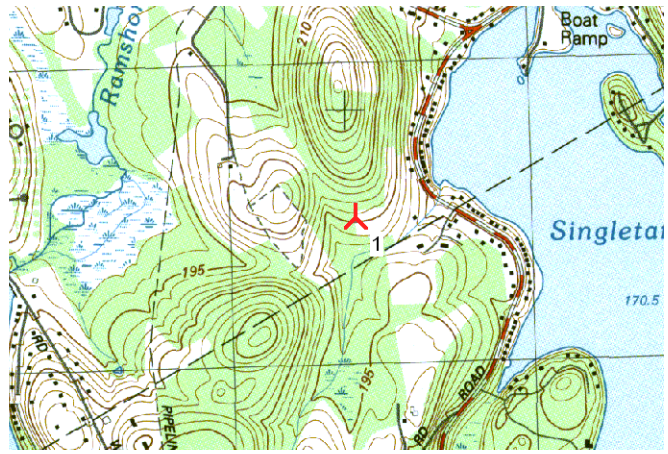
Loss&Uncertainty - WTG results

Calculation: 30yr 3Tier Data - Elecon0.6

Main data for PARK

PARK calculation 2.7.473: Elecon0.6 - 30yr 3Tier Data - Wiebell

Count	1
Rated power	0.6 MW
Mean wind speed	6.0 m/s at hub height
Sensitivity	2.2 %AEP / %Mean Wind Speed
Expected lifetime	20 Years



Scale: 25,000

Expected AEP per WTG including bias, loss and uncertainty evaluation

	Description	User label	Calculated GROSS*)	Bias	Loss	Unc.	P50	P84	P90
							20 years averaging		
			[MWh/y]	[%]	[%]	[%]	[MWh/y]	[MWh/y]	[MWh/y]
1	ELECON - TURBOWINDS T600-48 DS 600-120 48.0 !O! hub: 50.0 m (3)	WTG3	1,426.9	0.0	14.6	9.5	1,219.1	1,104.2	1,071.0
	PARK		**1,426.9**	**0.0**	**14.6**	**9.5**	**1,219.1**	**1,104.2**	**1,071.0**

Project:
MillburyMA_WP27-Windog-R2

Printed/Page
12/10/2010 1:44 PM / 1

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:34 PM/2.7.473

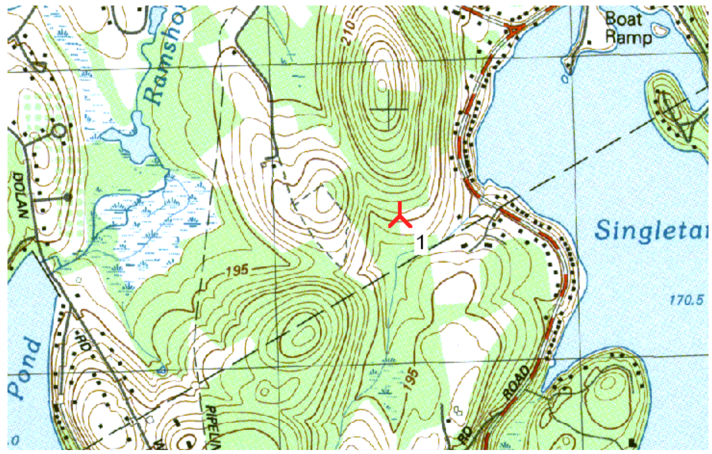
Loss&Uncertainty - Main result

Calculation: 30yr 3Tier Data - GE1.5

Main data for PARK

PARK calculation 2.7.473: GE1.5 - 30yr 3Tier Data - Wiebell

Count	1
Rated power	1.5 MW
Mean wind speed	6.4 m/s at hub height
Sensitivity	2.1 %AEP / %Mean Wind Speed
Expected lifetime	20 Years



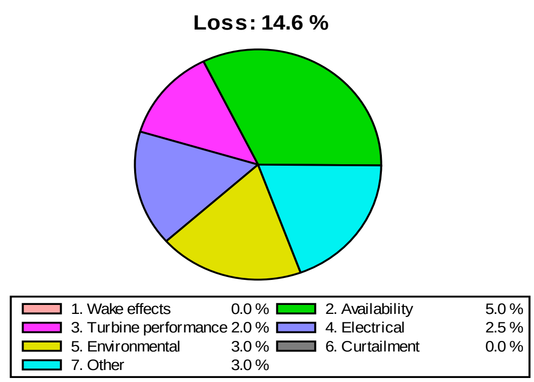
Scale: 25,000

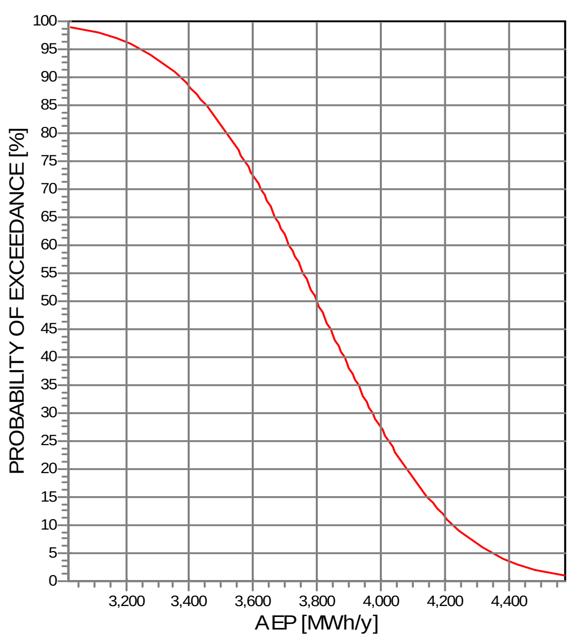
RESULTS

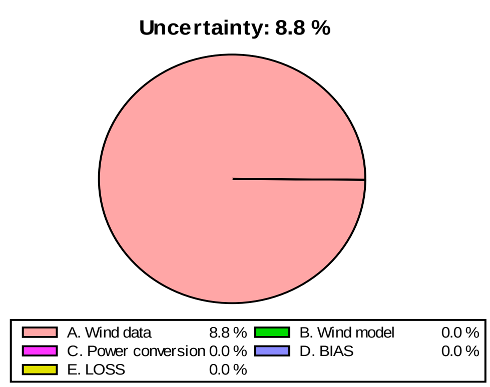
		P50	P84	P90
NET AEP	**[MWh/y]**	**3,799**	**3,466**	**3,370**
Capacity factor	[%]	28.9	26.4	25.6
Full load hours	[h/y]	2,533	2,311	2,247

Result details

	P50		Uncertainty
GROSS AEP *)	4,447 MWh/y		8.8 %
Bias correction	0 MWh/y	0.0 %	0.0 %
Loss correction	-648 MWh/y	-14.6 %	0.0 %
Wake loss		*0.0 %*	
Other losses		*-14.6 %*	
NET AEP	**3,799 MWh/y**		**8.8 %**







*) Calculated Annual Energy Production before any bias or loss corrections
Assumptions: Uncertainty and percentiles (PXX values) are calculated for the expected lifetime

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:34 PM/2.7.473

Loss&Uncertainty - Assumptions and results

Calculation: 30yr 3Tier Data - GE1.5

ASSUMPTIONS

LOSS

		Method *)	Loss [%]	Loss [MWh/y]	Std dev**) [%]	Comment
1.	Wake effects					
	Wake effects, all WTGs	Calculation	0.0	0	0.0	
2.	Availability					
	Turbine availability	Estimate	5.0	222	0.0	
3.	Turbine performance					
	Power curve	Estimate	2.0	89	0.0	
4.	Electrical					
	Electrical losses	Estimate	2.5	111	0.0	
5.	Environmental					
	Performance degradation not due to icing	Estimate	1.0	44	0.0	
	Performance degradation due to icing	Estimate	1.0	44	0.0	
	Shutdown due to icing, lightning, hail, etc.	Estimate	1.0	44	0.0	
6.	Curtailment					No input
7.	Other					
	Other loss	Estimate	3.0	133	0.0	
	LOSS, total		**14.6**	**648**	**0.0**	

UNCERTAINTY

		Method *)	Std dev, wind speed [%]	Std dev, AEP [%]	Comment
A.	Wind data				
	Wind measurement/Wind data	Estimate	3.0	6.2	
	Long term correction	Estimate	2.0	4.1	
	Year-to-year variability	Estimate	5.0	10.3	
	Future climate	Estimate	2.0	4.1	
	Other wind related				
B.	Wind model				
	Vertical extrapolation				
	Horizontal extrapolation				
	Other wind model related				
C.	Power conversion				
	Power curve uncertainty				
	Metering uncertainty				
	Other AEP related uncertainties				
D.	BIAS, total uncertainty			0.0	
E.	LOSS, total uncertainty			0.0	
	UNCERTAINTY, total (1y average)			13.4	
	UNCERTAINTY, total (20y average)			**8.8**	

VARIABILITY

Years	Variability (std dev)	Total std dev
1	10.32	13.4
5	4.61	9.7
10	3.26	9.1
20	2.31	**8.8**

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:34 PM/2.7.473

Loss&Uncertainty - Assumptions and results

Calculation: 30yr 3Tier Data - GE1.5

RESULTS

AEP versus exceedance level / time horizon

PXX [%]	1 y [MWh/y]	5 y [MWh/y]	10 y [MWh/y]	20 y [MWh/y]
50	3,799	3,799	3,799	3,799
75	3,457	3,551	3,566	3,573
84	3,294	3,434	3,455	3,466
90	3,148	3,328	3,356	3,370
95	2,963	3,194	3,230	3,248

**) Calculation means that a calculation method available in the WindPRO software is used. This still typically involve a user judgement and user data where the quality of those decides the accuracy. If calculation method is used, the values will often be different from turbine to turbine, here the average is shown, but at page "WTG results" the individual turbine results are shown.*
***) For totals the std dev refers to the full AEP, otherwise std dev refers to the bias or loss component which is a fraction of the total AEP.*

Project:
MillburyMA_WP27-Windog-R2

Printed/Page
12/10/2010 1:44 PM / 4

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

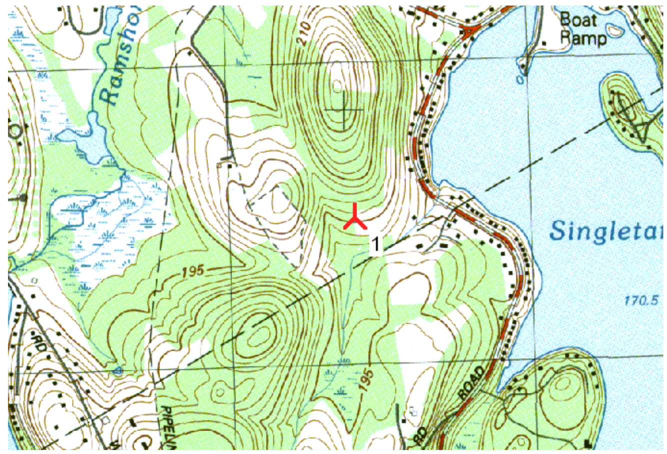
Calculated:
12/10/2010 1:34 PM/2.7.473

Loss&Uncertainty - WTG results

Calculation: 30yr 3Tier Data - GE1.5

Main data for PARK

PARK calculation 2.7.473: GE1.5 - 30yr 3Tier Data - Wiebell
Count 1
Rated power 1.5 MW
Mean wind speed 6.4 m/s at hub height
Sensitivity 2.1 %AEP / %Mean Wind Speed
Expected lifetime 20 Years



Scale: 25,000

Expected AEP per WTG including bias, loss and uncertainty evaluation

	Description	User label	Calculated GROSS*)	Bias	Loss	Unc.	P50	P84	P90
						20 years averaging			
			[MWh/y]	[%]	[%]	[%]	[MWh/y]	[MWh/y]	[MWh/y]
1	GE WIND ENERGY GE 1.5 xle 1500 82.5 !O! hub: 80.0 m (5)	WTG2	4,447.1	0.0	14.6	8.8	3,799.3	3,466.2	3,370.0
	PARK		**4,447.1**	**0.0**	**14.6**	**8.8**	**3,799.3**	**3,466.2**	**3,370.0**

Project:
MillburyMA_WP27-Windog-R2

Printed/Page
12/10/2010 1:42 PM / 1

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:32 PM/2.7.473

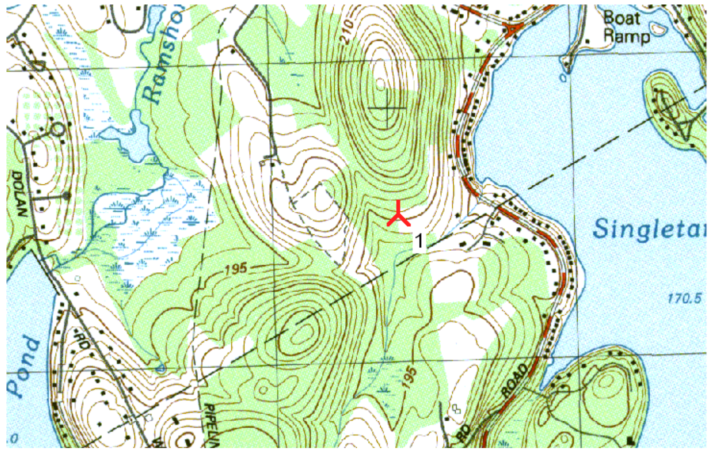
Loss&Uncertainty - Main result

Calculation: 30yr 3Tier Data - V90

Main data for PARK

PARK calculation 2.7.473: V90 - 30yr 3Tier Data - Wiebell

Count	1
Rated power	1.8 MW
Mean wind speed	6.4 m/s at hub height
Sensitivity	2.1 %AEP / %Mean Wind Speed
Expected lifetime	20 Years



Scale: 25,000

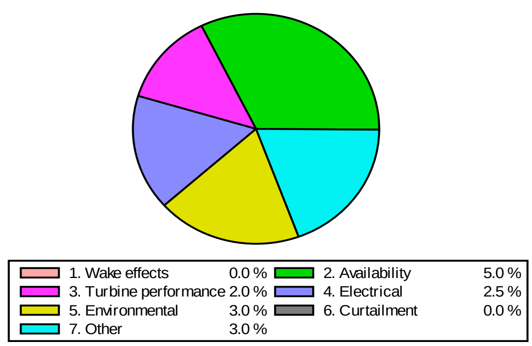
RESULTS

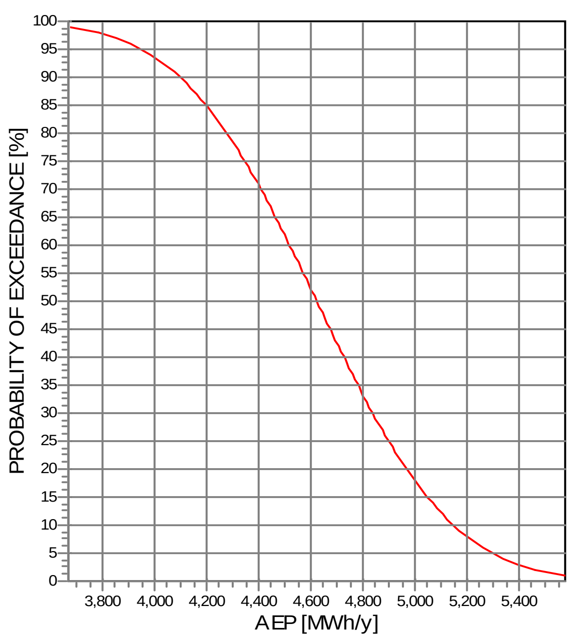
		P50	P84	P90
NET AEP	**[MWh/y]**	**4,622**	**4,214**	**4,097**
Capacity factor	[%]	29.3	26.7	26.0
Full load hours	[h/y]	2,568	2,341	2,276

Result details

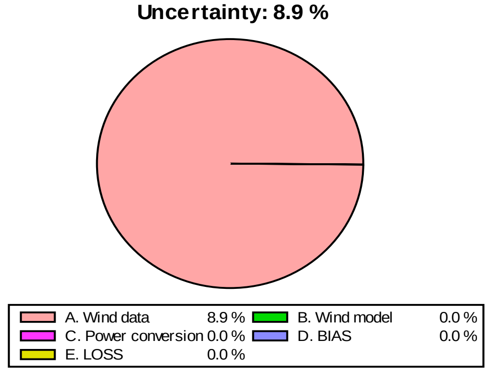
	P50		Uncertainty
GROSS AEP *)	5,410 MWh/y		8.9 %
Bias correction	0 MWh/y	0.0 %	0.0 %
Loss correction	-788 MWh/y	-14.6 %	0.0 %
Wake loss		*0.0 %*	
Other losses		*-14.6 %*	
NET AEP	**4,622 MWh/y**		**8.9 %**

Loss: 14.6 %





Uncertainty: 8.9 %



*) Calculated Annual Energy Production before any bias or loss corrections
Assumptions: Uncertainty and percentiles (PXX values) are calculated for the expected lifetime

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:32 PM/2.7.473

Loss&Uncertainty - Assumptions and results

Calculation: 30yr 3Tier Data - V90

ASSUMPTIONS

LOSS

		Method *)	Loss [%]	Loss [MWh/y]	Std dev**) [%]	Comment
1.	Wake effects					
	Wake effects, all WTGs	Calculation	0.0	0	0.0	
2.	Availability					
	Turbine availability	Estimate	5.0	270	0.0	
3.	Turbine performance					
	Power curve	Estimate	2.0	108	0.0	
4.	Electrical					
	Electrical losses	Estimate	2.5	135	0.0	
5.	Environmental					
	Performance degradation not due to icing	Estimate	1.0	54	0.0	
	Performance degradation due to icing	Estimate	1.0	54	0.0	
	Shutdown due to icing, lightning, hail, etc.	Estimate	1.0	54	0.0	
6.	Curtailment					No input
7.	Other					
	Other loss	Estimate	3.0	162	0.0	
	LOSS, total		**14.6**	**788**	**0.0**	

UNCERTAINTY

		Method *)	Std dev, wind speed [%]	Std dev, AEP [%]	Comment
A.	Wind data				
	Wind measurement/Wind data	Estimate	3.0	6.2	
	Long term correction	Estimate	2.0	4.2	
	Year-to-year variability	Estimate	5.0	10.4	
	Future climate	Estimate	2.0	4.2	
	Other wind related				
B.	Wind model				
	Vertical extrapolation				
	Horizontal extrapolation				
	Other wind model related				
C.	Power conversion				
	Power curve uncertainty				
	Metering uncertainty				
	Other AEP related uncertainties				
D.	BIAS, total uncertainty			0.0	
E.	LOSS, total uncertainty			0.0	
	UNCERTAINTY, total (1y average)			13.5	
	UNCERTAINTY, total (20y average)			**8.9**	

VARIABILITY

Years	Variability (std dev)	Total std dev
1	10.38	13.5
5	4.64	9.7
10	3.28	9.2
20	2.32	**8.9**

Project:
MillburyMA_WP27-Windog-R2

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:32 PM/2.7.473

Loss&Uncertainty - Assumptions and results

Calculation: 30yr 3Tier Data - V90

RESULTS

AEP versus exceedance level / time horizon

PXX [%]	1 y [MWh/y]	5 y [MWh/y]	10 y [MWh/y]	20 y [MWh/y]
50	4,622	4,622	4,622	4,622
75	4,203	4,318	4,336	4,346
84	4,004	4,174	4,201	4,214
90	3,825	4,045	4,079	4,097
95	3,599	3,882	3,925	3,948

**) Calculation means that a calculation method available in the WindPRO software is used. This still typically involve a user judgement and user data where the quality of those decides the accuracy. If calculation method is used, the values will often be different from turbine to turbine, here the average is shown, but at page "WTG results" the individual turbine results are shown.*
***) For totals the std dev refers to the full AEP, otherwise std dev refers to the bias or loss component which is a fraction of the total AEP.*

Project:
MillburyMA_WP27-Windog-R2

Printed/Page
12/10/2010 1:42 PM / 4

Licensed user:
Weston & Sampson Engineers Inc.
Five Centennial Drive
US-PEABODY, MA 01960
+1 978 532 1900
Alex McBrien / mcbriena@wseinc.com

Calculated:
12/10/2010 1:32 PM/2.7.473

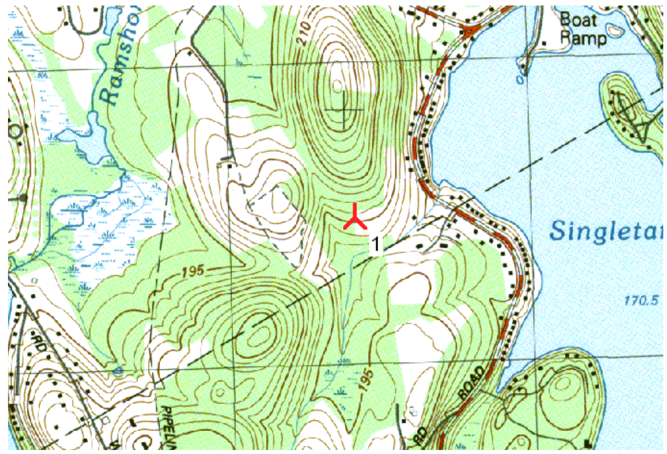
Loss&Uncertainty - WTG results

Calculation: 30yr 3Tier Data - V90

Main data for PARK

PARK calculation 2.7.473: V90 - 30yr 3Tier Data - Wiebell

Count	1
Rated power	1.8 MW
Mean wind speed	6.4 m/s at hub height
Sensitivity	2.1 %AEP / %Mean Wind Speed
Expected lifetime	20 Years



Scale: 25,000

Expected AEP per WTG including bias, loss and uncertainty evaluation

	Description	User label	Calculated GROSS*) [MWh/y]	Bias [%]	Loss [%]	Unc. [%]	20 years averaging P50 [MWh/y]	P84 [MWh/y]	P90 [MWh/y]
1	VESTAS V90 60Hz 1800 90.0 !O! hub: 80.0 m (4)	WTG1	5,410.0	0.0	14.6	8.9	4,622.0	4,214.4	4,096.8
	PARK		**5,410.0**	**0.0**	**14.6**	**8.9**	**4,622.0**	**4,214.4**	**4,096.8**

Appendix J

Economic Calculations

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**Northern Power 100**		
Turbine size (kW)			100
Capacity Factor			4.7%
Annual Energy Production (kWh)			37,055
Annual Energy Use (kWh/yr)			3,627,800
Value of Retail Off Set (kWh)		$	0.1237
Net Metering Credit		$	0.0883
REC value (kWh)	Y1-Y10	$	0.045
REC value (kWh)	Y11-Y20	$	0.035
Coincidence			100.0%
O&M ($/kW)			$40
NPV	($880,700)		
Net Cash Flow	($784,183)		
Present Value Benefit	$185,323		
Present Value Cost	$1,066,024		
Benefit Cost Ratio	0.17		
Internal Rate of Return	-7.2%		

Tower Height	37	meters
Average Wind Speed	4.0	m/s
Project Term	20	years
Financing:	Equity	
Energy Inflation	2%	
General Inflation	2%	
Discount Rate	4.0%	
Project Cost (No Grant)	$1,032,314	
Simple Payback	22,726.86	years
Residual Value	$258,079	

Annual Use:	3,627,800	kWh	
	Avg. Rate	Total	
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-
Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1	
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1	
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12	

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$875	$1,032,314	$0	$1,033,189	($1,033,189)	($1,033,189)
2	$0	$3,270	$1,667	$4,938	$4,938	$40,000	$893	$0	$0	$40,893	($35,955)	($1,069,144)
3	$0	$3,336	$1,667	$5,003	$9,941	$40,800	$910	$0	$0	$41,710	($36,707)	($1,105,851)
4	$0	$3,403	$1,667	$5,070	$15,011	$41,616	$929	$0	$0	$42,545	($37,475)	($1,143,325)
5	$0	$3,471	$1,667	$5,138	$20,149	$42,448	$947	$0	$0	$43,395	($38,257)	($1,181,582)
6	$0	$3,540	$1,667	$5,208	$25,357	$43,297	$966	$0	$0	$44,263	($39,056)	($1,220,638)
7	$0	$3,611	$1,667	$5,278	$30,635	$44,163	$985	$0	$0	$45,149	($39,870)	($1,260,509)
8	$0	$3,683	$1,667	$5,351	$35,986	$45,046	$1,005	$0	$0	$46,052	($40,701)	($1,301,210)
9	$0	$3,757	$1,667	$5,424	$41,410	$45,947	$1,025	$0	$0	$46,973	($41,548)	($1,342,758)
10	$0	$3,832	$1,667	$5,499	$46,909	$46,866	$1,046	$0	$0	$47,912	($42,413)	($1,385,171)
11	$0	$3,908	$1,297	$5,205	$52,115	$47,804	$1,067	$0	$0	$48,870	($43,665)	($1,428,836)
12	$0	$3,987	$1,297	$5,284	$57,398	$48,760	$1,088	$0	$0	$49,848	($44,564)	($1,473,400)
13	$0	$4,066	$1,297	$5,363	$62,762	$49,735	$1,110	$0	$0	$50,845	($45,481)	($1,518,881)
14	$0	$4,148	$1,297	$5,445	$68,206	$50,730	$1,132	$0	$0	$51,862	($46,417)	($1,565,298)
15	$0	$4,231	$1,297	$5,528	$73,734	$51,744	$1,155	$0	$0	$52,899	($47,371)	($1,612,669)
16	$0	$4,315	$1,297	$5,612	$79,346	$52,779	$1,178	$0	$0	$53,957	($48,345)	($1,661,014)
17	$0	$4,402	$1,297	$5,699	$85,045	$53,835	$1,201	$0	$0	$55,036	($49,337)	($1,710,351)
18	$0	$4,490	$1,297	$5,787	$90,831	$54,911	$1,225	$0	$0	$56,137	($50,350)	($1,760,701)
19	$0	$4,579	$1,297	$5,876	$96,707	$56,010	$1,250	$0	$0	$57,259	($51,383)	($1,812,084)
20	$0	$4,671	$1,297	$5,968	$102,675	$57,130	$1,275	$0	$0	$58,405	($52,437)	($1,606,443)

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**RRB 600**		
Turbine size (kW)			600
Capacity Factor			7.6%
Annual Energy Production (kWh)			359,510
Annual Town Energy Use (kWh/yr)			3,627,800
Value of Retail Off Set (kWh)		$	0.1237
Net Metering Credit		$	0.0883
REC value (kWh)	Y1-Y10	$	0.045
REC value (kWh)	Y11-Y20	$	0.035
Coincidence			100.0%
O&M ($/kW)			$40
NPV	($1,371,375)		
Net Cash Flow	($1,083,352)		
Present Value Benefit	$868,837		
Present Value Cost	$2,240,212		
Benefit Cost Ratio	0.39		
Internal Rate of Return	-5.3%		

Tower Height	63	meters
Average Wind Speed	4.9	m/s
Project Term	20	years
Financing:	Equity	
Energy Inflation	2%	
General Inflation	2%	
Discount Rate	4.0%	
Project Cost (No Grant)	$1,871,717	
Simple Payback	100.88	years
Residual Value	$467,929	

Annual Use: 3,627,800 kWh

	Avg. Rate		Total
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-

Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$5,250	$1,871,717	$0	$1,876,967	($1,876,967)	($1,876,967)
2	$0	$31,730	$16,178	$47,908	$47,908	$40,000	$5,355	$0	$0	$45,355	$2,553	($1,874,414)
3	$0	$32,365	$16,178	$48,543	$96,451	$40,800	$5,462	$0	$0	$46,262	$2,281	($1,872,133)
4	$0	$33,012	$16,178	$49,190	$145,642	$41,616	$5,571	$0	$0	$47,187	$2,003	($1,870,130)
5	$0	$33,673	$16,178	$49,851	$195,492	$42,448	$5,683	$0	$0	$48,131	$1,719	($1,868,410)
6	$0	$34,346	$16,178	$50,524	$246,016	$43,297	$5,796	$0	$0	$49,094	$1,430	($1,866,980)
7	$0	$35,033	$16,178	$51,211	$297,227	$44,163	$5,912	$0	$0	$50,076	$1,135	($1,865,845)
8	$0	$35,734	$16,178	$51,912	$349,138	$45,046	$6,031	$0	$0	$51,077	$834	($1,865,010)
9	$0	$36,448	$16,178	$52,626	$401,765	$45,947	$6,151	$0	$0	$52,099	$528	($1,864,483)
10	$0	$37,177	$16,178	$53,355	$455,120	$46,866	$6,274	$0	$0	$53,141	$215	($1,864,268)
11	$0	$37,921	$12,583	$50,504	$505,623	$47,804	$6,400	$0	$0	$54,203	($3,700)	($1,867,968)
12	$0	$38,679	$12,583	$51,262	$556,886	$48,760	$6,528	$0	$0	$55,287	($4,025)	($1,871,994)
13	$0	$39,453	$12,583	$52,036	$608,921	$49,735	$6,658	$0	$0	$56,393	($4,358)	($1,876,351)
14	$0	$40,242	$12,583	$52,825	$661,746	$50,730	$6,791	$0	$0	$57,521	($4,696)	($1,881,048)
15	$0	$41,047	$12,583	$53,630	$715,375	$51,744	$6,927	$0	$0	$58,672	($5,042)	($1,886,090)
16	$0	$41,868	$12,583	$54,450	$769,826	$52,779	$7,066	$0	$0	$59,845	($5,395)	($1,891,484)
17	$0	$42,705	$12,583	$55,288	$825,114	$53,835	$7,207	$0	$0	$61,042	($5,754)	($1,897,238)
18	$0	$43,559	$12,583	$56,142	$881,255	$54,911	$7,351	$0	$0	$62,263	($6,121)	($1,903,359)
19	$0	$44,430	$12,583	$57,013	$938,268	$56,010	$7,498	$0	$0	$63,508	($6,495)	($1,909,854)
20	$0	$45,319	$12,583	$57,902	$996,170	$57,130	$7,648	$0	$0	$64,778	($6,876)	($1,448,801)

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	GE 1.5 XLE		
Turbine size (kW)			1500
Capacity Factor			8.6%
Annual Energy Production (kWh)			1,017,036
Annual Town Energy Use (kWh/yr)			3,627,800
Value of Retail Off Set (kWh)		$	0.1237
Net Metering Credit		$	0.0883
REC value (kWh)	Y1-Y10	$	0.045
REC value (kWh)	Y11-Y20	$	0.035
Coincidence			100.0%
O&M ($/kW)			$40
NPV	($3,042,014)		
Net Cash Flow	($2,475,357)		
Present Value Benefit	$2,151,033		
Present Value Cost	$5,193,047		
Benefit Cost Ratio	0.41		
Internal Rate of Return	-5.9%		

Tower Height	80	meters
Average Wind Speed	5.2	m/s
Project Term	20	years
Financing:	Equity	
Energy Inflation	2%	
General Inflation	2%	
Discount Rate	4.0%	
Project Cost (No Grant)	$4,255,511	
Simple Payback	68.48	years
Residual Value	$651,378	

Annual Use:	3,627,800	kWh	
	Avg. Rate	Total	
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-

Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$13,125	$4,255,511	$0	$4,268,636	($4,268,636)	($4,268,636)
2	$0	$89,764	$45,767	$135,530	$135,530	$40,000	$13,388	$0	$0	$53,388	$82,143	($4,186,493)
3	$0	$91,559	$45,767	$137,325	$272,856	$40,800	$13,655	$0	$0	$54,455	$82,870	($4,103,623)
4	$0	$93,390	$45,767	$139,157	$412,012	$41,616	$13,928	$0	$0	$55,544	$83,612	($4,020,011)
5	$0	$95,258	$45,767	$141,024	$553,037	$42,448	$14,207	$0	$0	$56,655	$84,369	($3,935,642)
6	$0	$97,163	$45,767	$142,930	$695,966	$43,297	$14,491	$0	$0	$57,788	$85,141	($3,850,500)
7	$0	$99,106	$45,767	$144,873	$840,839	$44,163	$14,781	$0	$0	$58,944	$85,929	($3,764,571)
8	$0	$101,088	$45,767	$146,855	$987,694	$45,046	$15,076	$0	$0	$60,123	$86,732	($3,677,839)
9	$0	$103,110	$45,767	$148,877	$1,136,571	$45,947	$15,378	$0	$0	$61,325	$87,551	($3,590,288)
10	$0	$105,172	$45,767	$150,939	$1,287,510	$46,866	$15,686	$0	$0	$62,552	$88,387	($3,501,901)
11	$0	$107,276	$35,596	$142,872	$1,430,382	$47,804	$15,999	$0	$0	$63,803	$79,069	($3,422,832)
12	$0	$109,421	$35,596	$145,018	$1,575,400	$48,760	$16,319	$0	$0	$65,079	$79,939	($3,342,894)
13	$0	$111,610	$35,596	$147,206	$1,722,606	$49,735	$16,646	$0	$0	$66,381	$80,825	($3,262,068)
14	$0	$113,842	$35,596	$149,438	$1,872,044	$50,730	$16,979	$0	$0	$67,708	$81,730	($3,180,338)
15	$0	$116,119	$35,596	$151,715	$2,023,759	$51,744	$17,318	$0	$0	$69,062	$82,653	($3,097,686)
16	$0	$118,441	$35,596	$154,037	$2,177,796	$52,779	$17,665	$0	$0	$70,444	$83,594	($3,014,092)
17	$0	$120,810	$35,596	$156,406	$2,334,203	$53,835	$18,018	$0	$0	$71,853	$84,554	($2,929,538)
18	$0	$123,226	$35,596	$158,822	$2,493,025	$54,911	$18,378	$0	$0	$73,290	$85,533	($2,844,005)
19	$0	$125,691	$35,596	$161,287	$2,654,312	$56,010	$18,746	$0	$0	$74,755	$86,532	($2,757,474)
20	$0	$128,205	$35,596	$163,801	$2,818,113	$57,130	$19,121	$0	$0	$76,250	$87,550	($2,018,546)

1.5MW: Equity - No Grant

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**GE 1.5 SLE**		
Turbine size (kW)			1500
Capacity Factor			6.8%
Annual Energy Production (kWh)			804,168
Annual Town Energy Use (kWh/yr)			3,627,800
Value of Retail Off Set (kWh)		$	0.1237
Net Metering Credit		$	0.0883
REC value (kWh)	Y1-Y10	$	0.045
REC value (kWh)	Y11-Y20	$	0.035
Coincidence			100.0%
O&M ($/kW)			$40
NPV	($1,843,471)		
Net Cash Flow	($1,415,194)		
Present Value Benefit	$1,763,038		
Present Value Cost	$3,606,509		
Benefit Cost Ratio	0.49		
Internal Rate of Return	-4.9%		

Tower Height		80	meters
Average Wind Speed		5.2	m/s
Project Term		20	years
Financing:	Equity		
Energy Inflation		2%	
General Inflation		2%	
Discount Rate		4.0%	
Project Cost (No Grant)	$2,605,511		
Simple Payback	77.14		years
Residual Value	$651,378		

Annual Use:	3,627,800	kWh	
	Avg. Rate	Total	
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-

Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$13,125	$2,605,511	$0	$2,618,636	($2,618,636)	($2,618,636)
2	$0	$70,976	$36,188	$107,163	$107,163	$40,000	$13,388	$0	$0	$53,388	$53,776	($2,564,860)
3	$0	$72,395	$36,188	$108,583	$215,746	$40,800	$13,655	$0	$0	$54,455	$54,128	($2,510,732)
4	$0	$73,843	$36,188	$110,031	$325,777	$41,616	$13,928	$0	$0	$55,544	$54,486	($2,456,246)
5	$0	$75,320	$36,188	$111,508	$437,285	$42,448	$14,207	$0	$0	$56,655	$54,852	($2,401,393)
6	$0	$76,827	$36,188	$113,014	$550,299	$43,297	$14,491	$0	$0	$57,788	$55,226	($2,346,168)
7	$0	$78,363	$36,188	$114,551	$664,850	$44,163	$14,781	$0	$0	$58,944	$55,607	($2,290,561)
8	$0	$79,930	$36,188	$116,118	$780,968	$45,046	$15,076	$0	$0	$60,123	$55,995	($2,234,566)
9	$0	$81,529	$36,188	$117,717	$898,684	$45,947	$15,378	$0	$0	$61,325	$56,391	($2,178,175)
10	$0	$83,160	$36,188	$119,347	$1,018,031	$46,866	$15,686	$0	$0	$62,552	$56,795	($2,121,380)
11	$0	$84,823	$28,146	$112,969	$1,131,000	$47,804	$15,999	$0	$0	$63,803	$49,166	($2,072,214)
12	$0	$86,519	$28,146	$114,665	$1,245,665	$48,760	$16,319	$0	$0	$65,079	$49,586	($2,022,628)
13	$0	$88,250	$28,146	$116,395	$1,362,060	$49,735	$16,646	$0	$0	$66,381	$50,015	($1,972,614)
14	$0	$90,015	$28,146	$118,160	$1,480,221	$50,730	$16,979	$0	$0	$67,708	$50,452	($1,922,161)
15	$0	$91,815	$28,146	$119,961	$1,600,182	$51,744	$17,318	$0	$0	$69,062	$50,898	($1,871,263)
16	$0	$93,651	$28,146	$121,797	$1,721,979	$52,779	$17,665	$0	$0	$70,444	$51,353	($1,819,910)
17	$0	$95,524	$28,146	$123,670	$1,845,649	$53,835	$18,018	$0	$0	$71,853	$51,818	($1,768,092)
18	$0	$97,435	$28,146	$125,581	$1,971,229	$54,911	$18,378	$0	$0	$73,290	$52,291	($1,715,801)
19	$0	$99,383	$28,146	$127,529	$2,098,758	$56,010	$18,746	$0	$0	$74,755	$52,774	($1,663,027)
20	$0	$101,371	$28,146	$129,517	$2,228,275	$57,130	$19,121	$0	$0	$76,250	$53,266	($958,383)

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**Vestas V90**		
Turbine size (kW)			1800
Capacity Factor			10.8%
Annual Energy Production (kWh)			1,532,650
Annual Town Energy Use (kWh/yr)			3,627,800
Value of Retail Off Set (kWh)		$	0.1237
Net Metering Credit		$	0.0883
REC value (kWh)	Y1-Y10	$	0.045
REC value (kWh)	Y11-Y20	$	0.035
Coincidence			100.0%
O&M ($/kW)			$40
NPV	($2,613,307)		
Net Cash Flow	($1,687,001)		
Present Value Benefit	$3,090,842		
Present Value Cost	$5,704,149		
Benefit Cost Ratio	0.54		
Internal Rate of Return	-3.6%		

Tower Height	80	meters
Average Wind Speed	5.2	m/s
Project Term	20	years
Financing:	Equity	
Energy Inflation	2%	
General Inflation	2%	
Discount Rate	4.0%	
Project Cost (No Grant)	$4,558,006	
Simple Payback	39.23	years
Residual Value	$651,378	

Annual Use: 3,627,800 kWh

	Avg. Rate	Total	
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-

Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$15,750	$4,558,006	$0	$4,573,756	($4,573,756)	($4,573,756)
2	$0	$135,272	$68,969	$204,241	$204,241	$40,000	$16,065	$0	$0	$56,065	$148,176	($4,425,580)
3	$0	$137,977	$68,969	$206,946	$411,187	$40,800	$16,386	$0	$0	$57,186	$149,760	($4,275,820)
4	$0	$140,737	$68,969	$209,706	$620,893	$41,616	$16,714	$0	$0	$58,330	$151,376	($4,124,444)
5	$0	$143,551	$68,969	$212,521	$833,414	$42,448	$17,048	$0	$0	$59,497	$153,024	($3,971,420)
6	$0	$146,422	$68,969	$215,392	$1,048,805	$43,297	$17,389	$0	$0	$60,687	$154,705	($3,816,715)
7	$0	$149,351	$68,969	$218,320	$1,267,125	$44,163	$17,737	$0	$0	$61,900	$156,420	($3,660,295)
8	$0	$152,338	$68,969	$221,307	$1,488,432	$45,046	$18,092	$0	$0	$63,138	$158,169	($3,502,127)
9	$0	$155,385	$68,969	$224,354	$1,712,786	$45,947	$18,454	$0	$0	$64,401	$159,953	($3,342,174)
10	$0	$158,492	$68,969	$227,462	$1,940,248	$46,866	$18,823	$0	$0	$65,689	$161,772	($3,180,401)
11	$0	$161,662	$53,643	$215,305	$2,155,553	$47,804	$19,199	$0	$0	$67,003	$148,302	($3,032,099)
12	$0	$164,895	$53,643	$218,538	$2,374,091	$48,760	$19,583	$0	$0	$68,343	$150,195	($2,881,904)
13	$0	$168,193	$53,643	$221,836	$2,595,927	$49,735	$19,975	$0	$0	$69,710	$152,126	($2,729,778)
14	$0	$171,557	$53,643	$225,200	$2,821,127	$50,730	$20,374	$0	$0	$71,104	$154,096	($2,575,682)
15	$0	$174,988	$53,643	$228,631	$3,049,758	$51,744	$20,782	$0	$0	$72,526	$156,105	($2,419,577)
16	$0	$178,488	$53,643	$232,131	$3,281,889	$52,779	$21,197	$0	$0	$73,977	$158,154	($2,261,423)
17	$0	$182,058	$53,643	$235,701	$3,517,589	$53,835	$21,621	$0	$0	$75,456	$160,244	($2,101,178)
18	$0	$185,699	$53,643	$239,342	$3,756,931	$54,911	$22,054	$0	$0	$76,965	$162,376	($1,938,802)
19	$0	$189,413	$53,643	$243,056	$3,999,987	$56,010	$22,495	$0	$0	$78,505	$164,551	($1,774,251)
20	$0	$193,201	$53,643	$246,844	$4,246,831	$57,130	$22,945	$0	$0	$80,075	$166,769	($956,104)

1.8MW: Equity - No Grant

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**Noethern Power 100**		
Turbine size (kW)			100
Capacity Factor			4.7%
Annual Energy Production (kWh)			37,055
Annual Town Energy Use (kWh/yr)			3,627,800
Value of Retail Off Set (kWh)		$	0.1237
Net Metering Credit		$	0.0883
REC value (kWh)	Y1-Y10	$	0.045
REC value (kWh)	Y11-Y20	$	0.035
Coincidence			100.0%
O&M ($/kW)			$40
NPV	($722,046)		
Net Cash Flow	($619,183)		
Present Value Benefit	$185,323		
Present Value Cost	$907,370		
Benefit Cost Ratio	0.20		
Internal Rate of Return	-6.3%		

Tower Height	37	meters
Average Wind Speed	4.0	m/s
Project Term	20	years
Financing:	Equity	
Energy Inflation	2%	
General Inflation	2%	
Discount Rate	4.0%	
Project Cost (with Grant)	$867,314	
Simple Payback	19,094.31	years
Residual Value	$258,079	

Annual Use:	3,627,800	kWh	
	Avg. Rate	Total	
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-

Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$875	$867,314	$0	$868,189	($868,189)	($868,189)
2	$0	$3,270	$1,667	$4,938	$4,938	$40,000	$893	$0	$0	$40,893	($35,955)	($904,144)
3	$0	$3,336	$1,667	$5,003	$9,941	$40,800	$910	$0	$0	$41,710	($36,707)	($940,851)
4	$0	$3,403	$1,667	$5,070	$15,011	$41,616	$929	$0	$0	$42,545	($37,475)	($978,325)
5	$0	$3,471	$1,667	$5,138	$20,149	$42,448	$947	$0	$0	$43,395	($38,257)	($1,016,582)
6	$0	$3,540	$1,667	$5,208	$25,357	$43,297	$966	$0	$0	$44,263	($39,056)	($1,055,638)
7	$0	$3,611	$1,667	$5,278	$30,635	$44,163	$985	$0	$0	$45,149	($39,870)	($1,095,509)
8	$0	$3,683	$1,667	$5,351	$35,986	$45,046	$1,005	$0	$0	$46,052	($40,701)	($1,136,210)
9	$0	$3,757	$1,667	$5,424	$41,410	$45,947	$1,025	$0	$0	$46,973	($41,548)	($1,177,758)
10	$0	$3,832	$1,667	$5,499	$46,909	$46,866	$1,046	$0	$0	$47,912	($42,413)	($1,220,171)
11	$0	$3,908	$1,297	$5,205	$52,115	$47,804	$1,067	$0	$0	$48,870	($43,665)	($1,263,836)
12	$0	$3,987	$1,297	$5,284	$57,398	$48,760	$1,088	$0	$0	$49,848	($44,564)	($1,308,400)
13	$0	$4,066	$1,297	$5,363	$62,762	$49,735	$1,110	$0	$0	$50,845	($45,481)	($1,353,881)
14	$0	$4,148	$1,297	$5,445	$68,206	$50,730	$1,132	$0	$0	$51,862	($46,417)	($1,400,298)
15	$0	$4,231	$1,297	$5,528	$73,734	$51,744	$1,155	$0	$0	$52,899	($47,371)	($1,447,669)
16	$0	$4,315	$1,297	$5,612	$79,346	$52,779	$1,178	$0	$0	$53,957	($48,345)	($1,496,014)
17	$0	$4,402	$1,297	$5,699	$85,045	$53,835	$1,201	$0	$0	$55,036	($49,337)	($1,545,351)
18	$0	$4,490	$1,297	$5,787	$90,831	$54,911	$1,225	$0	$0	$56,137	($50,350)	($1,595,701)
19	$0	$4,579	$1,297	$5,876	$96,707	$56,010	$1,250	$0	$0	$57,259	($51,383)	($1,647,084)
20	$0	$4,671	$1,297	$5,968	$102,675	$57,130	$1,275	$0	$0	$58,405	($52,437)	($1,441,443)

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**RRB 600**				Annual Use:	3,627,800	kWh	
Turbine size (kW)		600	Tower Height	63 meters		Avg. Rate	Total	
Capacity Factor		7.6%	Average Wind Speed	4.9 m/s	Customer Service	10.00000	$	10.00
Annual Energy Production (kWh)		359,510	Project Term	20 years	**Distribution (first 2,000)**	**0.03545**	$	-
Annual Town Energy Use (kWh/yr)		3,627,800	Financing:	Equity	**Distribution (> 2,000)**	**0.05317**		
Value of Retail Off Set (kWh)		$ 0.1237	Energy Inflation	2%	**Transition**	**0.00197**	$	-
Net Metering Credit		$ 0.0883	General Inflation	2%	**Transmission**	**0.01629**	$	-
REC value (kWh)	Y1-Y10	$ 0.045	Discount Rate	4.0%	**Energy**	**0.07000**	$	-
REC value (kWh)	Y11-Y20	$ 0.035	Project Cost (with Grant)	$1,551,217	Renewable Energy	0.00050	$	-
Coincidence		100.0%	Simple Payback	83.61 years	Energy Conservation	0.00660	$	-
O&M ($/kW)		$40	Residual Value	$467,929				
NPV	($1,063,202)							
Net Cash Flow	($762,852)				**Estimated Value of Retail Offset**	**0.12371**	Nat Grid G-1	
Present Value Benefit	$868,837				**Estimated Value of Net Metering Credit**	**0.08826**	Nat Grid G-1	
Present Value Cost	$1,932,039				**Estimated Wholesale Electric Supply**	**0.03694**	LMP on 9/27/12	
Benefit Cost Ratio	0.45							
Internal Rate of Return	-4.2%							

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$5,250	$1,551,217	$0	$1,556,467	($1,556,467)	($1,556,467)
2	$0	$31,730	$16,178	$47,908	$47,908	$40,000	$5,355	$0	$0	$45,355	$2,553	($1,553,914)
3	$0	$32,365	$16,178	$48,543	$96,451	$40,800	$5,462	$0	$0	$46,262	$2,281	($1,551,633)
4	$0	$33,012	$16,178	$49,190	$145,642	$41,616	$5,571	$0	$0	$47,187	$2,003	($1,549,630)
5	$0	$33,673	$16,178	$49,851	$195,492	$42,448	$5,683	$0	$0	$48,131	$1,719	($1,547,910)
6	$0	$34,346	$16,178	$50,524	$246,016	$43,297	$5,796	$0	$0	$49,094	$1,430	($1,546,480)
7	$0	$35,033	$16,178	$51,211	$297,227	$44,163	$5,912	$0	$0	$50,076	$1,135	($1,545,345)
8	$0	$35,734	$16,178	$51,912	$349,138	$45,046	$6,031	$0	$0	$51,077	$834	($1,544,510)
9	$0	$36,448	$16,178	$52,626	$401,765	$45,947	$6,151	$0	$0	$52,099	$528	($1,543,983)
10	$0	$37,177	$16,178	$53,355	$455,120	$46,866	$6,274	$0	$0	$53,141	$215	($1,543,768)
11	$0	$37,921	$12,583	$50,504	$505,623	$47,804	$6,400	$0	$0	$54,203	($3,700)	($1,547,468)
12	$0	$38,679	$12,583	$51,262	$556,886	$48,760	$6,528	$0	$0	$55,287	($4,025)	($1,551,494)
13	$0	$39,453	$12,583	$52,036	$608,921	$49,735	$6,658	$0	$0	$56,393	($4,358)	($1,555,851)
14	$0	$40,242	$12,583	$52,825	$661,746	$50,730	$6,791	$0	$0	$57,521	($4,696)	($1,560,548)
15	$0	$41,047	$12,583	$53,630	$715,375	$51,744	$6,927	$0	$0	$58,672	($5,042)	($1,565,590)
16	$0	$41,868	$12,583	$54,450	$769,826	$52,779	$7,066	$0	$0	$59,845	($5,395)	($1,570,984)
17	$0	$42,705	$12,583	$55,288	$825,114	$53,835	$7,207	$0	$0	$61,042	($5,754)	($1,576,738)
18	$0	$43,559	$12,583	$56,142	$881,255	$54,911	$7,351	$0	$0	$62,263	($6,121)	($1,582,859)
19	$0	$44,430	$12,583	$57,013	$938,268	$56,010	$7,498	$0	$0	$63,508	($6,495)	($1,589,354)
20	$0	$45,319	$12,583	$57,902	$996,170	$57,130	$7,648	$0	$0	$64,778	($6,876)	($1,128,301)

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**GE 1.5 XLE**		
Turbine size (kW)			1500
Capacity Factor			8.6%
Annual Energy Production (kWh)			1,017,036
Annual Town Energy Use (kWh/yr)			3,627,800
Value of Retail Off Set (kWh)		$	0.1237
Net Metering Credit		$	0.0883
REC value (kWh)	Y1-Y10	$	0.045
REC value (kWh)	Y11-Y20	$	0.035
Coincidence			100.0%
O&M ($/kW)			$40
NPV	($2,657,399)		
Net Cash Flow	($2,075,357)		
Present Value Benefit	$2,151,033		
Present Value Cost	$4,808,432		
Benefit Cost Ratio	0.45		
Internal Rate of Return	-5.3%		

Tower Height	80	meters
Average Wind Speed	5.2	m/s
Project Term	20	years
Financing:	Equity	
Energy Inflation	2%	
General Inflation	2%	
Discount Rate	4.0%	
Project Cost (with Grant)	$3,855,511	
Simple Payback	62.04	years
Residual Value	$651,378	

Annual Use:	3,627,800	kWh	
	Avg. Rate	Total	
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-

Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$13,125	$3,855,511	$0	$3,868,636	($3,868,636)	($3,868,636)
2	$0	$89,764	$45,767	$135,530	$135,530	$40,000	$13,388	$0	$0	$53,388	$82,143	($3,786,493)
3	$0	$91,559	$45,767	$137,325	$272,856	$40,800	$13,655	$0	$0	$54,455	$82,870	($3,703,623)
4	$0	$93,390	$45,767	$139,157	$412,012	$41,616	$13,928	$0	$0	$55,544	$83,612	($3,620,011)
5	$0	$95,258	$45,767	$141,024	$553,037	$42,448	$14,207	$0	$0	$56,655	$84,369	($3,535,642)
6	$0	$97,163	$45,767	$142,930	$695,966	$43,297	$14,491	$0	$0	$57,788	$85,141	($3,450,500)
7	$0	$99,106	$45,767	$144,873	$840,839	$44,163	$14,781	$0	$0	$58,944	$85,929	($3,364,571)
8	$0	$101,088	$45,767	$146,855	$987,694	$45,046	$15,076	$0	$0	$60,123	$86,732	($3,277,839)
9	$0	$103,110	$45,767	$148,877	$1,136,571	$45,947	$15,378	$0	$0	$61,325	$87,551	($3,190,288)
10	$0	$105,172	$45,767	$150,939	$1,287,510	$46,866	$15,686	$0	$0	$62,552	$88,387	($3,101,901)
11	$0	$107,276	$35,596	$142,872	$1,430,382	$47,804	$15,999	$0	$0	$63,803	$79,069	($3,022,832)
12	$0	$109,421	$35,596	$145,018	$1,575,400	$48,760	$16,319	$0	$0	$65,079	$79,939	($2,942,894)
13	$0	$111,610	$35,596	$147,206	$1,722,606	$49,735	$16,646	$0	$0	$66,381	$80,825	($2,862,068)
14	$0	$113,842	$35,596	$149,438	$1,872,044	$50,730	$16,979	$0	$0	$67,708	$81,730	($2,780,338)
15	$0	$116,119	$35,596	$151,715	$2,023,759	$51,744	$17,318	$0	$0	$69,062	$82,653	($2,697,686)
16	$0	$118,441	$35,596	$154,037	$2,177,796	$52,779	$17,665	$0	$0	$70,444	$83,594	($2,614,092)
17	$0	$120,810	$35,596	$156,406	$2,334,203	$53,835	$18,018	$0	$0	$71,853	$84,554	($2,529,538)
18	$0	$123,226	$35,596	$158,822	$2,493,025	$54,911	$18,378	$0	$0	$73,290	$85,533	($2,444,005)
19	$0	$125,691	$35,596	$161,287	$2,654,312	$56,010	$18,746	$0	$0	$74,755	$86,532	($2,357,474)
20	$0	$128,205	$35,596	$163,801	$2,818,113	$57,130	$19,121	$0	$0	$76,250	$87,550	($1,618,546)

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**GE 1.5 SLE**		
Turbine size (kW)			1500
Capacity Factor			6.8%
Annual Energy Production (kWh)			804,168
Annual Town Energy Use (kWh/yr)			3,627,800
Value of Retail Off Set (kWh)		$	0.1237
Net Metering Credit		$	0.0883
REC value (kWh)	Y1-Y10	$	0.045
REC value (kWh)	Y11-Y20	$	0.035
Coincidence			100.0%
O&M ($/kW)			$40
NPV	($1,458,855)		
Net Cash Flow	($1,015,194)		
Present Value Benefit	$1,763,038		
Present Value Cost	$3,221,893		
Benefit Cost Ratio	0.55		
Internal Rate of Return	-3.9%		

Tower Height	80	meters
Average Wind Speed	5.2	m/s
Project Term	20	years
Financing:	Equity	
Energy Inflation	2%	
General Inflation	2%	
Discount Rate	4.0%	
Project Cost (with Grant)	$2,205,511	
Simple Payback	65.30	years
Residual Value	$651,378	

Annual Use:	3,627,800	kWh	
	Avg. Rate	Total	
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-

Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$13,125	$2,205,511	$0	$2,218,636	($2,218,636)	($2,218,636)
2	$0	$70,976	$36,188	$107,163	$107,163	$40,000	$13,388	$0	$0	$53,388	$53,776	($2,164,860)
3	$0	$72,395	$36,188	$108,583	$215,746	$40,800	$13,655	$0	$0	$54,455	$54,128	($2,110,732)
4	$0	$73,843	$36,188	$110,031	$325,777	$41,616	$13,928	$0	$0	$55,544	$54,486	($2,056,246)
5	$0	$75,320	$36,188	$111,508	$437,285	$42,448	$14,207	$0	$0	$56,655	$54,852	($2,001,393)
6	$0	$76,827	$36,188	$113,014	$550,299	$43,297	$14,491	$0	$0	$57,788	$55,226	($1,946,168)
7	$0	$78,363	$36,188	$114,551	$664,850	$44,163	$14,781	$0	$0	$58,944	$55,607	($1,890,561)
8	$0	$79,930	$36,188	$116,118	$780,968	$45,046	$15,076	$0	$0	$60,123	$55,995	($1,834,566)
9	$0	$81,529	$36,188	$117,717	$898,684	$45,947	$15,378	$0	$0	$61,325	$56,391	($1,778,175)
10	$0	$83,160	$36,188	$119,347	$1,018,031	$46,866	$15,686	$0	$0	$62,552	$56,795	($1,721,380)
11	$0	$84,823	$28,146	$112,969	$1,131,000	$47,804	$15,999	$0	$0	$63,803	$49,166	($1,672,214)
12	$0	$86,519	$28,146	$114,665	$1,245,665	$48,760	$16,319	$0	$0	$65,079	$49,586	($1,622,628)
13	$0	$88,250	$28,146	$116,395	$1,362,060	$49,735	$16,646	$0	$0	$66,381	$50,015	($1,572,614)
14	$0	$90,015	$28,146	$118,160	$1,480,221	$50,730	$16,979	$0	$0	$67,708	$50,452	($1,522,161)
15	$0	$91,815	$28,146	$119,961	$1,600,182	$51,744	$17,318	$0	$0	$69,062	$50,898	($1,471,263)
16	$0	$93,651	$28,146	$121,797	$1,721,979	$52,779	$17,665	$0	$0	$70,444	$51,353	($1,419,910)
17	$0	$95,524	$28,146	$123,670	$1,845,649	$53,835	$18,018	$0	$0	$71,853	$51,818	($1,368,092)
18	$0	$97,435	$28,146	$125,581	$1,971,229	$54,911	$18,378	$0	$0	$73,290	$52,291	($1,315,801)
19	$0	$99,383	$28,146	$127,529	$2,098,758	$56,010	$18,746	$0	$0	$74,755	$52,774	($1,263,027)
20	$0	$101,371	$28,146	$129,517	$2,228,275	$57,130	$19,121	$0	$0	$76,250	$53,266	($558,383)

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**Vestas V90**				
Turbine size (kW)		1800	Tower Height	80	meters
Capacity Factor		10.8%	Average Wind Speed	5.2	m/s
Annual Energy Production (kWh)		1,532,650	Project Term	20	years
Annual Town Energy Use (kWh/yr)		3,627,800	Financing:	Equity	
Value of Retail Off Set (kWh)		$ 0.1237	Energy Inflation	2%	
Net Metering Credit		$ 0.0883	General Inflation	2%	
REC value (kWh)	Y1-Y10	$ 0.045	Discount Rate	4.0%	
REC value (kWh)	Y11-Y20	$ 0.035	Project Cost (with Grant)	$4,158,006	
Coincidence		100.0%	Simple Payback	35.79	years
O&M ($/kW)		$40	Residual Value	$651,378	
NPV	($2,228,692)				
Net Cash Flow	($1,287,001)				
Present Value Benefit	$3,090,842				
Present Value Cost	$5,319,534				
Benefit Cost Ratio	0.58				
Internal Rate of Return	-2.9%				

Annual Use:	3,627,800	kWh	
	Avg. Rate		Total
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-

Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$15,750	$4,158,006	$0	$4,173,756	($4,173,756)	($4,173,756)
2	$0	$135,272	$68,969	$204,241	$204,241	$40,000	$16,065	$0	$0	$56,065	$148,176	($4,025,580)
3	$0	$137,977	$68,969	$206,946	$411,187	$40,800	$16,386	$0	$0	$57,186	$149,760	($3,875,820)
4	$0	$140,737	$68,969	$209,706	$620,893	$41,616	$16,714	$0	$0	$58,330	$151,376	($3,724,444)
5	$0	$143,551	$68,969	$212,521	$833,414	$42,448	$17,048	$0	$0	$59,497	$153,024	($3,571,420)
6	$0	$146,422	$68,969	$215,392	$1,048,805	$43,297	$17,389	$0	$0	$60,687	$154,705	($3,416,715)
7	$0	$149,351	$68,969	$218,320	$1,267,125	$44,163	$17,737	$0	$0	$61,900	$156,420	($3,260,295)
8	$0	$152,338	$68,969	$221,307	$1,488,432	$45,046	$18,092	$0	$0	$63,138	$158,169	($3,102,127)
9	$0	$155,385	$68,969	$224,354	$1,712,786	$45,947	$18,454	$0	$0	$64,401	$159,953	($2,942,174)
10	$0	$158,492	$68,969	$227,462	$1,940,248	$46,866	$18,823	$0	$0	$65,689	$161,772	($2,780,401)
11	$0	$161,662	$53,643	$215,305	$2,155,553	$47,804	$19,199	$0	$0	$67,003	$148,302	($2,632,099)
12	$0	$164,895	$53,643	$218,538	$2,374,091	$48,760	$19,583	$0	$0	$68,343	$150,195	($2,481,904)
13	$0	$168,193	$53,643	$221,836	$2,595,927	$49,735	$19,975	$0	$0	$69,710	$152,126	($2,329,778)
14	$0	$171,557	$53,643	$225,200	$2,821,127	$50,730	$20,374	$0	$0	$71,104	$154,096	($2,175,682)
15	$0	$174,988	$53,643	$228,631	$3,049,758	$51,744	$20,782	$0	$0	$72,526	$156,105	($2,019,577)
16	$0	$178,488	$53,643	$232,131	$3,281,889	$52,779	$21,197	$0	$0	$73,977	$158,154	($1,861,423)
17	$0	$182,058	$53,643	$235,701	$3,517,589	$53,835	$21,621	$0	$0	$75,456	$160,244	($1,701,178)
18	$0	$185,699	$53,643	$239,342	$3,756,931	$54,911	$22,054	$0	$0	$76,965	$162,376	($1,538,802)
19	$0	$189,413	$53,643	$243,056	$3,999,987	$56,010	$22,495	$0	$0	$78,505	$164,551	($1,374,251)
20	$0	$193,201	$53,643	$246,844	$4,246,831	$57,130	$22,945	$0	$0	$80,075	$166,769	($556,104)

Wind Turbine Project Pro Forma
Town of Millbury, MA

Wind Turbine	**Vestas V90**		
Turbine size (kW)			1800
Capacity Factor			10.8%
Annual Energy Production (kWh)			1,532,650
Annual Town Energy Use (kWh/yr)			3,627,800
Value of Retail Off Set (kWh)		$	0.1237
Net Metering Credit		$	0.0883
REC value (kWh)	Y1-Y10	$	0.045
REC value (kWh)	Y11-Y20	$	0.035
Coincidence			100.0%
O&M ($/kW)			$40
NPV	($1,686,493)		
Net Cash Flow	($2,214,795)		
Present Value Benefit	$3,090,842		
Present Value Cost	$4,777,335		
Benefit Cost Ratio	0.65		
Internal Rate of Return	#NUM!		

Tower Height	80	meters
Average Wind Speed	5.2	m/s
Project Term	20	years
Financing:	2%	Bond/Loan
Energy Inflation	2%	
General Inflation	2%	
Discount Rate	4.0%	
Project Cost (with Grant)	$4,158,006	
Simple Payback	(30.11)	years
Residual Value	$651,378	

Annual Use:	3,627,800	kWh	
	Avg. Rate	Total	
Customer Service	10.00000	$	10.00
Distribution (first 2,000)	**0.03545**	$	-
Distribution (> 2,000)	**0.05317**		
Transition	**0.00197**	$	-
Transmission	**0.01629**	$	-
Energy	**0.07000**	$	-
Renewable Energy	0.00050	$	-
Energy Conservation	0.00660	$	-

Estimated Value of Retail Offset	**0.12371**	Nat Grid G-1
Estimated Value of Net Metering Credit	**0.08826**	Nat Grid G-1
Estimated Wholesale Electric Supply	**0.03694**	LMP on 9/27/12

Year	Retail Offset	Net Metering Credit	RECs Revenue	Total Annual Revenue	Cummulative Revenue	Annual O&M	Annual Insurance	Annual Principal	Annual Interest	Total Annual Cost	Net Annual Cash Flow	Cummulative Cash Flow
1	$0	$0	$0	$0	$0	$0	$15,750	$171,130	$83,160	$270,040	($270,040)	($270,040)
2	$0	$135,272	$68,969	$204,241	$204,241	$40,000	$16,065	$174,552	$79,738	$310,355	($106,114)	($376,154)
3	$0	$137,977	$68,969	$206,946	$411,187	$40,800	$16,386	$178,044	$76,246	$311,476	($104,530)	($480,684)
4	$0	$140,737	$68,969	$209,706	$620,893	$41,616	$16,714	$181,604	$72,686	$312,620	($102,914)	($583,598)
5	$0	$143,551	$68,969	$212,521	$833,414	$42,448	$17,048	$185,236	$69,054	$313,787	($101,266)	($684,864)
6	$0	$146,422	$68,969	$215,392	$1,048,805	$43,297	$17,389	$188,941	$65,349	$314,977	($99,585)	($784,449)
7	$0	$149,351	$68,969	$218,320	$1,267,125	$44,163	$17,737	$192,720	$61,570	$316,190	($97,870)	($882,319)
8	$0	$152,338	$68,969	$221,307	$1,488,432	$45,046	$18,092	$196,574	$57,716	$317,428	($96,121)	($978,441)
9	$0	$155,385	$68,969	$224,354	$1,712,786	$45,947	$18,454	$200,506	$53,784	$318,691	($94,337)	($1,072,778)
10	$0	$158,492	$68,969	$227,462	$1,940,248	$46,866	$18,823	$204,516	$49,774	$319,979	($92,518)	($1,165,295)
11	$0	$161,662	$53,643	$215,305	$2,155,553	$47,804	$19,199	$208,606	$45,684	$321,293	($105,988)	($1,271,283)
12	$0	$164,895	$53,643	$218,538	$2,374,091	$48,760	$19,583	$212,778	$41,512	$322,633	($104,095)	($1,375,378)
13	$0	$168,193	$53,643	$221,836	$2,595,927	$49,735	$19,975	$217,034	$37,256	$324,000	($102,164)	($1,477,542)
14	$0	$171,557	$53,643	$225,200	$2,821,127	$50,730	$20,374	$221,375	$32,915	$325,394	($100,194)	($1,577,736)
15	$0	$174,988	$53,643	$228,631	$3,049,758	$51,744	$20,782	$225,802	$28,488	$326,816	($98,185)	($1,675,921)
16	$0	$178,488	$53,643	$232,131	$3,281,889	$52,779	$21,197	$230,318	$23,972	$328,267	($96,136)	($1,772,057)
17	$0	$182,058	$53,643	$235,701	$3,517,589	$53,835	$21,621	$234,925	$19,365	$329,746	($94,046)	($1,866,102)
18	$0	$185,699	$53,643	$239,342	$3,756,931	$54,911	$22,054	$239,623	$14,667	$331,255	($91,914)	($1,958,016)
19	$0	$189,413	$53,643	$243,056	$3,999,987	$56,010	$22,495	$244,416	$9,874	$332,795	($89,739)	($2,047,755)
20	$0	$193,201	$53,643	$246,844	$4,246,831	$57,130	$22,945	$249,304	$4,986	$334,365	($87,521)	($1,483,898)

Appendix K

FINAL Millbury Wind Turbine Noise Study

Millbury Wind Turbine Noise Study

Final Report

Millbury, Massachusetts

HMMH Report No. 304640
December 2010

Prepared for:

Weston & Sampson Engineers, Inc.
5 Centennial Drive
Peabody, MA 01960

Millbury Wind Turbine Noise Study

Final Report

Millbury, Massachusetts

HMMH Report No. 304640
December 2010

Prepared for:

Weston & Sampson Engineers, Inc.
5 Centennial Drive
Peabody, MA 01960

Prepared by:

Michael Carr
Christopher Menge
James Ferguson III

HARRIS MILLER MILLER & HANSON INC.

Harris Miller Miller & Hanson Inc.
77 South Bedford Street
Burlington, MA 01803
T 781.229.0707
F 781.229.7939

Executive Summary

The Town of Millbury Massachusetts proposes to develop a utility scale wind energy project on land it owns within the Millbury town limits. The Project being considered is proposed to entail the installation of one utility-scale wind turbine with a nameplate capacity of 1.8 MW. The Project is proposed to be located on the town-owned Butler Farm property at 44 Singletary Road in Millbury, MA. Butler Farm is a 50-acre site containing a meadow, the vestiges of an orchard, forest and wooded areas along with the single-family house that was converted for use as office space and a meeting facility. Collocated on the property is a wireless facility for use by the fire department, which is powered using solar energy.

Harris Miller Miller & Hanson Inc. (HMMH) has completed a noise study for a proposed Millbury Wind project. In this report, HMMH has reviewed applicable noise standards and criteria, presented the data collection program associated with the ambient noise environment, described the modeling used to project noise emissions from the selected wind turbine, and analyzed all of this information to assess potential noise impacts from the project.

Based on this study, we conclude the following:

- Under most turbine operating conditions, increases in existing ambient noise caused by the turbine will be well below the Massachusetts Department of Environmental Protection (DEP) noise guideline of 10 dBA increases in broadband noise levels.
- During the quietest nighttime hours with hub-height wind speeds of approximately 7 m/s, the proposed Millbury Wind project is predicted to exceed the 10 dBA MassDEP guideline at the nearby occupied structure on the Butler Farm property east of the proposed turbine site.
- No residential properties will be exposed to increases in existing noise levels greater than 10 dBA, but projected worst-case increases equal 10 dBA at the nearest homes during the quietest nighttime hours when hub wind speeds are approximately 7 m/s. However, at hub wind speeds less or greater than 7 m/s, the sound-level increases will be less, because of decreasing turbine noise emissions at lower speeds and increasing background noise at higher speeds.
- The Project is in compliance with the MassDEP noise guideline for a pure tone condition.
- The Town of Millbury noise limits will not be exceeded in any of the nearby noise-sensitive areas.

During quiet nighttime periods when winds are low near the ground but sufficient for the turbine to operate, sound from the turbine will be audible and noticeable to some in the nearest surrounding residential areas.

Contents

Figures

Tables

1 Introduction

The Town of Millbury Massachusetts proposes to develop a utility scale wind energy project on land it owns within the Millbury town limits. The Project being considered is proposed to entail the installation of one utility-scale wind turbine with a nameplate capacity of 1.8 MW. The Project is proposed to be located on the town-owned Butler Farm property at 44 Singletary Road in Millbury, MA. Butler Farm is a 50-acre site containing a meadow, the vestiges of an orchard, forest and wooded areas along with the single-family house that was converted for use as office space and a meeting facility. Also on the property is a wireless facility for use by the fire department, which is powered with solar energy.

Harris Miller Miller & Hanson Inc. (HMMH) was retained by Weston & Sampson Engineers Inc. to perform a noise assessment for the proposed wind energy project. This report reviews applicable noise standards and criteria, summarizes the results of the noise and wind measurement program, describes the modeling used to predict noise emissions from the selected wind turbine, and assess potential noise impacts associated with project. Appendix A provides a description of the various noise metrics used in this report.

2 Noise Standards and Criteria

Applicable noise standards for the proposed wind turbine are the Town of Millbury Zoning Ordinance, and the Massachusetts Department of Environmental Protection (MassDEP) noise guidelines.

Article 4, Section 50.7 of the Town of Millbury Zoning Ordinance presents design standards and siting requirements applicable to “small wind turbines.” The Section definitions do not outline what qualifies as a “Small Wind Turbine” and there are no other ordinances or regulations for wind turbine installations that are not “Small.” As such, the ordinance is summarized in this report for reference purposes. The Noise section of the Town of Millbury Zoning Ordinance requires that wind turbine and associated equipment conform to the Massachusetts DEP noise regulations. Additionally, wind turbine noise levels cannot exceed 70 dBA, except during short-term events.

The Code of Massachusetts Regulations (Title 310, Section 7.10, amended September 1, 1972) empowers the Division of Air Quality Control (DAQC) of the Massachusetts DEP to enforce its noise standards. According to DAQC Policy 90-001 (February 1, 1990), a source of sound will be considered to be violating the Department’s noise regulation if the source (1) increases the broadband sound level by more than 10 dBA above ambient, or (2) produces a “pure tone condition,” when any octave-band center frequency sound pressure level exceeds the two adjacent frequency sound pressure levels by 3 decibels or more. Ambient is defined as the background A-weighted sound level that is exceeded 90 percent of the time (i.e. L90) measured during equipment operating hours.

The Massachusetts DEP provides further specification and interpretation of the noise standards and their application on the MassDEP internet site: Noise Pollution Policy Interpretation (http://www.mass.gov/dep/air/laws/noisepol.htm, accessed 5/4/2010). The MassDEP noise pollution policy is used to evaluate noise impacts at both the property boundary and the nearby noise sensitive receptor. However, source noise levels resulting in an exceedance of the MassDEP criteria does not directly result in an impact. The policy intent is to protect the residents and sensitive occupants, not necessarily neighboring areas exposed to source noise levels that are not frequented by human use.

3 Existing Ambient Noise Environment

Noise measurements of existing conditions in the project study area were conducted by Cross-Spectrum Labs of Springfield, MA under HMMH's direction and with HMMH-owned instrumentation, from November 18 through November 22, 2010. Noise measurements were performed at a total of six measurement locations in the project study area. Long-term monitoring was conducted at one location continuously from November 18 through November 22, 2010. Short-term monitoring was performed at five measurement sites on November 18 and November 21, 2010, for durations of 20 to 30 minutes at each site.

Noise measurements were performed using Bruel & Kjaer Type 2250 Type 1 "precision" sound level meters/noise analyzers owned by HMMH. Field calibrations with acoustic calibrators were conducted before and after the measurements. All instrumentation components, including microphones, preamplifiers and field calibrators have current laboratory certified calibrations traceable to the National Institute of Standards and Technology.

Noise measurement sites were chosen to represent nearby noise-sensitive receptors and residential areas, which would potentially have the most significant noise impacts from operations of the proposed wind energy project. Figure 1 shows the locations of each of the noise measurement sites on an aerial photograph of the study area, with the proposed wind turbine location shown for context. On the figure, the long-term noise measurement site is represented as LT-1 and the short-term measurement sites are represented as ST-1 through ST-4. Microphones were located 5 ft above the ground, an average height for a person standing.

The sections below separately report the results at the short-term and long-term measurement locations.

H:\GIS\USA\MA\304640_Millbury_Wind\304640_Millbury_Figure_1_Noise_Monitor_Locations.mxd

- Proposed Wind Turbine Location
- Noise Monitor & Prediction Location
- Parcel Boundary
- Municipal Boundary

Millbury Wind Turbine Noise Study

Millbury, Massachusetts

Figure 1
Noise Monitoring Location Map

Source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Energy and Environmental Affairs

HARRIS MILLER MILLER & HANSON INC.

3.1 Short-term Noise Measurements

Table 1 provides a summary of the measured noise levels at the short-term sites; several standard descriptors of the time-varying A-weighted noise level are shown in the table. These descriptors include Leq, which is the average sound level with equivalent sound energy as a continuous sound at that level and the Lmax, which is the maximum sound level that occurred during the measurement period. Common statistical descriptors presented include the L33, which is the sound level exceeded 1/3 of the time, and the L90, which is the sound level exceeded 90 percent of the time and represents the background sound level. Appendix A provides a description of the various noise metrics used in this report.

Table 1 Noise Measurement Results at Short-term Sites

Site Name	Address	Start Time	Duration	A-weighted sound level metrics (dBA)			
				Leq	Lmax	L33	L90
Daytime							
ST-1	12 Singletary Rd	11/18/2010 2:10 pm	30	60	76	49	39
ST-2	34 Singletary Rd	11/18/2010 3:40 pm	10	47	60	45	40
ST-2	34 Singletary Rd	11/22/2010 9:50 am	30	53	68	45	36
ST-3	18 Singletary Rd	11/22/2010 10:30 am	30	45	54	40	36
ST-3a	20 Singletary Rd	11/18/2010 10:20 am	30	58	74	46	38
ST-4	29 McGrath Rd	11/18/2010 11:20 am	30	54	69	46	38
Nighttime							
ST-1	12 Singletary Rd	11/20/2010 11:30 pm	20	53	67	37	33
ST-2	34 Singletary Rd	11/21/2010 12:10 am	20	44	59	33	29
ST-3	18 Singletary Rd	11/21/2010 1:40 am	20	38	41	33	31
ST-4	29 McGrath Rd	11/21/2010 2:20 am	20	37	38	32	31

During the short-term measurements, the table shows that average (Leq) daytime noise levels ranged from approximately 45 to 60 dBA in the study area and from 37 to 53 dBA in late night hours. Background L90 noise levels ranged from 36 to 40 dBA during the day and from 29 to 33 dBA at night. The primary contributions to the ambient noise level in the project area observed during the attended short-term measurement periods were from local traffic, aircraft flyovers, and wind in foliage. Nighttime measurements were conducted between 11:30 p.m. and 3 a.m. because the data from the long-term site (see below) showed those time periods to be the quietest times of the night.

3.2 Long-term Noise Measurements

As noted above and shown in Figure 1, long-term noise monitoring was conducted at a noise-sensitive residential location near the proposed wind energy facility. The noise measurements at long-term site LT-1 spanned from the morning of Thursday, November 18 through late Tuesday morning, November 22, 2010. Weather during the measurement period was good, with clear skies and calm to light winds. Temperatures ranged from the high 20s to the low 50s, with an average temperature of 39º F. No precipitation was experienced during the measurement period. Figure 2 presents a graph of measured sound levels in 10-minute intervals at site LT-1, showing the noise level descriptors Leq, Lmax, L1, L33 and L90. As mentioned, to ensure the validity of the collected measurement data the sound level meter was field calibrated prior to and at the conclusion of the measurement.

The graph in Figure 2 shows that during the daytime periods, typical Leq sound levels varied from approximately 32 to 57 dBA. During nighttime periods, typical Leq sound levels at LT-1 ranged from 31 to 46 dBA. The L90 background values varied from about 30 to 46 dBA during the day and 28 to 41 dBA at night. It is notable that the quietest portions of the nighttime periods during the monitoring occurred approximately between 11:30 AM and 3:00 AM; during those periods background L90 sound levels ranged from 28 to 36 dBA.

All noise measurements were conducted with the instruments' interval duration set to 10 minutes. This is the approach HMMH has developed for wind noise studies, since anemometer data is typically reported in 10-minute intervals. The correlation between wind speed and background noise levels is important because wind turbines do not operate or generate noise when winds are calm; furthermore, calm-wind conditions most commonly result in the lowest ambient background noise environments. To characterize the wind speeds during our measurements of the background noise level, HMMH conducted concurrent wind data collection with an anemometer near the LT-1 measurement site for the duration of the measurement period. For purposes of comparison with the operation of the proposed wind turbine, the measured wind speeds have been adjusted to those expected at the hub height of 80m. This adjustment is based on a wind shear exponent of 0.248 for the Butler Farm site, which results in a multiplier of 2.69 for wind speeds measured at HMMH's 1.5m high anemometer. The graph in Figure 3 shows the measured background L90 sound levels along with the simultaneous hub height wind speed at site LT-1, as 10-min averages.

Figure 2 Long-Term Noise Measurement Data

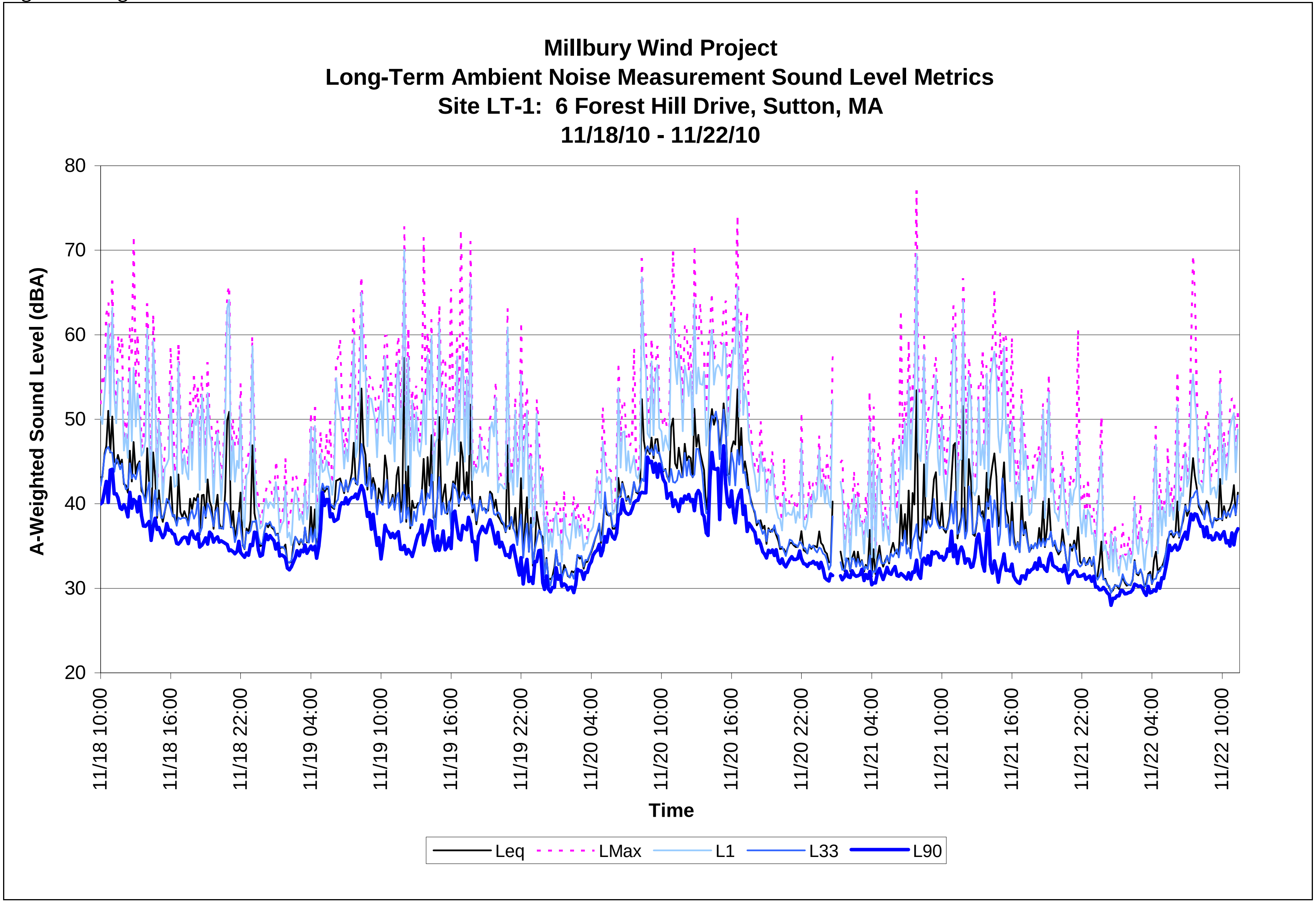
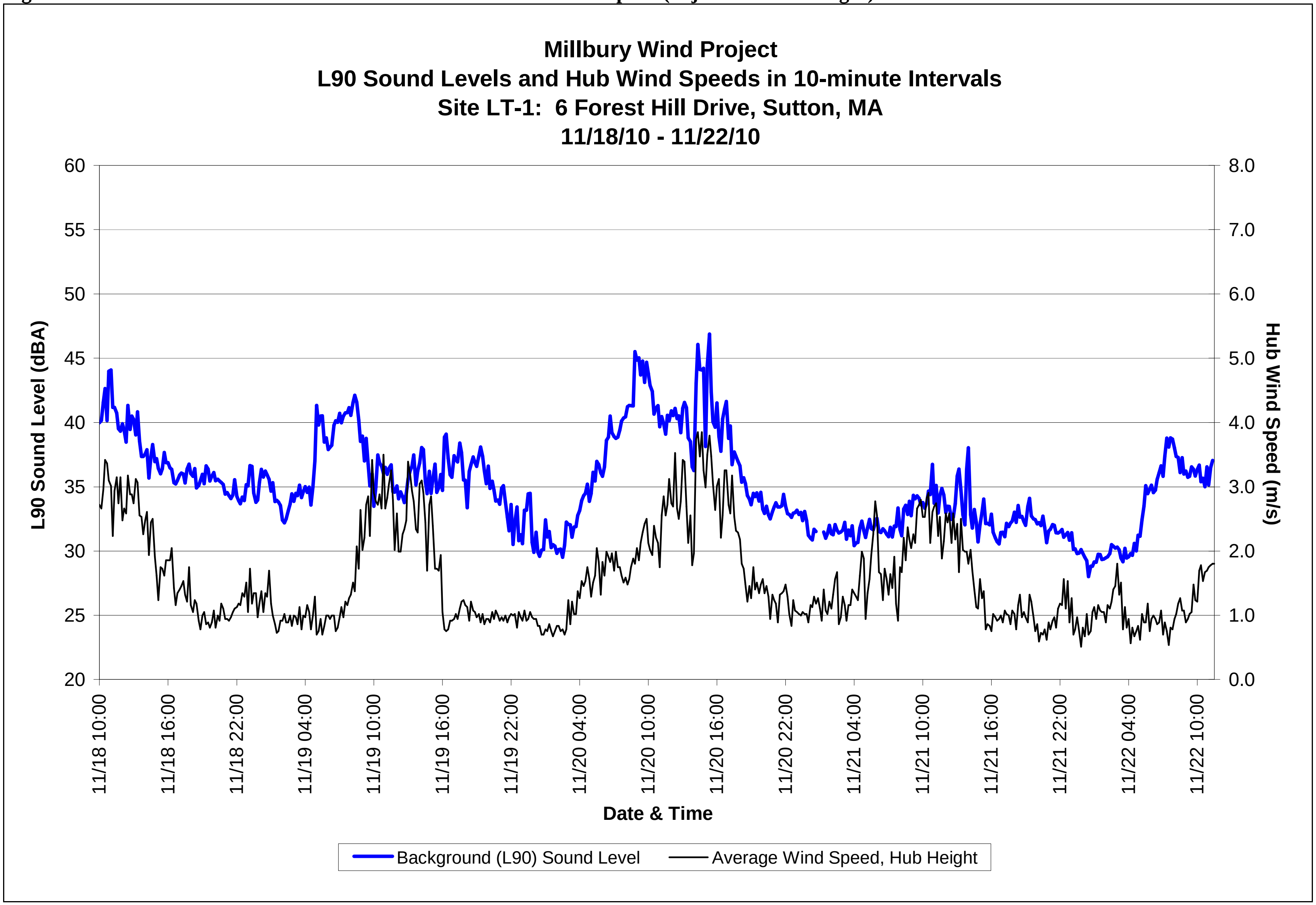


Figure 3 LT-1 Measured L90 Sound Levels and Simultaneous Wind Speed (adjusted to hub height)



3.3 Characterization of Nighttime Background Noise

Nighttime background noise level data within the study area was collected at long-term measurement site LT-1 from November 18 through November 22, 2010 and at short-term measurement sites ST-1 through ST-4 during the early morning hours of November 21, 2010. Significantly more data was acquired at long-term site LT-1 than at the short-term sites. This was due inherently to the longer duration of the measurement period at the long-term measurement location. In reviewing the nighttime L90 background sound levels collected during the measurement period, background noise levels appear to be least influenced by man-made noise sources during the time period from 11:30 PM to 3:00 AM. Noise levels during the overnight period of November 18, 2010 appear to be uncharacteristically elevated, and therefore, to provide a conservative characterization of the nighttime background levels, are not included in this portion of the analysis. Therefore, the nighttime sound level data collected during the overnight measurement periods from November 19 through November 21 2010, and short-term measurements from November 21, 2010 were used to characterize nighttime background noise levels throughout the project study area.

Observations made during attended nighttime noise measurements at the project site indicate that nighttime background noise levels in the study area were influenced primarily by wind blowing through foliage and across terrain features, and distant regional traffic noise. The study area surrounding the project site is fairly homogeneous, with small meadows, woodland areas surrounding the rolling landscape and wetland areas. L90 noise levels measured at the long-term and short-term monitoring locations were found to range from 28 to 34 dBA during the quietest nighttime periods at all measurement locations. Therefore it is appropriate to characterize the background noise levels experienced throughout the study area by the median of the 10-minute interval L90 noise levels measured during these quiet periods of the late night and early morning. The median of the measured L90 noise levels for all measurement sites during the 11:30 AM to 3:00 AM period was 31.5 dBA.

4 Predicted Wind Turbine Noise Levels and Impact

HMMH predicted the wind turbine noise levels in the Millbury study area using 1) reference noise emissions data and frequency spectrum information for the Vestas V90 turbine provided by the manufacturer, 2) aerial photography and digital terrain information from MassGIS, and 3) the SoundPLAN® noise prediction model.

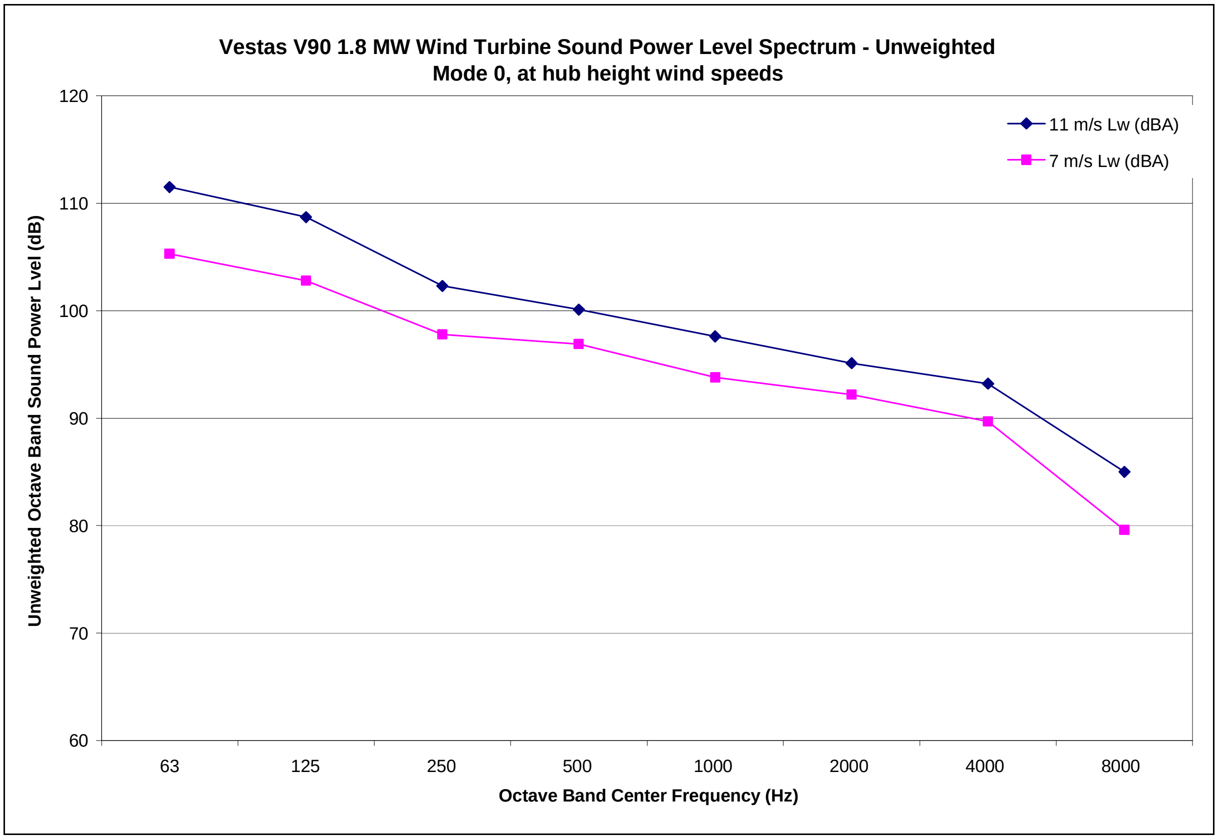
Wind turbine noise levels are evaluated for compliance with the criteria outlined in Section 2 of this report. Turbine noise levels have been assessed under two operational conditions. One is based on the maximum reference noise level generated by the proposed turbine, and the other is based on the greatest potential for increased ambient noise and therefore noise impact with respect to the MassDEP noise guidelines. For the Vestas V90 1.8MW wind turbine the maximum reference noise level output occurs when wind speeds at the hub height exceed 11 m/s[1]. The greatest potential for increasing ambient noise levels from noise generated by the proposed wind turbine would occur during periods of low background noise while maintaining wind speeds sufficient to sustain turbine power generation. For the Vestas V90 turbine, the lower wind speed limit (cut-in speed) for sustained power generation is 3.5 m/s or greater. As hub wind speeds increase above 7 m/s, background noise levels rise at a greater rate than the wind turbine noise emissions, resulting in a lower potential for impact with respect to the MassDEP guidelines. Therefore, this analysis evaluates wind turbine noise emissions at hub-height wind speed conditions of 7 m/s and 11 m/s[1].

[1] Based on hub height and 10m reference height wind speeds as presented in manufacturer reference data, Appendix B.

4.1 Pure tone evaluation

HMMH evaluated the expected frequency spectrum of sound from the proposed Vestas V90 wind turbine to determine compliance with the MassDEP pure tone guideline. Figure 4 shows a frequency plot of the *un-weighted* octave band sound power spectrum of a Vestas V90 wind turbine operating at the reference wind speed of 11 m/s at the hub height (8 m/s measured at a 10-m height), and at the 7 m/s hub height wind speed. These data are taken from Vestas' published noise testing data for the V90 turbine.[2] According to the MassDEP guidelines a sound is said to have a "pure tone component" if one octave band in the frequency spectrum is 3 dB or more higher than both adjacent octave bands. It is clear from the graphs at both wind speeds that no octave bands are higher than adjacent bands by 3 dB or more, therefore, no pure tone condition will exist, according to the MassDEP guidelines.

Figure 4 Frequency Plot of the Vestas V90 Octave Band Sound Power Spectrum



[2] "General Specification Vestas V90-1.8 MW VCUS" Vestas Wind Systems A/S, Document no.: 0004-6205 V04, October 20, 2010. The published A-weighted spectral values are *un-weighted* in the graph to enable the pure-tone evaluation.

4.2 Noise Prediction Model and Noise Source Characteristics

The SoundPLAN® computer noise model was used for computing sound levels from the proposed wind turbine throughout the surrounding community. An industry standard, SoundPLAN was developed by Braunstein + Berndt GmbH to provide estimates of sound levels at distances from specific noise sources taking into account the effects of terrain features including relative elevations of noise sources, receivers, and intervening objects (buildings, hills, trees), and ground effects due to areas of hard ground (pavement, water) and soft ground (grass, field, forest). In addition to computing sound levels at specific receiver positions, SoundPLAN can compute noise contours showing areas of equal and similar sound level.

As input, SoundPLAN incorporated a *geometric model* of the study area and reference *noise source* levels for the turbine. SoundPLAN uses a *sound propagation model* to project noise levels from the turbine into the surrounding community.

The three-dimensional geometric model of the study area was developed from aerial photography and digital terrain information (with 1-m contour intervals) provided through the MassGIS Executive Office of Energy and Environmental Affairs.

The reference noise source levels were provided by Vestas Wind Systems 1.8MW V90 turbine, in the form of octave-band *A-weighted* Sound Power Levels (LwA)[3] for the reference wind speeds of 7 m/s measured at the hub height (5 m/s at 10m height) and 11 m/s at the hub height (8 m/s at 10m). These levels are shown in Table 2 as included in the SoundPLAN noise prediction model.

Table 2 Reference Sound Power Level Spectrum for Vestas V90

Octave-band Center Frequency (Hz)	LwA reference (A-weighted)	
	7 m/s @ Hub	11 m/s @ Hub
31.5	68.5	75.3
63	79.1	85.3
125	86.7	92.6
250	89.2	93.7
500	93.7	96.9
1000	93.8	97.6
2000	93.4	96.3
4000	90.7	94.2
8000	78.5	83.9
A-weighted, total	99.8	103.5

The sound propagation model within SoundPLAN that was used for this study was ISO 9613-2.[4] This international standard propagation model is used nearly universally in the U.S. for wind turbine noise studies, due to its conservative propagation equations. ISO 9613-2 uses "worst-case" downwind propagation conditions in all directions, and accounts for variations in terrain and the effects of ground type.

[3] The Sound Power Level represents the total sound energy produced by the wind turbine under the specified operating conditions. Sound Power Levels cannot be measured directly; instead they are computed from reference sound pressure level measurements, conducted by the manufacturer.
[4] International Organization for Standardization (ISO), International Standard ISO 9613-2, "Acoustics – Attenuation of Sound during Propagation Outdoors", Part 2: General Method of Calculation, 1996-12-15.

4.3 Predicted Turbine Noise Levels in the Community

Table 3 presents the predicted Leq noise levels from the proposed Vestas V90 wind turbine at the noise measurement sites, property boundaries and additional noise-sensitive receptors in immediate vicinity of the proposed project location. The noise measurement sites are labeled as LT-1 and ST-1 through ST-4, additional noise prediction receivers at nearby noise-sensitive locations are labeled as P-01 and P-02, and property boundaries of the proposed project site are labeled as PB_01 through PB_06. Figure 5 shows all of the noise measurement and prediction locations, and graphically depicts predicted turbine noise levels in the form of noise contours on an aerial photograph of the study area.

The noise level predictions in this section are based on the maximum sound power output condition of the Vestas V90 turbine, which occurs at a reference wind speeds of 11 m/s or greater as measured at the turbine hub height of 80 m, according to data provided by the manufacturer. A design margin of 2 dB is included in the analysis account for modeling uncertainties and potential unforeseen variations in turbine installation, configuration, or design.

As presented in Table 3, predicted noise levels from the proposed wind turbine are not expected to exceed the Town of Millbury noise limit of 70 dBA at any of the modeled receivers or nearby noise-sensitive areas.

Table 3 Predicted Noise Levels from Proposed Wind Turbine (11 m/s wind speed at 80 m hub height)

Site Name	Site Address	Predicted Turbine, Leq (dBA)	Design Margin (dB)	Worst-Case Turbine Leq (dBA)
LT-1	6 Forest Hill Dr.	43	2	45
ST-1	12 Singletary Rd.	36	2	38
ST-2	34 Singletary Rd.	42	2	44
ST-3	18 Singletary Rd.	36	2	38
ST-3a	20 Singletary Rd.	38	2	40
ST-4	29 McGrath Rd.	36	2	38
P_01	Near residence to northeast	43	2	45
P_02	Closest occupied structure on Butler Farm property to east	45	2	47
PB_01	Northern property boundary	37	2	39
PB_02	Eastern property boundary	46	2	48
PB_03	Southeastern property boundary	46	2	48
PB_04	Southern property boundary	46	2	48
PB_05	Western property boundary	47	2	49
PB_06	Northwestern property boundary	43	2	45

H:\GIS\USA\MA\304640_Millbury_Wind\304640_Millbury_Figure_5_Noise_Contour_Map.mxd

30 dBA (Leq) Contour	Proposed Wind Turbine Location
35 dBA (Leq) Contour	Noise Monitor & Prediction Location
40 dBA (Leq) Contour	Noise Prediction Location
45 dBA (Leq) Contour	Parcel Boundary
50 dBA (Leq) Contour	Municipal Boundary

Source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Energy and Environmental Affairs

Millbury Wind Turbine Noise Study

Millbury, Massachusetts

Figure 5
Site Layout Plan and Noise Contours
Vestas V90, 1.8MW Turbine, Mode 0
Wind Speed 11 m/s at Hub height

HARRIS MILLER MILLER & HANSON INC.

4.4 Comparison with Ambient L90 levels

As discussed above in Section 2, the MassDEP noise guidelines state that a noise source should not increase the broadband sound level by more than 10 dBA above ambient. Ambient is defined as the background L90 measured during equipment operational hours. A wind turbine only operates when there is sufficient wind speed to generate power. The wind speed required for operation of the Vestas V90 turbine is 3.5 m/s, measured at the hub height. Therefore, it is appropriate to determine the background L90 when winds are blowing at speeds of 3.5 m/s or higher at the wind turbine hub height, for purposes of comparison to the turbine noise emissions.

HMMH has learned through a number of wind turbine noise studies comparing ambient and turbine source sound levels to the MassDEP noise guidelines, that the most potential for noise impact occurs at low wind speeds just above the turbine cut-in speed. As reference wind speeds increase, the background sound levels are notably higher than calm wind conditions due to wind-induced noise in trees and foliage near the ground. The increase in ambient noise levels as wind speed increases lessens the contribution of the turbine to the background sound levels. Therefore, the worst-case increase in ambient levels occurs above the turbine cut-in wind speed, but before background levels reach the reference wind speeds. For the Vestas V90 turbine the cut-in wind speed is 3.5 m/s, therefore, for this analysis a sound power level for the reference wind speed of 7 m/s at the hub height of 80 meters was evaluated.

Wind speeds greater than 4 m/s at the hub height were not experienced during the monitoring period, and therefore, the relationship between ambient noise levels and wind speed are not known for the project study area. Because the ambient noise level as a function of wind speed is unknown at this time, no adjustment can be made to the ambient noise level in the project study area for contributions caused by wind speed. As such, HMMH *conservatively* applied the median L90 sound levels measured during the time frame previously found to have the quietest background noise levels in the study area. It is appropriate to note that it would be during these periods of low background noise levels that turbine operations would be most apparent. As presented in Section 3.3, the median L90 measured during the late night and early morning hours was 31.5 dBA. The median L90 sound level of 31.5 dBA will serve as the baseline for the MassDEP increase analysis.

It should be noted that empirical data for other wind turbine noise studies indicate median L90 ambient *nighttime* noise levels when hub height wind speeds average 5-7 m/s are typically in the low to mid 30’s dBA range for rural and suburban areas. As wind speeds approach the 11 m/s level, where turbine noise emissions reach maximum output, ambient background L90 nighttime noise levels are typically in the mid 40’s dBA in rural and suburban areas.

Table 4 presents the predicted turbine sound levels and sound-level increase at all measurement and prediction sites for a reference wind speed of 7 m/s at an 80 m hub height.[5] The “worst-case” turbine Leq values shown in the table include a 2-decibel design margin added to the noise levels at each site predicted based on the manufacturer’s published noise emissions.

As shown in Table 4, the greatest increase in noise levels is predicted to occur at the nearest property boundaries; however, as mentioned in Section 2, a property line exceedance of the 10 dBA increase criteria does not directly result in an impact if there is not an occupied noise-sensitive use in the vicinity. The greatest increase at a an occupied structure is predicted to occur at prediction point P_02, located at the building on the Butler Farm property, east of the proposed turbine location. As shown in the table, ambient L90 noise levels would be 31.5 dBA, wind turbine Leq noise levels would be approximately 43 dBA, resulting in an overall noise level of 43 dBA and a sound level increase of 12

[5] Noise levels and relative increases shown in the table may not correlate directly due to decimal rounding.

dBA at site P_02. Increases of 10 dBA are predicted to occur at the nearest residential areas represented by noise monitoring site LT-1 and prediction site P_01. While these increases do not constitute violations of the MassDEP noise guidelines because they do not *exceed* 10 dBA, they are notable increases in the existing background noise environment nevertheless. However, at hub wind speeds less or greater than 7 m/s, the sound-level increases will be less, because of decreasing turbine noise emissions at lower speeds and increasing background noise at higher speeds.

During quiet nighttime periods when winds are low near the ground but sufficient for the turbine to operate, sound from the turbine will be audible and noticeable to some in the nearest surrounding residential areas. Under these conditions, turbine sound is expected to be audible at night where increases of 5 dBA or more are projected, or up to distances of approximately 1500 ft from the turbine.

Table 4 Comparison of Projected Worst-case Turbine Noise Levels to Ambient L90 (7 m/s wind speed at 80m hub height)

Site Name	Site Address	Ambient L90 (dBA)	Worst-case Turbine Leq (dBA)	Worst-case Turbine Leq plus L90 (dBA)[1]	Sound Level Increase (dBA)
LT-1	6 Forest Hill Dr.	31.5	41	41	10
ST-1	12 Singletary Rd.	31.5	34	36	5
ST-2	34 Singletary Rd.	31.5	40	41	9
ST-3	18 Singletary Rd.	31.5	34	36	4
ST-3a	20 Singletary Rd.	31.5	36	37	6
ST-4	29 McGrath Rd.	31.5	34	36	4
P_01	Near residence to northeast	31.5	41	42	10
P_02	Closest occupied structure on Butler Farm property to east	31.5	43	43	**12**
PB_01	Northern property boundary	31.5	35	37	5
PB_02	Eastern property boundary	31.5	44	45	**13**
PB_03	Southeastern property boundary	31.5	44	44	**13**
PB_04	Southern property boundary	31.5	44	44	**13**
PB_05	Western property boundary	31.5	45	45	**13**
PB_06	Northwestern property boundary	31.5	41	42	10

Notes:
1 –Levels presented may vary slightly due to rounding of decimals.
Bold indicates exceeds applicable criteria.

5 Conclusions

Harris Miller Miller & Hanson Inc. (HMMH) has completed a noise assessment for the proposed West Millbury Wind project, incorporating the installation of one Vestas V90 1.8MW wind turbine at the Butler Farm property in Millbury, Massachusetts. The Millbury Wind project is proposed to be located on property owned by the Town of Millbury, generally located along Singletary Road. The analysis summarized the existing noise environment, presented calculated noise levels anticipated to be generated by the wind turbine and compared the resultant noise levels with the applicable criteria.

The Town of Millbury noise limit of 70 dBA is not anticipated to be exceeded at any of the nearby noise-sensitive receptors. The frequency spectrum data provided for the Vestas V90 1.8 MW wind turbine shows that the proposed project would comply with the DEP noise guidance for a pure tone condition.

Under most turbine operating conditions, increases in existing ambient noise caused by the turbine will be well below the MassDEP noise guideline of greater than 10 dBA increases in broadband noise levels. However, during the quietest nighttime hours with hub-height wind speeds at approximately 7 m/s, the proposed Millbury Wind project is predicted to exceed the 10 dBA MassDEP guideline at the nearby occupied structure on the Butler Farm property east of the proposed turbine site. Under the same conditions, increases of 10 dBA are predicted to occur at the few nearest residential areas represented by noise monitoring site LT-1 and prediction site P_01. However, at hub wind speeds less or greater than 7 m/s, the sound-level increases will be less, because of decreasing turbine noise emissions at lower speeds and increasing background noise at higher speeds. While the nighttime increases in ambient noise at these homes do not constitute violations of the MassDEP noise guidelines because they do not exceed 10 dBA, they are notable increases in the existing background noise environment nevertheless.

During quiet nighttime periods when winds are low near the ground but sufficient for the turbine to operate, sound from the turbine will be audible and noticeable to some in the nearest surrounding residential areas.

Appendix A Description of Noise Metrics

This Appendix describes the noise metrics used in this report.

A.1 A-weighted Sound Level, dBA

Loudness is a subjective quantity that enables a listener to order the magnitude of different sounds on a scale from soft to loud. Although the perceived loudness of a sound is based somewhat on its frequency and duration, chiefly it depends upon the sound pressure level. Sound pressure level is a measure of the sound pressure at a point relative to a standard reference value; sound pressure level is always expressed in decibels (dB), a logarithmic quantity.

Another important characteristic of sound is its frequency, or "pitch." This is the rate of repetition of sound pressure oscillations as they reach our ears. Frequency is expressed in units known as Hertz (abbreviated "Hz" and equivalent to one cycle per second). Sounds heard in the environment usually consist of a range of frequencies. The distribution of sound energy as a function of frequency is termed the "frequency spectrum." The frequency spectrum of sound is often represented as the sum of the sound energy in frequency bands that are one octave or 1/3-octave wide. An octave represents a doubling of frequency.

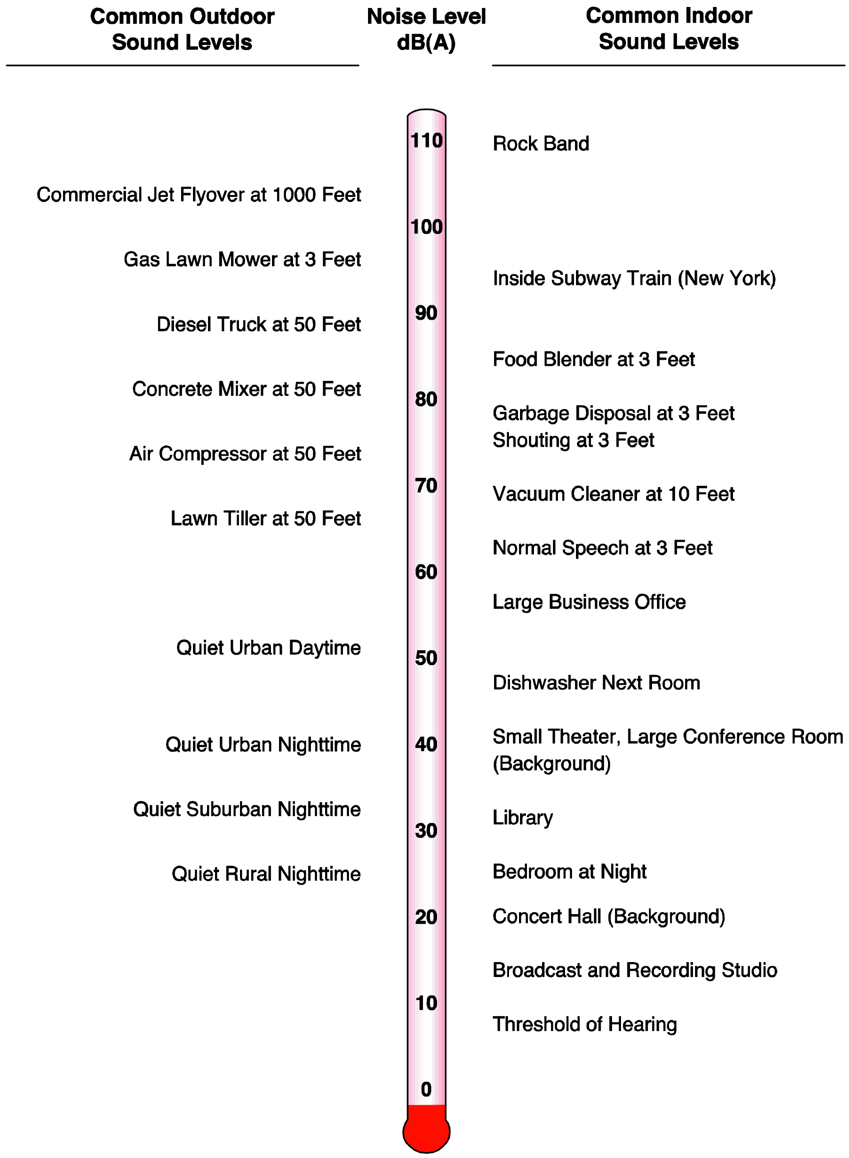
The human ear does not respond equally to identical noise levels at different frequencies. Although the normal frequency range of hearing for most people extends from a low of about 20 Hz to a high of 10,000 Hz to 20,000 Hz, people are most sensitive to sounds in the voice range, between about 500 Hz to 2,000 Hz. Therefore, to correlate the amplitude of a sound with its level as perceived by people, the sound energy spectrum is adjusted, or "weighted."

The weighting system most commonly used to correlate with people's response to noise is "A-weighting" (or the "A-filter") and the resultant noise level is called the "A-weighted noise level" (dBA). A-weighting significantly de-emphasizes those parts of the frequency spectrum from a noise source that occurs both at lower frequencies (those below about 500 Hz) and at very high frequencies (above 10,000 Hz) where we do not hear as well. The filter has very little effect, or is nearly "flat," in the middle range of frequencies between 500 and 10,000 Hz. A-weighted sound levels have been found to correlate better than other weighting networks with human perception of "noisiness." One of the primary reasons for this is that the A-weighting network emphasizes the frequency range where human speech occurs, and noise in this range interferes with speech communication. The figure below shows common indoor and outdoor A-weighted sound levels and the environments or sources that produce them.

A.2 Equivalent Sound Level, Leq

The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the total exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest -- for example, an hour, an 8-hour school day, nighttime, or a full 24-hour day. However, because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric. Such durations are often identified through a subscript, for example L_{eq1h}, or $L_{eq\ (24)}$.

L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as (is "equivalent" to) the actual time-varying sound level with its normal peaks and valleys. It is important to recognize, however, that the two signals (the constant one and the time-varying one) would sound very different from each other. Also, the "average" sound level suggested by L_{eq} is not an



arithmetic value, but a logarithmic, or “energy-averaged” sound level. Thus, the loudest events may dominate the noise environment described by the metric, depending on the relative loudness of the events.

A.3 Statistical Sound Level Descriptors

Statistical descriptors of the time-varying sound level are often used instead of, or in addition to L_{eq} to provide more information about how the sound level varied during the time period of interest. The descriptor includes a subscript that indicates the percentage of time the sound level is exceeded during the period. The L_{50} is an example, which represents the sound level exceeded 50 percent of the time, and equals the median sound level. Another commonly used descriptor is the L_{10}, which represents the sound level exceeded 10 percent of the measurement period and describes the sound level during the louder portions of the period. The L_{90} is often used to describe the quieter background sound levels that occurred, since it represents the level exceeded 90 percent of the period.

Appendix B Vestas V90 1.8MW VCUS Sound Power Levels, Mode 0

12.3 Performance Noise Levels

12.3.1 Noise Curve, Noise Mode 0

Sound Power Level at Hub Height: V90-1.815 MW-60 Hz, Noise mode 0		
Conditions for Sound Power Level:	**Measurement standard IEC 61400-11 ed. 2 2002** **Wind shear: 0.16** **Maximum turbulence at 10 metre height: 16%** **Inflow angle (vertical): 0 ±2°** **Air density: 1.225 kg/m^3**	
Hub Height	**80 m**	**95 m**
L_{WA} @ 3 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	92.4 4.2	92.6 4.3
L_{WA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	95.6 5.6	96.1 5.7
L_{WA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	99.8 7.0	100.3 7.2
L_{WA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	102.5 8.4	102.7 8.6
L_{WA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	103.2 9.8	103.3 10.0
L_{WA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	103.5 11.2	103.5 11.5
L_{WA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	103.5 12.6	103.5 12.9
L_{WA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	103.5 13.9	103.5 14.3
L_{WA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	103.5 15.3	103.5 15.8
L_{WA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	103.5 16.7	103.5 17.2
L_{WA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hub height [m/sec]	103.5 18.1	103.5 18.6

Table 12-9: Noise curve, noise mode 0.