Town of Brewster

Wind Energy Site Screening and
Development Options Analysis

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Acknowledgements

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Abstract

Black & Veatch screened the three identified sites near Brewster, Massachusetts for the potential of installing a community wind energy project. The wind resource was estimated using wind data collected on site, as well as from the state wind resource map. Land use and operational issues were reviewed, specifically the proximity of the sites to protected open space and to privately-owned land. The electrical infrastructure near the sites was reviewed to understand the feasibility of connecting a wind turbine to the existing electrical grid. Production from a candidate wind turbine was estimated, and the likely cost for project was reviewed. Black & Veatch found no obvious fatal flaws for the project, although concerns regarding setbacks, protected open space, and electrical interconnection will require further review.

Keywords

Renewable Energy Trust
Massachusetts Technology Collaborative
Community Wind Collaborative
Town of Brewster
Town of Brewster Alternative Energy Committee
Cape Cod
Wind Energy
Wind Power
Black & Veatch
Site Screening and Development Options
Feasibility Study

1.0 Conclusions and Recommendations

The Massachusetts Technology Collaborative (MTC) has entered into a Work Order (WO07-2) with Black & Veatch to perform a wind project site screening study for the Town of Brewster Alternative Energy Committee. This report provides the results from this study, and provides recommendations regarding further review of this project. A summary of the results and recommendations are:

- The annual average wind resource at the project site is approximately 5.73 m/s at 49 meters above ground level, and 7.20 at 80 meters. The wind shear component a was estimated at 0.47, based on the collected data. (Section 4)
- Three potential project locations were identified by the Town of Brewster Alternative Energy Committee for a wind energy project. Each site can likely support only one large wind turbine. While a turbine at the Pumping Station location appears to have no setback issues, turbines at either the Commerce Park or Golf Course Parking Lot locations could have fatal flaws regarding setback (depending upon the final setback requirement language). (Section 5)
- The electrical infrastructure at each location should be able to accept the generation from the recommended project sizes after moderate upgrades are performed. Electrical consumption at the Pumping Station and Golf Course Parking Lot locations should be able to be significantly offset by an on-site wind energy project. (Section 6)
- The Pumping Station location is listed as an open-space area, which could be a fatal flaw for the site. The Commerce Park and Golf Course Parking Lot sites do not appear to have similar restrictions. (Section 7)
- Airspace obstruction study indicates perspective turbine size and locations may impact a local long range radar facility and will require further review of potential impacts to airport flight paths before a maximum allowable height can be determined. (Section 7)
- Annual production estimates is expected to be around 4402 MWh per turbine for large turbines with net capacity factors between 29 percent and 32 percent. Black & Veatch would classify the capacity factors as “good”. (Section 9)
- The capital costs for a single 2 MW wind turbine at any of the sites is approximately $4.0 million, or $2,000 per kW. (Section 10)
- Assuming no on-site consumption of generation, a single-turbine project is expected to have a payback of approximately 10.3 years . (Section 11)
- Black & Veatch has not determined any of the three sites have an obvious fatal flaw, although each site has siting challenges to be further reviewed. Black & Veatch recommends the feasibility study be performed.

2.0 Review of On-Site and Community Wind Energy

Black & Veatch has included the following section to help readers better understand the technology being evaluated in this study, as well as the feasibility of installing wind turbines near or within facilities and cities.

2.1 Wind Energy Technology

The design of the typical wind turbine has changed greatly over the past twenty years. Although many types of wind turbine designs were initially developed, the "Danish" design of a three-bladed, up-wind horizontal axis turbine has emerged as the standard of the industry.

Although the size and complexity of wind turbines has increased, their basic operating principles have remained virtually unchanged. Figure 2-1 from the U.S. Department of Energy shows the typical layout of equipment in a turbine's hub, which is the "pod" of equipment at the top of the tower to which the turbine's blades are connected. Wind energy is captured by the wind turbine blades, and cause the rotor to rotate the turbine's low-speed shaft. This shaft will rotate at a speed of about 15 to 30 revolutions per minute (RPM). The low speed shaft is then connected to a gearbox, which transfers the energy to the high-speed shaft connected to the generator. The speed of the high-speed shaft depends on the generator type and electrical frequency of the site, but for the U.S. typical speeds are 1,800 and 3,600 RPM. The electrical output of the generator is then transferred to the base of the wind turbine via electrical droop cables. At the base, these cables connect to a transformer, which increases the voltage of the power from the low voltage of the generator (480 or 600 VAC) to the distribution voltage of the plant (anywhere from 12 kV to 46 kV). The orientation of the wind turbine is kept into the wind by a yaw drive, with the wind direction determined by a wind vane located on top of the hub. The turbine's controller has independent control of the wind turbine's operation, without requiring commands from a user or central control center. If the controller senses a problem, the wind speed increases beyond the turbine's operational range, or a shut-down command is given manually, the turbine will come to a stop by means of electrical, mechanical, and aerodynamic brakes (the design of which depend on the turbine).

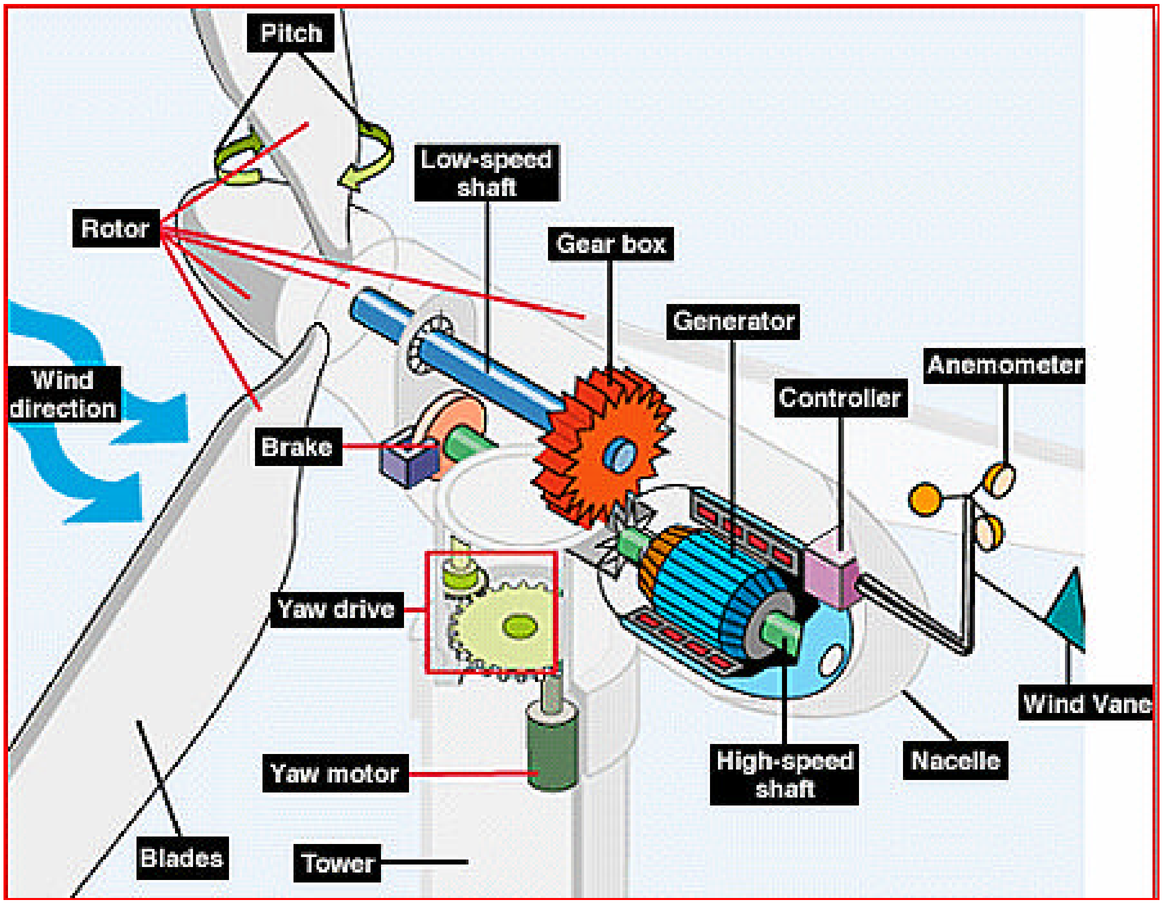

Figure 2-1 Wind Turbine Components (from US Dept. of Energy)

Obviously, the output of the wind turbine is dependent upon wind speed. The relationship of a wind turbine's electrical output as a function of wind speed is given in its power curve. A typical curve will show power production beginning when the wind speed increases beyond the turbine's minimum (cut-in) wind speed. As wind speed increases, the output power also increases in a roughly linear manner until the turbine's rated power is reached. The minimum wind speed at which a wind turbine delivers this nameplate output power is called its rated wind speed. For most modern wind turbines, winds higher than the rated wind speed will not produce any additional power, and turbine will continue to output its rated power. If the wind speed increases beyond the safe operating limits of the turbine (cut-out), the turbine will automatically shutdown and wait for the wind speeds to decrease. The wind speeds and power amounts for the above values depend mostly on the size of the wind turbine and the design of the blade airfoils. On average, larger wind turbines have lower cut-in wind speeds, have higher rated power, and reach that power at lower winds.

Two representative designs of large commercial wind turbines are discussed below. The Vestas V80 and the General Electric 1.5MW wind turbines are currently two of the most popular turbine designs for new wind farms in the U.S., and have been chosen by MTC as the standard designs for study purposes. Because one location of interest in this study could accommodate a multiple small wind turbines, Black & Veatch also considered the Fuhrländer FL250 as a small wind turbine design. Wind turbines from other manufacturers may be equally appropriate for these sites.

2.1.1 Vestas V80

Vestas is one of the world's largest manufacturer of wind turbines. Based in Denmark, Vestas has about one-third of the market for wind turbine sales. They recently merged with the wind turbine manufacturer NEG Micon, and together represent a major vendor and installer for wind turbines in the United States.

Figure 2-2 Vestas V80s in Buffalo Mountain, Tennessee

The V80 is currently one of the largest on-shore wind turbines available in the U.S. Rated at 1,800 kW (1.8 MW), the V80 has a 80 meter rotor diameter, is commonly installed on 80 meter towers (although Vestas offers tower options between 60 and 80 meters), and has a rotational speed of 15.5 RPM (about one revolution every four seconds). For wind projects at sites of medium to high average wind speeds, the V80 has become the primary turbine design from Vestas. The Town of Hull (Massachusetts) recently installed a V80 as their "Hull 2" turbine, located at a closed landfill in that community.

2.1.2 GE 1.5MW

General Electric (GE) purchased Enron Wind Energy in 2002, and has integrated the company into GE's Power Systems company. GE has applied their efforts since this acquisition to improving the design and production of their only commercial on-shore wind turbine, the GE 1.5MW. This turbine is a 1,500 kW machine with a rotor diameter of 65, 70.5 or 77 meters. The turbine is commonly placed on either 65 or 80 meter towers. Because of its variable-speed ability, the GE 1.5MW has a rotational speed range between 10 and 20 RPM (or one revolution every three to six seconds). Projects with this design wind turbine include the Somerset, Mill Run, and Waymart projects in Pennsylvania and Fenner in New York.

Figure 2-3 GE 1.5MW turbines at Colorado Green Project

2.1.3 Fuhrländer FL250

Fuhrländer is one of the last remaining manufacturers of wind turbines rated between 50 and 500kW. Based in Germany, Fuhrländer specializes in smaller projects and turbine customization to client needs. In the U.S., Fuhrländer wind turbines are distributed by Lorax Energy Systems in Rhode Island.

The Fuhrländer FL250 is one of the smallest commercial wind turbines still available in the U.S. Rated at 250kW, the FL250 has a 29.5 meter rotor diameter, and is commonly installed on a 42 meter tower (although Fuhrländer offers a 50 meter tower option as well). This turbine design is considered too small for commercial wind farm development, although the size is considered a good option for on-site power projects. The closest FL250 to Massachusetts is likely the Harbec Plastics project in Ontario, New York, shown in Figure 2-4. A Fuhrländer FL100, a 100kW wind turbine of similar design from the same manufacturer, was recently installed at the IBEW Local 103 Training Center in Boston, and is discussed in Section 2.2.2.

Figure 2-4 Fuhrländer FL250 in Ontario, New York

2.2 Examples of On-Site and Community Wind Energy Projects

Black & Veatch has included an example each of wind energy projects installed on a community power level or directly onsite of major power consumers.

2.2.1 Palmdale, California

Black & Veatch was the engineer for the Palmdale Water District in Palmdale, California, for the design and installation a single 950 kW wind turbine at their water treatment facility. The wind turbine is a Micon (now Vestas) NM54, and is connected directly to the 12kV system of the treatment plant. This project was completed in July 2004.

This project was able to make use of two programs unique to California: the Self-Generation Incentive Program and a large Net Energy Metering allowance. The Self-Generation Incentive essentially requires the local utility (Southern California Edison) to pay for half of the costs of the project. The Net Energy Metering program in California allows for wind turbines up to 1MW to qualify for net metering, which is a requirement that the utility purchase of energy produced by the wind turbine at the same rate the customer who owns it buys power, up to the point where the wind turbine offsets the total annual consumption of their site. The Net Energy Metering allows the Palmdale project to have a turbine that will generate power at times greater than the site's consumption. Neither of these programs are presently available in Massachusetts.

Figure 2-5 Palmdale Water District On-Site Wind Turbine

2.2.2 Boston, Massachusetts

There are currently three projects in Boston that utilize wind energy on a community or smaller scale. The first is the single Vestas V47 installed by Hull Municipal Light Plant in Hull, Massachusetts. This project was installed in 2002, and is located near the local high school on the northern tip of the peninsula. The Town of Hull has a Municipal Light Board that provides electricity to the residents of Hull, and because of this they are able to use the wind generation to offset electricity purchases made by the Town. To date the Hull wind turbine has offset over 5,500 MWh of electricity purchases for the town's street and traffic lights. Due to the positive performance of this turbine, Hull Municipal Light Board has subsequently installed a larger Vestas V80 wind turbine.

Another example of small wind in Boston is the 100 kW Furhlander installed at the International Brotherhood of Electrical Workers (IBEW) training center in Dorchester. This small turbine connects directly into the building's utility connection, and offsets the electricity purchased for the building in the same manner the Hull turbine offsets a portion of the electricity purchased for the town. The IBEW turbine was installed in 2005.

Figure 2-6 Hull 1 Wind Turbine

Figure 2-7 IBEW Wind Turbine

2.2.3 Toronto, Ontario

As part of a community wind power effort, the people of Toronto developed a single 750kW Lagerway wind turbine project for installation at the city's Exhibition

Place. This turbine was installed in 1999, and is used to provide the power for the exhibition complex in downtown Toronto. While intended for a grassroots beginning for wind power in Ontario, this project has proven that urban wind power can work well in North America, as it does in much of Northern Europe.

Figure 2-8 Wind Turbine at Toronto's Exhibition Place

3.0 Project and Site Descriptions

Black & Veatch is supporting MTC in technical aspects of the Community Wind Collaborative. The goal of the Community Wind Collaborative is to support communities in determining the feasibility of developing small to moderate-sized wind energy projects, and aiding in the development of those projects found to be feasible. This report is the result of an initial site screening review for a wind energy project for the Town of Brewster Alternative Energy Committee, Massachusetts. Issues of general development feasibility and obvious fatal flaws were reviewed, and Black & Veatch has prepared recommendations for future activities toward development of a project in Brewster. Figure 3-1 shows the location of Brewster on Cape Cod.

Figure 3-1. Brewster Location.

The Town of Brewster's Alternative Energy Committee has identified three potential locations where there is sufficient land owned by the Town to place one or more large wind turbines. These areas are referred to in this report at the Commerce Park Location, Pumping Station Location, and Golf Course Parking Lot Location. All three locations are shown in the satellite photo in Figure 3-2.

Figure 3-2 Brewster Site Locations

The Commerce Park location is a Town owned industrial area adjacent to Mid-Cape Highway and is approximately 450 feet from the Captain's Golf Course driving range. The surrounding rolling hills in this location are heavily wooded, however; this site is easily accessible. Only Lots 9 and 18 of this area are under consideration for development. The second site is the Pumping Station location and it is approximately 900 feet to the Southwest of the overpass of Freemans Way over Mid-Cape highway. This site is located on relatively flat terrain within a densely wooded area. This location is zoned as Residential Rural and includes parcels of land used for the Brewster Water Department water wells. The Golf Course Parking Lot location is similar to the previous two in that dense wooded areas surround this site. This location is set on the west side of the golf course parking lot and is easily accessible. A meteorological tower was installed at this location for over ten months for wind resource monitoring (see Section 4). An analysis of each location is provided in Section 5.

Black & Veatch further evaluated the area in and around Brewster, and has not located an additional site deemed more feasible than those identified by the Brewster Committee.

4.0 Site Wind Resource

The wind energy resource of a project site is the most critical single aspect to understand, and is one of the few that cannot be overcome with technical solutions. This section discusses the various sources of wind resource information available for the region, and combines them into an estimate of the wind resource for Brewster.

4.1 Wind Data Reviewed

For Brewster, Black & Veatch reviewed seven data sources, five of which were generated by the University of Massachusetts Renewable Energy Research Lab (RERL). These sources were:

- Wind data collected by RERL on a meteorological tower at the Golf Course Parking Lot Location (February 2006 – December 2006)
- *Wind Data Report: Brewster*, RERL, Spring 2006 Quarterly Report
- *Wind Data Report: Brewster*, RERL, Summer 2006 Quarterly Report
- *Wind Data Report: Brewster*, RERL, Fall 2006 Quarterly Report
- *Wind Data Report: Brewster*, RERL, Winter 2006 Quarterly Report
- *Wind Data Report: Brewster*, RERL, Winter 2007 Quarterly Report
- The New England Wind Map web site operated by TrueWind Solutions (http://truewind.teamcamelot.com/ne/)
- Massachusetts High Resolution Wind Resource GIS data provided by NREL (http://www.nrel.gov/gis/data_analysis.html)

The information available from each above resource is discussed in this section, and the resources are combined into a complete wind resource estimate for Brewster in Section 4.2.

4.1.1 Brewster Met Tower Data and RERL Report

RERL installed a 50 meter (164 feet) tall meteorological (met) tower at the Golf Course Parking Lot location on February 1, 2006. The exact location of the tower was at coordinates 41° 44 08.84 North by 70° 01 12.69 West (NAD83) in the western portion of the golf course parking lot, which places it about 0.42 km (0.26 miles) east of the Pumping Station location and 0.52 km (0.35 miles) southwest of the Commerce Park location. The tower collected wind speed and direction data from sensors at 49, 38, and 20 meters above ground level, as well as a low-mounted temperature sensor. The data from the tower was mailed to RERL for data analysis on a regular basis. The data set from this met tower provided to Black & Veatch by MTC ends on December 18, 2006 (although the met tower was installed into March 2007). Data recovery from this tower over the data set is considered to be excellent.

The met tower was located in the center of a cleared wooded area with trees in every direction, but east. Trees surrounding the site appeared to be 10 meters (33 feet) in height or less, meaning the winds measured by the 20 meter anemometer were likely slowed due to the height and surface roughness imposed by the trees, but the 38 and 49 meter anemometers were not. Figure 4-1 and 2 shows the location of the met tower at the golf course parking lot.

Because there was a year of data available from this met tower, which was equipped and installed primarily for wind energy resource measurement, Black & Veatch concluded this to be the best source of data to base wind energy predictions upon.

Figure 4-1 Brewster Met Tower Location

Figure 4-2 Tree line from Met Tower Site

Black & Veatch reviewed each of the four *Wind Data Report: Brewster* RERL reports prepared quarterly on the met tower's data collection, as well as 10 minute data for February 2006 through March 2007. This information was all obtained from the RERL web site. The monthly average wind speeds are listed in Table 4-1 and shown in Figure 4-3. The values of wind shear were determined between the anemometers mounted at 49 meters and 38 meters above ground level; the results will be discussed further in Section 4.2.

Table 4-1
Measured Brewster Monthly Averages: February 2006 – March 2007

Month/Year	Wind Speed			Wind Shear (49 meters-38 meters)
	49 Meters	38 Meters	20 Meters	
January – 06’				
February – 06’	6.51	5.82	4.26	0.45
March – 06’	5.80	5.18	3.73	0.43
April – 06’	5.99	5.36	3.95	0.47
May – 06’	5.64	5.08	3.79	0.44
June – 06’	5.22	4.66	3.41	0.48
July – 06’	5.28	4.76	3.50	0.46
August – 06’	4.53	4.01	2.66	0.52
September – 06’	4.83	4.23	2.86	0.55
October – 06’	5.98	5.29	3.75	0.52
November – 06’	5.26	4.67	3.08	0.48
December – 06’	5.98	5.28	3.91	0.52
January – 07’	6.35	5.66	4.14	0.48
February – 07’	6.22	5.59	4.09	0.44
*March – 07’	6.80	6.15	4.51	0.40
Annual	**5.67**	**5.06**	**3.68**	**0.47**

Notes: **All wind speed values in meters per second.**
Wind speed values are averages of all wind speed sensors at the same height above ground.
Wind shear values determined between anemometers at 49 and 38 meters.
*Only 28 days of data for this month.

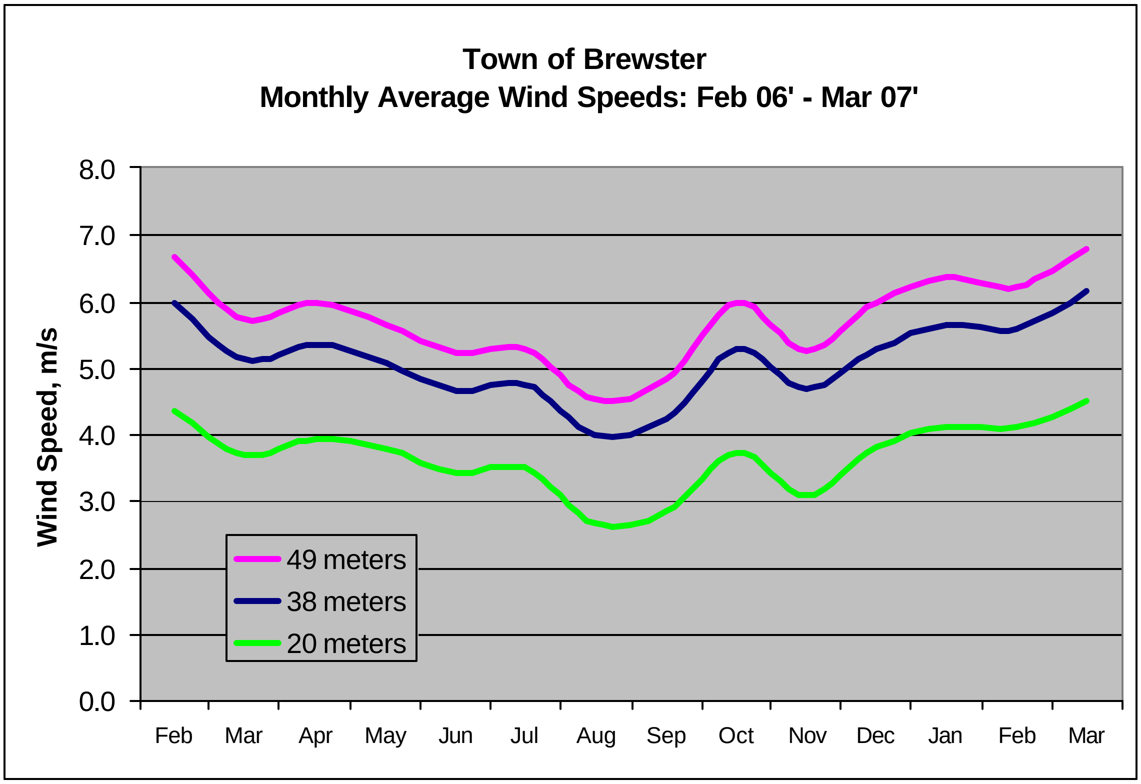

Figure 4-3 Brewster Monthly Wind Speed Averages

4.1.2 Long Term Reference Data

While a year of data collection at or near a project site is usually deemed necessary for a wind energy project, a long-term data source is also needed to put the collected data into a historical perspective. Since the wind conditions at a site can change considerably between individual years, comparing the year over which data was collected to a long-term average becomes important to understand a site's average long term wind resource.

Wind data collected at airports is not intended for wind energy resource measurement since it is commonly collected with instruments fairly low to the ground; scaling this low-level data upward to the proposed turbine hub heights would not take into consideration how much wind speed changes with height. Black & Veatch has not used any reference data in the wind resource estimation in this report, however; several nearby long-term sources are available for Brewster and are identified in figure 4-4 below. While each of these sites is in close proximity to one another, the nearest airport is the Chatham Municipal airport, located approximately 3.7 miles to the southeast of the project sides. Black & Veatch will evaluate the potential of using data from each of the airports within the vicinity of the projects sites for the use as a long term reference which will be included in the feasibility study.

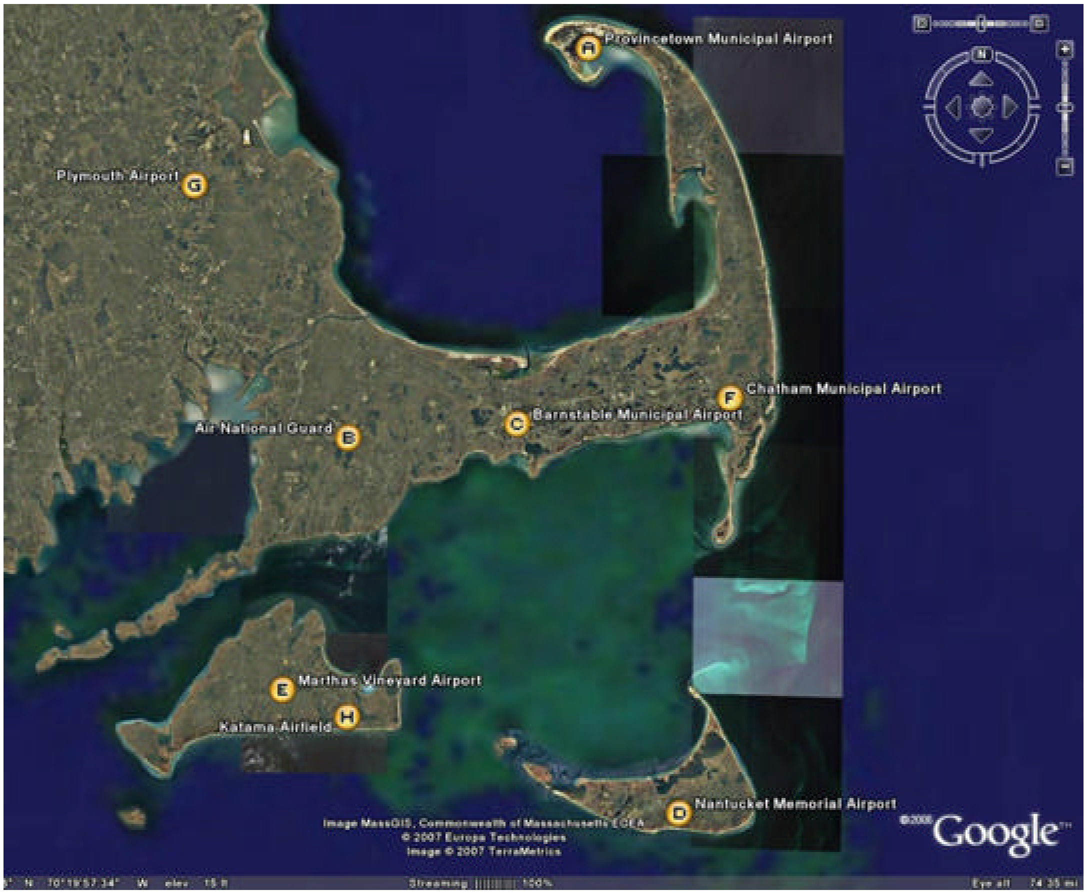

Figure 4-4 Airport Locations for Potential Long-Term References

4.1.3 Massachusetts Wind Resource Map Information

Black & Veatch also referenced the New England Wind Resource Map web site (truewind.teamcamelot.com/ne/) for general information on the wind resource for the area around the project site. This map is a model of the wind resources for all of New England, and was created from atmospheric data and calibrated using various data measurement locations. Creation of this map by TrueWind Solutions was funded by MTC, the Connecticut Clean Energy Fund, and the Northeast Utilities System.

By entering the coordinates of the Brewster Met Tower, the web service estimated the annual average wind speed to be 6.3 m/s at 50 meters above ground level, and 6.9 m/s at 70 meters above ground level. A wind rose for the site was also downloaded from the web site and shown below in Figure 4-5. These results should be considered to be a general estimate for the area, and not as accurate at the site collected data. The model has a specified resolution of 200 meters and a standard error estimated at 0.6 m/s.

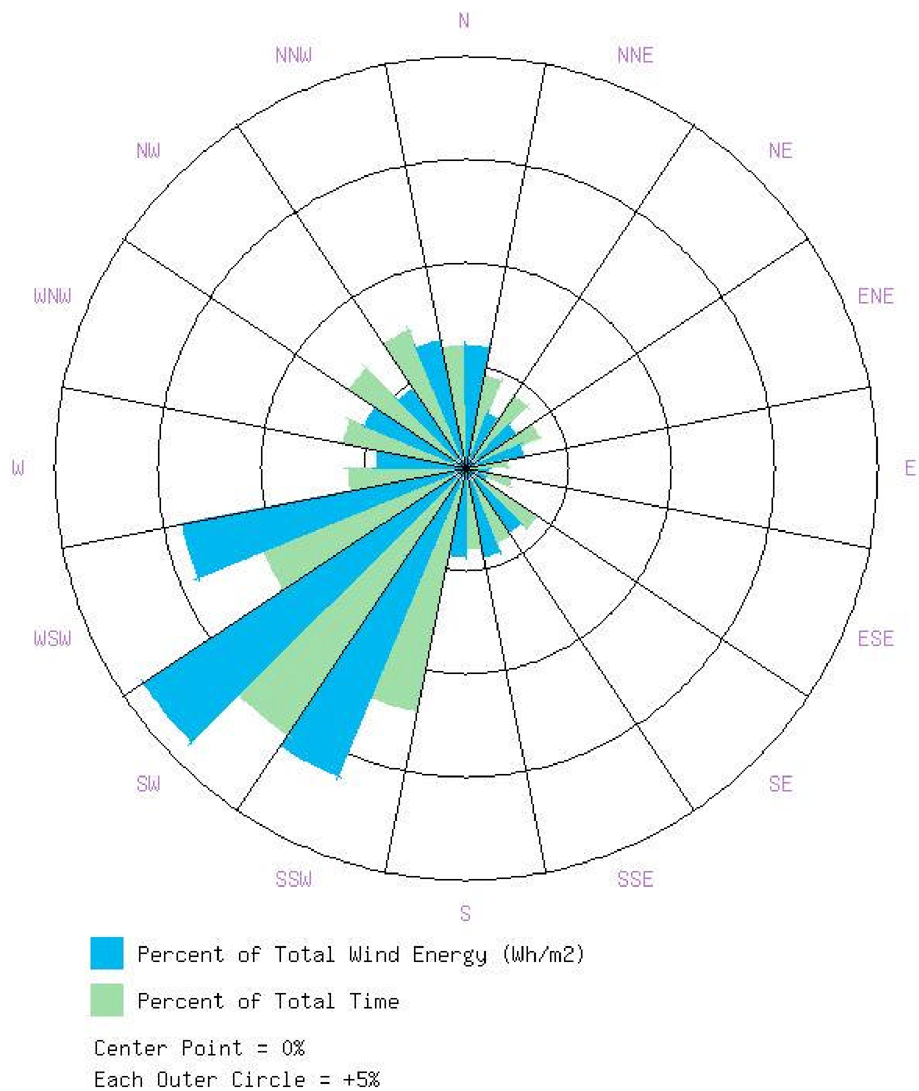

Figure 4-5 TrueWind Wind Rose for Brewster

5.0 Site Physical Characteristics

The three project locations described in this report are all within the town of Brewster, Massachusetts. Brewster is located on Cape Cod near the southern end of the north-south peninsula. The topography around the project locations is relatively flat with elevations varying between sea-level and 50 feet. There is significant tree cover surrounding each of these areas, with tree heights estimated to be up to about 50 feet tall. Only a handful of homes and buildings are close to all three locations, none of which were observed to be higher than the tree cover. A cellular (Cingular) tower and an AM Radio (WFPB 1170 AM) tower were observed to be in closest proximity to the Commerce Park Location; however, these structures should not impose any significant losses to turbine performance, nor should a turbine effect the operations of the cellular tower or radio tower. As mentioned earlier, there are many airports located on Cape Cod, the closet being Chatham Municipal Airport, approximately 3.7 miles to the southeast of the general area under review. All three locations can be readily accessed from Freemans Way or Mid-Cape Highway, making transport of wind turbine components to the sites relatively easy.

This screening review is focused on the placement of a single large wind turbine at one of the three locations described below. Multiple large turbines require a larger amount of land to reduce wake effects which greatly diminish the overall performance of each machine; whereas smaller turbines require less space between other small turbines to operate efficiently. At the request of the town, Black & Veatch could revise the results of this review to incorporate the use of multiple large or small wind turbines at the sites identified.

After meeting with the Tower of Brewster Wind Energy Committee on March 1, 2007, Black & Veatch inspected each identified location. Review of the Golf Course Parking Lot and Commerce Park sites was performed with a representative of the Massachusetts Technology Collaborative, and review of the Pumping Station site was done with the Superintendent of the Brewster Water Department.

While reviewing these locations and finding potential wind turbine sites, Black & Veatch noticed two issues impacted each site: intended setback requirements, and wind turbines overhanging property lines. Wind turbines in general are very safe machines, and cause little impact to their surrounding environments. However, very rare instances of wind turbine failures have occurred (including a wind turbine collapse in 2005), and after a strong ice storm, ice build-up on wind turbine blades could create a falling hazard on people below. As such, the Town of Brewster is developing setback requirements for wind turbines. As these setbacks have not been finalized, Black & Veatch made assumptions regarding the eventual setback requirements for this report. Also, Black & Veatch noticed some sites might have sufficient space at ground level to support a wind turbine, but the blades from that turbine could hang over property not owned by the Town of Brewster (or owned by the Town but leased to another party). Therefore, Black & Veatch applied two criteria for a wind turbine site:

- Each site must be far enough from the property boundaries so that the wind turbine blades will not overhang parcel boundaries; this distance is referred to as the "overhang radius." And is defined as one half the rotor diameter.
- Each site must be at least one and a half times the total height of the wind turbine distant from residences and highways; this distance is the "setback radius."

To apply these criteria Black & Veatch estimated parcel boundaries for each site location as illustrated in the subsequent figures below. Final turbine location options will need to be reviewed and revised based upon confirmation of exact boundary locations.

For the purpose of site evaluation, Black & Veatch applied the size characteristics for a general large wind turbine with an 80 meter rotor on an 80 meter tower to establish the setback distances. This yields an overhang radius of 40 meters (131 feet); meaning that a turbine will not be placed within 40 meters of any parcel boundary not owned by The Town of Brewster. A setback radius is also then assumed to be 180 meters (591 feet); meaning that a turbine will not be placed within 180 meters of residences and highways. More detailed evaluations of specific wind turbine models will be performed in the feasibility study.

5.1 Commerce Park Location

The Town of Brewster owns lots 9 and 18 in the Commerce Park location that are under consideration for a community wind project. Black & Veatch estimated the boundaries of these combined lots based on existing roads and tree clearings, then applied the siting criteria discussed above to determine a potential wind turbine site (see Figure 5-1). Black & Veatch has also prepared a 3-dimensional rendering of a typical 80m turbine at this location with the setback and overhang radii; this figure is included in Appendix B. While there are no apparent issues concerning the overhang radius of a turbine at this site, it should be noted that the Commerce Park access road, portions of the golf driving range, and an adjacent commercial building are within the setback radius defined above. Also, As mentioned earlier, the criteria used in this review assumed the setback radius will only apply to the turbine's proximity to homes and highways. If the final bylaw setback requirement applies also to commercial buildings, recreational areas, or surface streets, this site will need to be reconsidered with a smaller turbine design or potentially removed from further review.

The Commerce Park site is located within an industrial area. The site coordinates are approximately 41° 44' 22.03" North, 70° 0' 57.89" West (NAD27) and the base elevation is about 26 meters above sea level. Much of the land within this site has been primarily used as sand storage while the land surrounding this site is densely wooded with 30 foot to 50 foot trees. The land within this site is relatively clear of any significant obstructions and turbine installation would require moderate terracing, if any. However, this site could require some clearing for the construction of an access road for installation and maintenance. A wind turbine at this site should not impact normal traffic except possibly due to construction vehicles on the road during the turbine's installation. Public access to the site can be minimized relatively easily so that no safety issues arise. A picture toward this site from the west side of the pit is included as Figure 5-1.

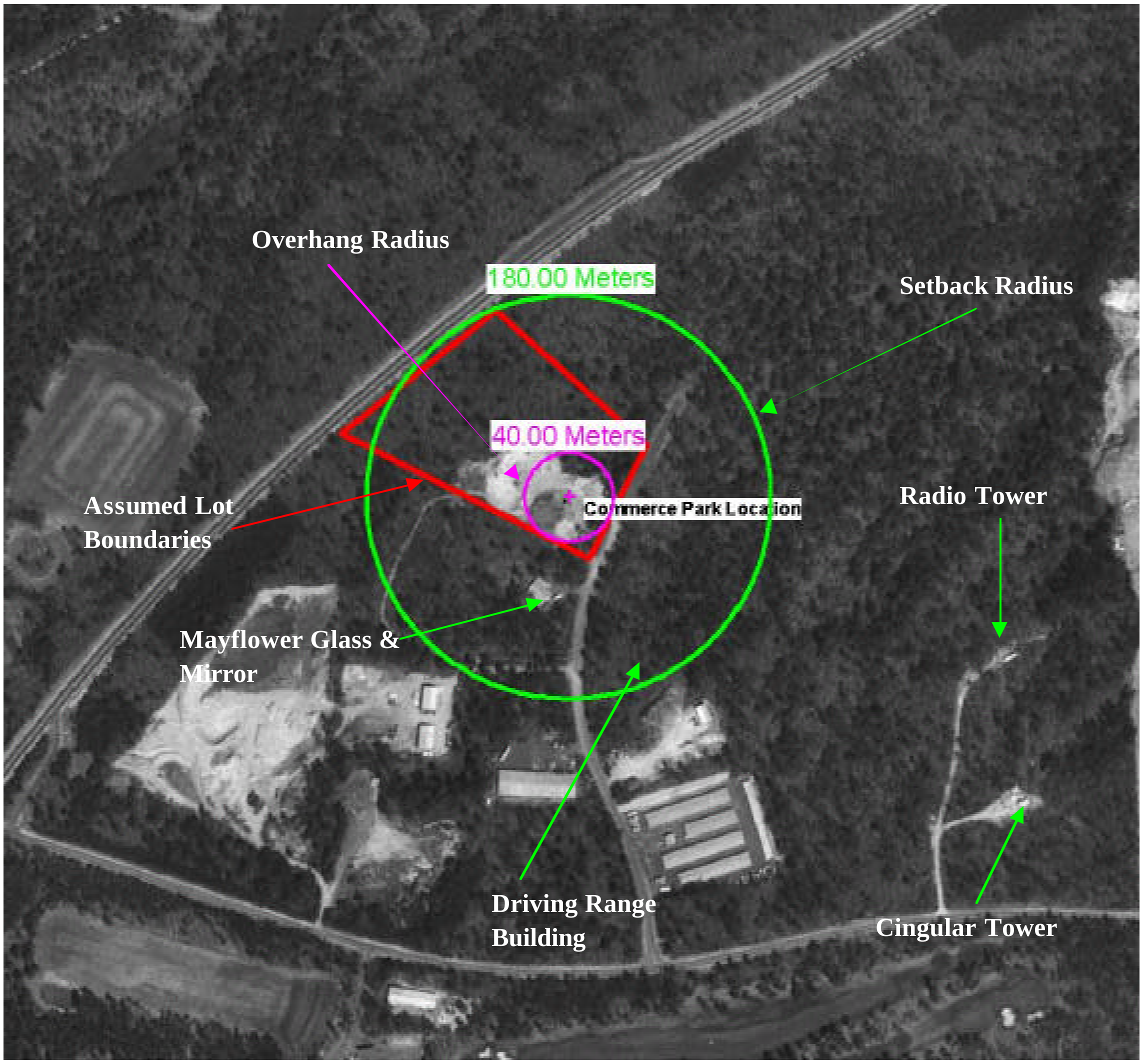

Figure 5-1 Commerce Park Location Aerial View

Black & Veatch understands that the combined lots 9 and 18 have also been selected as a potential site for a future Water Department headquarters building. The specific footprint of this building and associated parking lot and storage yard, have not yet been determined. Black & Veatch deems it likely the identified turbine location would interfere with the plans for this new building, and would encourage further discussion on this topic as this site is further considered.

Figure 5-2 Commerce Park Location

5.2 Pumping Station Location

Black & Veatch identified a possible wind turbine site near the town's water watershed conservation pumping stations No. 1 & 2 along Freemans Way, near Mid-Cape Highway. The site locations are shown in Figure 5-3. Black & Veatch has also prepared a 3-dimensional rendering of a typical 80m turbine at this location with the setback and overhang radii; this figure is included in Appendix B.

Figure 5-3 Pumping Station Location Aerial View

The coordinates of the site are approximately 41° 44’ 9.09” North, 70° 1’ 34.99” West (NAD27), and base elevation is about 22 meters (72 feet) above sea level. The land around this site is densely wooded with trees between 30 feet and 50 feet tall. Elevation gradually increases to the northeast with moderate slopes between 5 and 7 percent. Public access to the site can be minimized relatively easily. While this site has sufficient room to support a large wind turbine; a local residence exists approximately 900 feet away from this site. Although this home is outside the overhang and setback radius of the turbine site, it is possible this homeowner will hear the wind turbine operating in light winds, and may be impacted by shadow flicker (sunlight strobe effect caused by the rotating turbine blades) during sunrise. If the Town of Brewster Alternative Energy Committee has an interest in further developing this site, Black & Veatch recommends the homeowners closest to the sites be contacted and the project discussed. No other setback or overhang issues appear to exist at this site.

5.3 Golf Course Parking Lot Location

The Town of Brewster Alternative Energy Committee is considering an area in the western end of the Captain's Golf Course parking lot of for the potential site for a community wind energy development; this parcel was also the location where an RERL met tower was installed. For reference, this site is located 630 feet southeast of the Mid-Cape Highway 6's underpass with Freemans Way. The coordinates of the site are approximately 41° 44' 08.44" North, 70° 01' 14.62" West (NAD27), and base elevation is about 26 meters (85 feet) above sea level. The land in this area appears to be setup as a material staging area for the golf course and/or town's facilities and operations department. The land surrounding this site is densely wooded with 30 foot to 50 foot trees, whereas the land within this site is relatively clear of any significant obstructions and turbine installation would require little alterations to the existing roads or parking lots. Black & Veatch did not take measurements of the entry way into the parking lot, but it is possible that this short stretch of road would need to be widened to allow delivery of wind turbine parts and the crane used in construction. This location can only feasibly have one small or large wind turbine. Black & Veatch applied the siting criteria discussed above to determine a potential wind turbine site (see Figure 5-4).

Black & Veatch has also prepared a 3-dimensional rendering of a typical 80m turbine at this location with the setback and overhang radii; this figure is included in Appendix B. While there are no apparent issues concerning the overhang or setback radius of a turbine at this site, it should be noted that portions of the golf course parking lot are within the turbines' overhang radius and that Freemans Way road, the golf course parking lot and a portion of the golf course are within the setback radius defined above. As mentioned earlier, the criteria used in this review assumed the overhang radius will only apply to parcels of land not owned by the town and the setback radius will only apply to the turbine's proximity to homes and highways. If the final bylaw setback requirement applies also to commercial buildings, recreational areas, or surface streets, this site will likely need to be removed from further review. If this site is to remain under review, the town should consider restricting public access to an area outside of the overhang radius to maximize public safety.

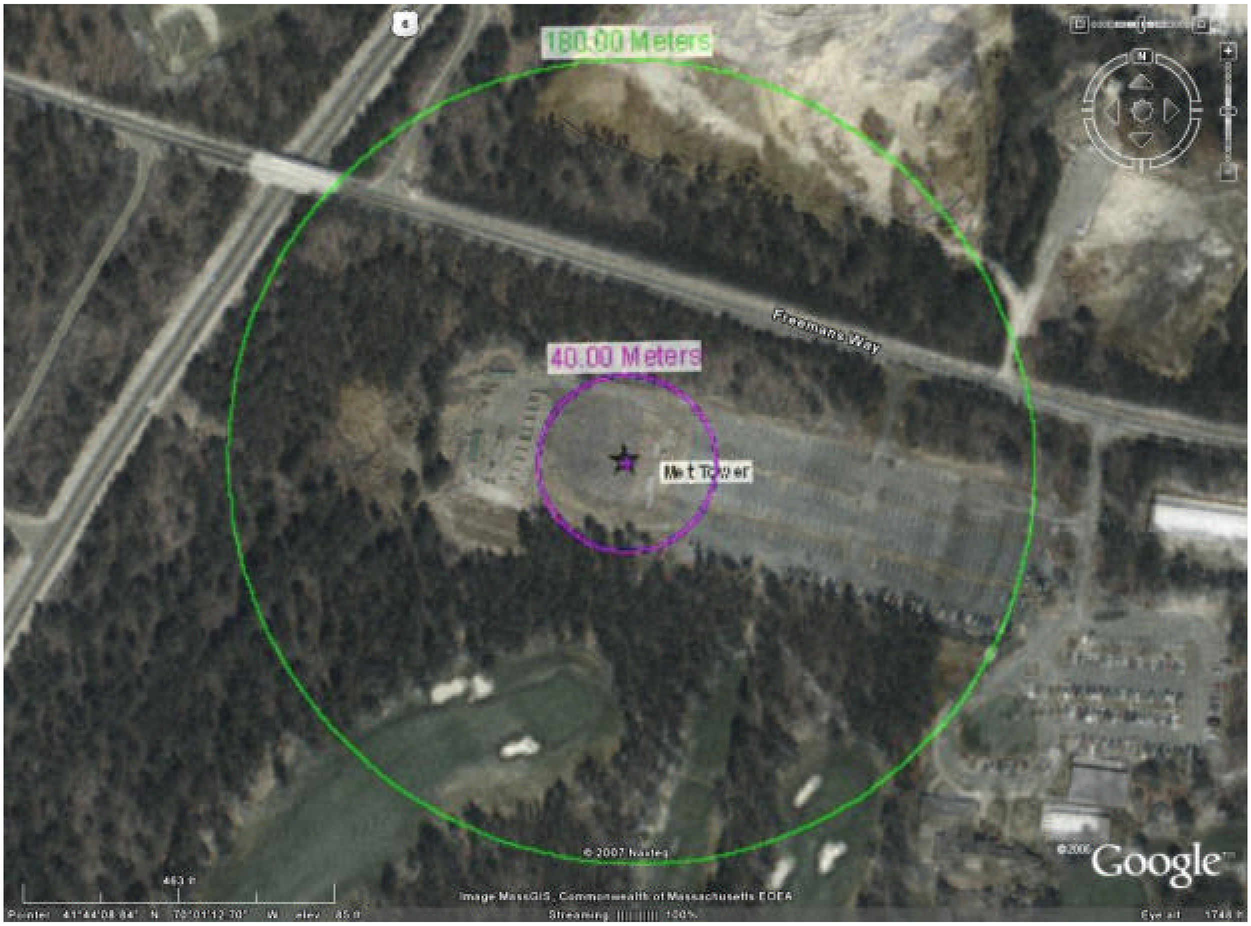

Figure 5-4 Golf Course Parking Lot Location Aerial View

5.4 Black & Veatch Recommendations

Due to the possibility that the town's final bylaw setback requirements may include commercial buildings, recreational areas, or surface streets, Black & Veatch anticipates that the Pumping Station Location will be the best location for a large turbine. A community scale wind energy project at this location would provide on-site generation to the Town of Brewster electrical loads and bring with it the possibility to sell the excess generation to the utility. As mentioned earlier, if the Town of Brewster Alternative Energy Committee has an interest in further developing a wind energy project at this site, Black & Veatch recommends the homeowners closest to the sites be contacted and the project discussed.

6.0 Electrical Interconnection and Offset

This section briefly discusses the likely manner in which the wind turbines would be electrically connected to the power grid, and the potential for offset of local electrical loads.

6.1 Electrical Interconnection

Wind turbines typically have low voltage (around 600 V) induction generators in the turbine's hub. Each turbine will have a transformer to increase the voltage to a medium voltage (typically between 12 and 34.5 kV), so the power can be transmitted without high-current losses. This voltage can be selected to match with local distribution system voltages if that system has sufficient capacity to allow the wind turbine to interconnect. Figure 6-1 shows a typical arrangement of a wind turbine's transformer to the base of the turbine tower (note that some larger wind turbines located this transformer in the turbine's hub).

Figure 6-1 Typical Wind Turbine Transformer Arrangement

Community wind energy projects can be connected in two general ways. The first is for the project to connect directly to a utility's transmission (high-voltage) or distribution (medium voltage) line. The wind turbines would sell power directly to the grid, and revenue meters would be positioned at the point of connection. This is the manner large commercial wind energy projects are connected, and the value for the energy would be similar to other commercial power plants. The other connection method is used when the goal is to first offset a large electrical load, and then sell any excess to the grid. For this method, the wind turbine must be located next to the large load, and electrically connected on the load side of the utility's meter. This connection method is sometimes referred to as co-metering, and allows the community to get the benefit of the wind energy at the same price the electricity is purchased.

Black & Veatch noted that each potential project location in Brewster has what appears to be distribution-level three-phase electrical lines adjacent to them. None of these lines appeared to have considerably high rating levels (based on wire sizes). Also, none of the sites were particularly close to the only transmission line in the area (115kV NSTAR line, see Figure 6-2). As such, it is expected that connecting a wind turbine at any of the three potential locations will require upgrading the nearby distribution lines to sufficient levels to accept the turbine's generation. Black & Veatch will need to consult with the local utilities to determine the line capacities as part of the feasibility study.

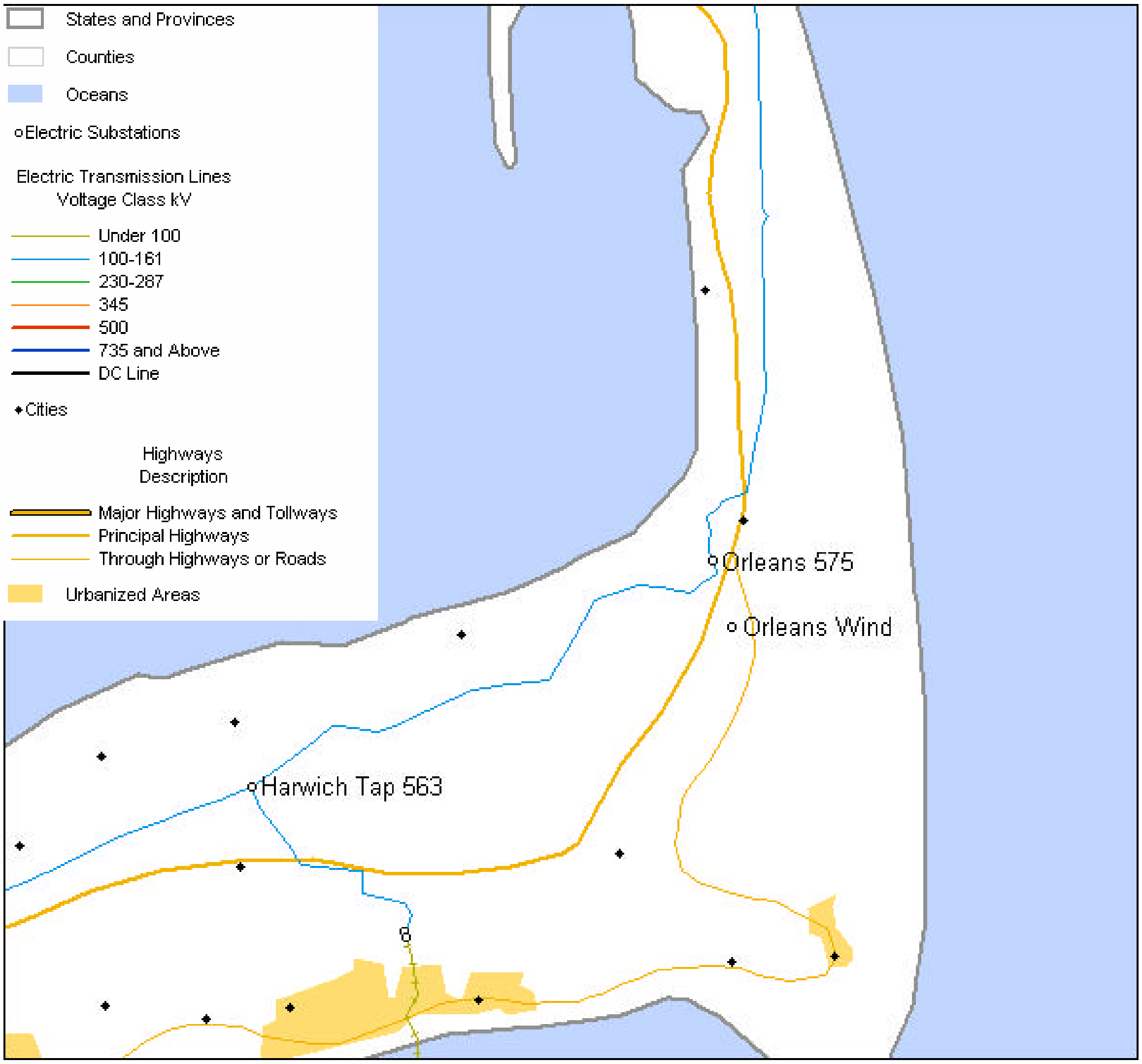

Figure 6-2 Regional Transmission Line

6.2 Power Consumption

One stated goal of a community wind energy project is to directly provide energy for Town of Brewster facilities. While the Commerce Park has no Town of Brewster loads, the other two locations do. Black & Veatch was unable to obtain electrical load data for either the Pumping Station or the Golf Course Parking Lot during the course of this review due to technical issues with the utility web site. As such, this report does not review the potential for electrical load offset at these locations. Black & Veatch does note that neither the Pumping Station nor the Golf Course Parking Lot is likely to have total loads that are particularly high as compared to the generation levels of a large wind turbine. While connection of a wind turbine at these sites can offset a significant portion of the loads at the sites, most of the turbine's generation will be exported and sold to the electrical grid. Therefore, for simplicity sake in this initial review, Black & Veatch has assumed all generation from the wind turbine will be exported and sold to the grid. A further evaluation of the potential interaction between a wind turbine and loads at these two sites will be performed in the feasibility study.

7.0 Environmental Concerns and Permitting

Given Brewster's location on Cape Cod, environmental concerns regarding a community wind energy project are expected to be an important component of the project's feasibility. Black & Veatch has prepared an initial list of likely environmental issues. Black & Veatch recommends a more complete environmental review be performed prior to committing to a wind energy project.

7.1 Potential Environmental Impacts

Black & Veatch reviewed information on environmental sensitivities at or near Brewster, based on publicly available information. The items listed in this section indicate some issues that need to be explored during a project environmental review.

7.1.1 Natural Heritage and Endangered Species Program

To determine which environmental concerns are likely to exist for a wind energy project in Brewster, Black & Veatch reviewed information obtained from the Massachusetts Division of Fisheries and Wildlife's Natural Heritage and Endangered Species Program (NHESP) web site (www.nhesp.org). This web site identifies areas of the state that are of particular concern for endangered wildlife and plant life. While this information is a good resource for an initial feasibility study, Black & Veatch would not consider the information below to be an exhaustive list, and would recommend a specific environmental review be done at the project site in future phases of project development.

The NHESP area designations reviewed and mapped for this site include:

- **Areas of Critical Environmental Concern (ACEC):** These are areas in Massachusetts that are considered special and highly significant due to their natural and cultural resources. Nominations for areas to receive ACEC designation are made by communities to the state Secretary of Environmental Affairs. Administration of the ACEC program is done by the Department of Conservation and Recreation.
- **Priority Habitat for Rare Species:** These areas are NHESP estimates of habitats for rare species. The boundaries of these habitats are considered approximate.
- **Protected and Recreational Open Space**: These are areas that have been designated at the state or community level as areas for limited or no development. The Massachusetts Geographic Information System (MassGIS), the service from where the data was obtained, indicated the accuracy of the identified open space locations was limited.

- **BioMap Core Habitats**: The BioMap program was completed in 2001 by NHESP, and identified areas considered to represent "habitats for the state's most viable rare plant and animal populations". BioMap Core Habitats and Living Water Core Habitats encompass almost 1.4 million acres, or about 28 percent of the land area of Massachusetts.
- **Certified Vernal Pools**: NHESP define vernal pools as "small, shallow ponds characterized by lack of fish and by periods of dryness." These pools are deemed critical to some wildlife, and are protected under a variety of state programs including the Massachusetts Wetlands Protection Act.
- **Living Waters Critical Supporting Watersheds:** These watersheds are identified as being critical for supporting Living Waters Core Habitats. They were identified in the Living Waters project completed in 2003 by NHESP.
- **Living Waters Core Habitats:** Similar to the BioMap Core Habitats, the Living Waters Core Habitats are those rivers, streams, lakes, and ponds critical to the biological diversity of Massachusetts

Figures 7-1 and 7-2 are maps showing the BioMap Core habitats and Living Waters Critical Supporting Watersheds identified near Brewster. There is a BioMap Core Habitat (C1245) and permanently protected open space defined for the entire Pumping Station location due to rare plant and animal species. Black & Veatch was unable to obtain information pertaining to the specific BioMap Core habitat; a detailed environmental review of the site would be performed in the feasibility study that would seek to determine the restrictions and the accuracy of the open space and habitat boundaries. The feasibility study would also determine which species are located at or near the site. Included in this review, would be the Brewster Alternative Energy Committee's interior exploration of the origination of the funding to purchase this land; which would help identify the applicable restrictions of land use.

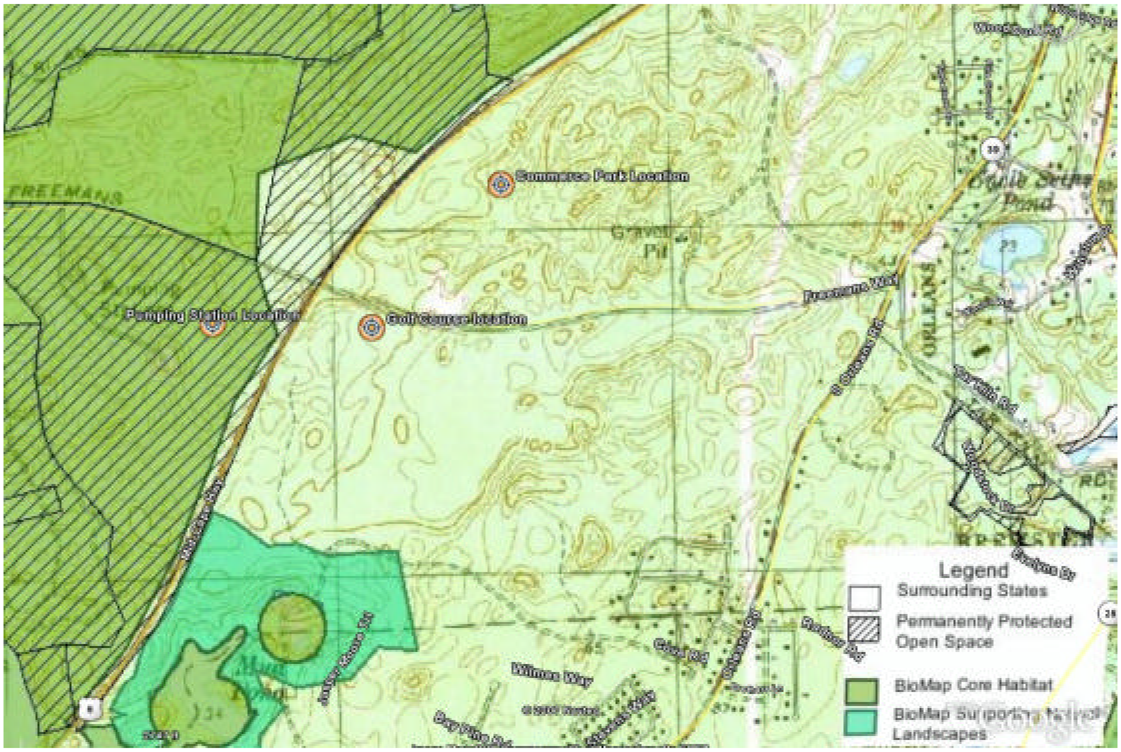

Figure 7-1 Environmental Protected Areas near Brewster

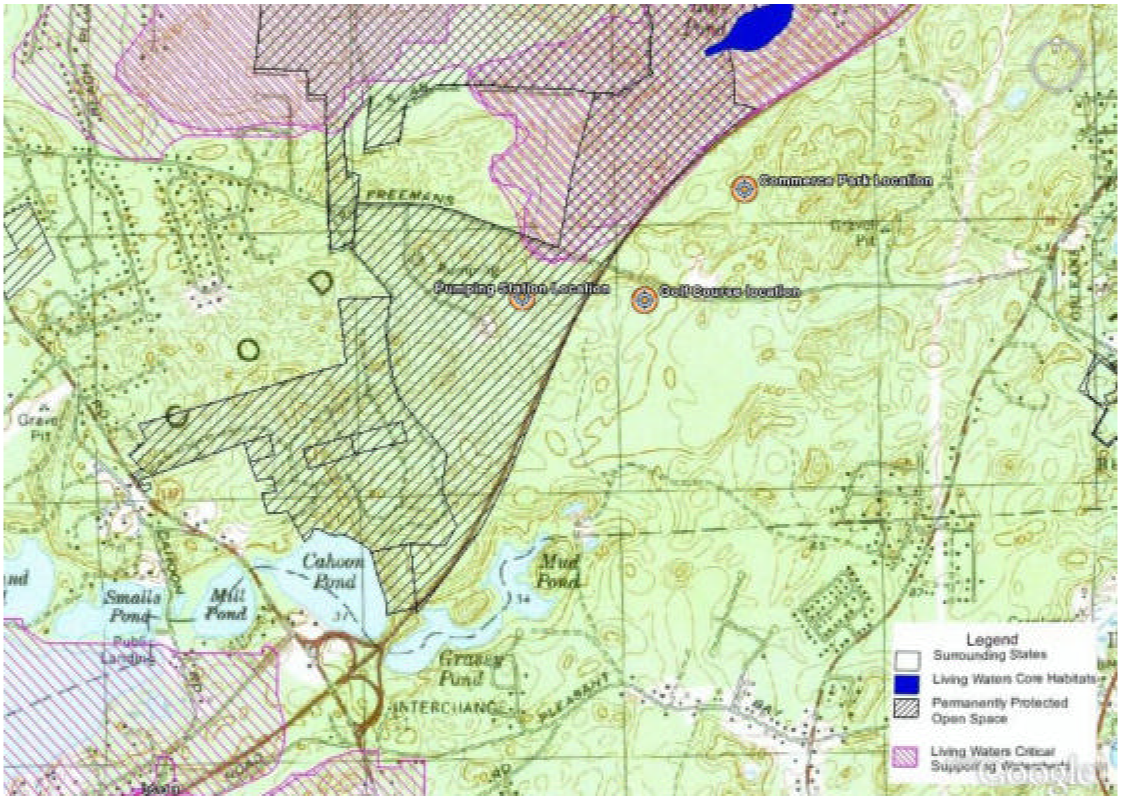

Figure 7-2 Protected Waters and Wetlands near Brewster

7.1.2 Avian Impacts

The largest biological concern for this project's development may be potential or perceived risk to avian species. During the permitting phase of project development, a wildlife impact study should be performed to identify any potential avian species that would be at risk. Modern wind turbines include slow rotating blades, and tower and hub designs that provide almost no perching or nesting points for birds. While most wind energy projects have little or no recorded bird strikes, it can be a significant problem at a few sites (such as Altamont, California, or the Mountaineer Wind Energy project in West Virginia). It is therefore important to determine if species known to be susceptible to wind turbine strikes can be found at the site.

An additional resource that may be beneficial for the review is the results of any wildlife studies performed for either the radio tower or cellular tower located 0.25 miles east of the Commerce Park site. Both towers are supported by a series of guy wires. These wires can be difficult to see, and since the tower presents numerous perching points, the wire could be far more dangerous to avian species that a wind turbine. Research done during the feasibility study and permitting stage should ascertain if any studies were done, and if those are available for review.

7.1.3 Nearby Residences

Some public concern is likely going to be generated regarding the visual and noise impacts of the project, and concerns for public safety. Black & Veatch recommends that visual simulations of project options be presented to the public at the first hearing of the project, including animations showing the rotational speed of the turbine. Additionally, noise readings should be taken and reviewed by acoustical experts prior to committing to a project, to ascertain if Massachusetts state requirements will be met. The current draft bylaws should be completed and voted upon as well before the project is finalized, to ensure the design meets the Town's requirements. Experience shows that sharing this information with the public early in the process can avoid unnecessary concerns regarding what the project might look and sound like, and ease fears of the potential dangers of the project. Black & Veatch will prepare some initial visual simulations of wind turbines during the feasibility study phase, once a project option has been selected. MTC and the Town of Brewster Alternative Energy Committee may wish to consider having additional simulations done in the future from other locations of likely public concern.

The Pumping station location is close enough to homes that issues regarding noise and safety may arise. While the turbine sites are located far enough from homes that even complete failure of the turbine's structure should not endanger them, public perception may be these that sites put the homeowners in undue risk. As mentioned earlier, Black & Veatch recommends these homeowners be contacted directly by the Town of Brewster, and their support on the project obtained, before committing to these sites.

Another issue often faced by community wind energy projects, or any wind project close to cities or landowners, is the project's potential to impact nearby property values. Some study work done in the U.S. has been unable to determine an impact, but this issue is being explored further. Black & Veatch cannot estimate if there will be an impact at these locations.

7.1.4 Airports

The closest airports to the Brewster locations are the Chatham Municipal Airport to the north, and the Barnstable Municipal Airport to the southwest. The Chatham Municipal Airport is approximately 3.7 miles from the closest wind turbine site in the Commerce Park location and the Barnstable Airport is about 14 miles, from the turbine site at the Pumping Station. According to Federal Aviation Administration (FAA) Advisory Circular 70/7460-2J, a Notice of Proposed Construction must be filed with the FAA for the construction of any structure over 200 feet (61 meters) tall or within a certain distance-height zone from commercial or military airports. All commercial-scale wind turbines are more than 200 feet tall, so a notice will be required to be filed with the FAA and will require markings and lighting.

An airspace obstruction study was performed by Aviation Systems Inc. (ASI) in November 2006, whose review focused on a location within the vicinity of the Pumping Station Location. The study was based on a total wind turbine height of 121 meters (397 feet; hub height plus one half rotor diameter) above ground level (AGL), resulting in a total overall height of 155m (509 feet) above measured seal level (AMSL). ASI study results indicate the following:

- **The maximum non-exceedence height of a structure at the studied location is 71 meters (232 feet) AGL:** This indicates that an extended study will be necessary; however, ASI also indicated that the operational procedures of the Chatham Municipal airport are not affected at the height studied and presumes that the FAA should issue a determination of no hazard for a turbine in this area.
- **The studied location is within 60 nautical miles of a long range radar site:** An individual assessment of the effects that a wind turbine could have upon the North TURO Joint use long range radar site will

need to be reviewed. The FAA may object to the project until this assessment is performed.

- **FAA may limit the structure to 93 meters (306 feet) AGL:** The FAA may apply Category D traffic pattern criteria to this site, limiting the total height of a structure; however, ASI expects that category C traffic patterns will be applied due to the length of the Chatham Municipal Airport's runway length (3000 feet) but did not indicate what limit the FAA would place upon a structure in that category.

Per direction from MTC and the Town of Brewster Alternative Energy Committee, Black & Veatch will submit notices of intended construction (Form 7460-1) to the FAA for Vestas V80s (or similar) at each of the sites under consideration and determine the actual FAA height restriction for a wind turbine at the pumping station location. Black & Veatch would also engage the military liaison to address the issue of potential impact to the long range radar installation; the results for each of these reviews would be provided with the results of the feasibility study.

7.2 Permitting Requirements

As with any energy project or significant construction project, a community-scale wind project in Brewster will require local, state, and federal permits. Black & Veatch will prepare a list of likely permits as part of the feasibility study, but likely permits for the project may include:

- Federal Aviation Administration (FAA) Notice of Proposed Construction and Alteration
- Federal Energy Reliability Commission (FERC) Exempt Wholesale Generator (EWG) and Qualifying Facility (QF) Status
- United States Environmental Protection Agency (EPA) Stormwater Discharge Permit
- Massachusetts Department of Public Utilities (MDPU)/Energy Facility Siting Board (EFSB) Site Certification
- Massachusetts Office of Consumer Affairs and Business Regulation – Division of Energy Resources (DOER) Statement of Qualification for Massachusetts Renewable Portfolio Standard (RPS)
- Massachusetts Aeronautics Commission (MAC) Request for Airspace Review
- Massachusetts Historical Commission (MHC) Archeological and Historical Review

- Barnstable County – Cape Cod Commission Development of Regional Impact Permit
- Town of Brewster Building Permit
- Town of Brewster Zoning Department Conditional Use Permit

8.0 Potential Wind Project Options

There are two general designs of community wind energy projects that utilize a large turbine; projects where the power is sold to the local utility or large energy consumer, and co-metering projects where an on-site load is satisfied before selling power to the utility. If a single large turbine were to be set up to sell all of the energy it produces, the Town of Brewster could build the project as an investment, and sell all the power generated without directly consuming it on or near the site. Alternatively, the Town could lease the land to a private developer and receive royalties from the project rather than making a direct investment. As discussed in earlier sections, this option would require an upgrade of the distribution lines near each of the site locations to support wind generation.

The other design option, co-metering, is configured at a location where the Town of Brewster has an electrical load that would allow the Town to use what energy is needed at the site, and sell the excess energy to a utility or large energy consumer. With this option, the Town would save money on the electrical bills of the load to which the wind turbine is connected, and make money from the sale of the electricity.

While the co-metering design option will also require upgrades to the distribution lines near each of the project sites, the electrical connections for each of the loads would need to be reconfigured so that they had a single point of connection with a shared utility meter. The wind turbine would be connected behind that meter, and would meet the needs of the loads on the site before sending excess power out to the grid. Such an approach also requires careful planning with the local utility providing power to the site.

Since the Town of Brewster's electrical load information was unavailable at the time of this screening study, Black & Veatch is unable to provide a recommendation on which project design option would best fit the town's needs. Black & Veatch would be able to perform this review in a follow-up to the report once this data is made available.

9.0 Preliminary Energy Production Estimate

Based on the wind resource data collected at the Golf Course Parking Lot Location me tower, Black & Veatch estimated the potential energy production for the three project options discussed in Section 8. The method and assumptions for these estimates are discussed below.

9.1 Wind Turbine Power Curves

The Vestas V80 and GE 1.5MW turbines were the large wind turbines evaluated for this report. The tower height option chosen for both the V80 and GE 1.5MW was 80 meters. A lower tower option would decrease the visual impact of the wind turbine, but would also significantly lower the turbine's production (due to the high wind shear in Brewster).

Based on site elevations between 15 and 28 meters (50 and 90 feet) and the annual average temperature data collected by the RERL met tower (approximately 13ºC or 55ºF), Black & Veatch determined the site's average air density was about 1.23 kg/m^3. The sea level air density power curves from wind turbine manufacturers reference 1.225 kg/m^3, so Black & Veatch used sea level power curves for the Vestas V80, and the GE 1.5MW, a comparison of the power curves is shown in Table 9-1.

Table 9-1. Wind Turbine Power Curves.

Hub Height Wind Speed, m/s	GE 1.5MW Output Power, kW	V80 Output Power, kW
0	0	0
1	0	0
2	0	0
3	0	0
4	43	3
5	131	99
6	250	260
7	416	465
8	640	735
9	924	1,015
10	1,181	1,345
11	1,359	1,639
12	1,436	1,775
13	1,481	1,797
14	1,494	1,802
15	1,500	1,802
16	1,500	1,802
17	1,500	1,802
18	1,500	1,802
19	1,500	1,802
20	1,500	1,802
21	1,500	1,802
22	1,500	1,802
23	1,500	1,802
24	1,500	1,800
25	1,500	1,800

9.2 Production Losses

Black & Veatch has examined the option of a large turbine for one of sites previously discussed to estimate the potential production losses that might impact wind turbines. Each loss factor is discussed below, and summarized in Table 9-2.

Table 9-2
Project Production Loss Factors

Loss Type	Loss Percent	Loss Adjustment Factor
Topographic Effect	0.0%	1.00
Wake Effect	0.0%	1.00
Turbine Availability	3.0%	0.97
Turbine Power Curve	0.0%	1.00
Grid Availability	0.5%	0.995
Electrical Losses	1.0%	0.99
Columnar Losses	0.0%	1.00
Blade Contamination	1.0%	0.99
Icing	1.0%	0.99
Model Estimate	0.0%	1.00
High Wind Hysteresis	0.0%	1.00
	Product of Loss Factors	**0.9365**

- **Topographic Effect:** This is the loss due to wind speed reductions between the met tower and turbine caused by the site's topography.
- **Wake Effect:** This is the energy loss due to the effect one turbine will have on another, or the wake caused by any structure on the wind turbines.
- **Turbine Availability:** Wind turbine manufacturers will specify an availability level to be covered in a warranty (this may be difficult to obtain for single turbine installations). This value assumes the turbine's availability is only at that warranty value.
- **Turbine Power Curve:** The wind turbine manufacturer will warranty a performance level from the turbine at a percentage of the power curve values (this may also be difficult to obtain for a single turbine installation.) Typical warranty levels are 95 to 97 percent of published power curve. However, industry practice is usually not to consider this as a potential loss, given most wind turbines operate at or slightly above their published

power curves. For this study, Black & Veatch left the value as a 0 percent loss.

- **Grid Availability:** An estimate is made as to the amount of time the utility (or in this case, the electrical system of the plant) will be available to receive power from the project. All grid systems are off-line periodically for maintenance, and projects in more remote locations will be connected to weaker grid systems that are more prone to failure. Losses for grid availability vary between 0.1 percent for very strong grid system to as high as 5 percent for weak systems (and even larger for systems outside the US). As Black & Veatch has no specific information on grid reliability in the project area, an estimated loss of 0.5 percent was assumed.
- **Electrical Losses:** Losses in the lines and electrical equipment prior to the plant's revenue meters are covered by this factor. Points of significant electrical losses in a wind energy project usually include the underground and overhead distribution lines connecting the turbines to a substation, and the substation's primary transformer. Typical electrical loss values range from as low as 1 percent to 10 percent or more, depending on the layout and equipment used. As Option 1 is spread out over a relatively large area, some additional losses will be experienced. By directly connecting the wind turbines in Options 2 and 3 to the load centers, the electrical losses are minimized.
- **Columnar Losses:** If a project of many wind turbines is arranged in rows, turbine manufacturers may require the shutdown of some turbines when the winds are coming from directions parallel to the rows. These losses will not apply to the options defined in this report.
- **Blade Contamination:** Wind turbine performance is sensitive to the cleanliness of the turbine's blades. In areas of high dust or insects, contamination can build on the wind turbine blades that will limit the turbine's performance (causing losses up to 5 percent or more). Often the blades are cleaned by occasional rainfall, but in some areas periodic blade washing is required. As the plant is not an area of high dust, the potential for blade contamination is fairly low and due mostly to insects. As such, an annual loss of 1 percent was assumed for blade contamination.
- **Icing:** During winter storms, snow and ice will build on the wind turbine blades causing the same degradation as caused by dust and insects. While this contamination will build much faster than summer contamination, it is

often cleared after a few hours of direct sunlight (even at continued subzero temperatures). Given the anticipated likelihood of several significant storms per winter, a loss of 1 percent was assumed for the lost energy due to icing.

- **Model Estimate:** Black & Veatch estimated the performance of potential wind turbines using manual calculations within a basic spreadsheet. While this approach can have significant uncertainties in complex terrain, it is believed to be fairly accurate for Brewster. Therefore, no losses were assumed due to wind model accuracy.
- **High Wind Hysteresis:** When wind speeds exceed the operational range of a wind turbine, the turbine shuts down to protect itself. Such shut-downs normally require the turbine to remain offline for several minutes, regardless if the wind speed returns to the operational range. Sites with a significant number of these high wind events suffer lost energy due to this hysteresis effect, which is additional to the amount of time the average wind speeds remain above the cut-out wind speed. As the Project site does not have a significant number of high wind events on record, no losses due to this hysteresis effect were applied.

9.3 Production Estimates and Comparisons

Based on the wind analysis discussed in Section 4, Black & Veatch estimated the production for the Vestas V80 and GE 1.5MW. The data was "binned" by hub height wind speed for each turbine to determine the number of hours per year the winds would be within a 1 m/s bin (for instance, the 5 m/s bin represents all wind speed data points between 4.5 m/s and 5.5 m/s). With the hours per bin known, the total energy produced each year from winds within each bin was estimated and summed to determine the total annual gross production from the turbine. Each wind turbine installation is subject to losses discussed in Section 9.2. These losses were applied to the gross energy estimate to determine the project's net energy estimate. Finally, a capacity factor was calculated which represents the net annual generation compared to maximum possible generation from the wind turbine (a value of 100% would mean the turbine would operate at rated power every hour of the year; a typical capacity factor for a project in the Northeast U.S. is about 30 percent). While more than a year of data was available (Feb 1, 2006 thru March 28 2007); however, Black & Veatch determined that the first few days of February has missing or invalid data. In order to work with a full year of data, or 8760 hours, Black & Veatch calculated the annual production based on data a stream beginning March 1, 2006 and ending February 28, 2007.

The resulting energy and capacity factor estimates are shown in Table 9-3. Figures 9-1 and 9-2 show the wind turbine power curves and wind speed frequency distributions used to create the production estimates. Figure 9-3 compares the monthly generation levels of each wind turbine option.

Table 9-3
Brewster Production Estimates

	V80		GE 1.5MW	
Month	**MWh**	**C.F.**	**MWh**	**C.F.**
March	418	31%	383	34%
April	423	33%	390	36%
May	392	29%	358	32%
June	296	23%	278	26%
July	308	23%	287	26%
August	221	17%	213	19%
September	282	22%	265	25%
October	470	35%	427	38%
November	326	25%	301	28%
December	458	34%	418	37%
January	541	40%	484	43%
February	458	38%	409	41%
Annual (P50)	**4,591**	**29.0%**	**4,214**	**32.0%**

Notes: C.F. is Capacity Factor P50 refer to the probability of exceedence, as discussed in Section 9.4.

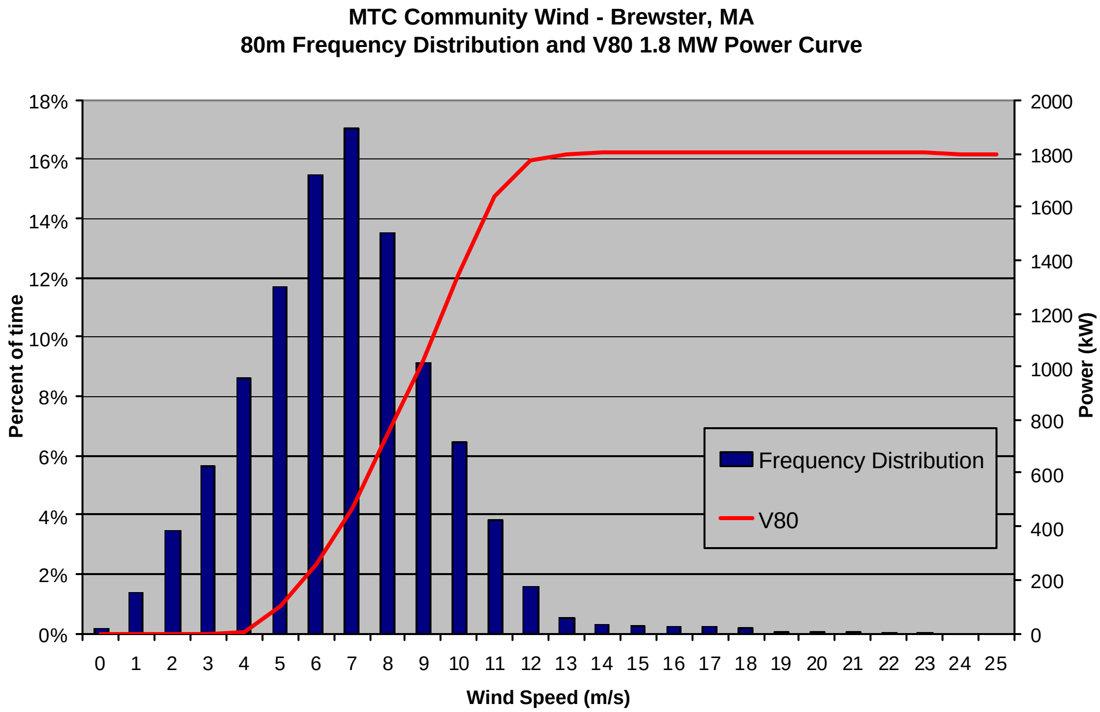

Figure 9-1 80m Wind Distribution and Vestas V80 Power Curve

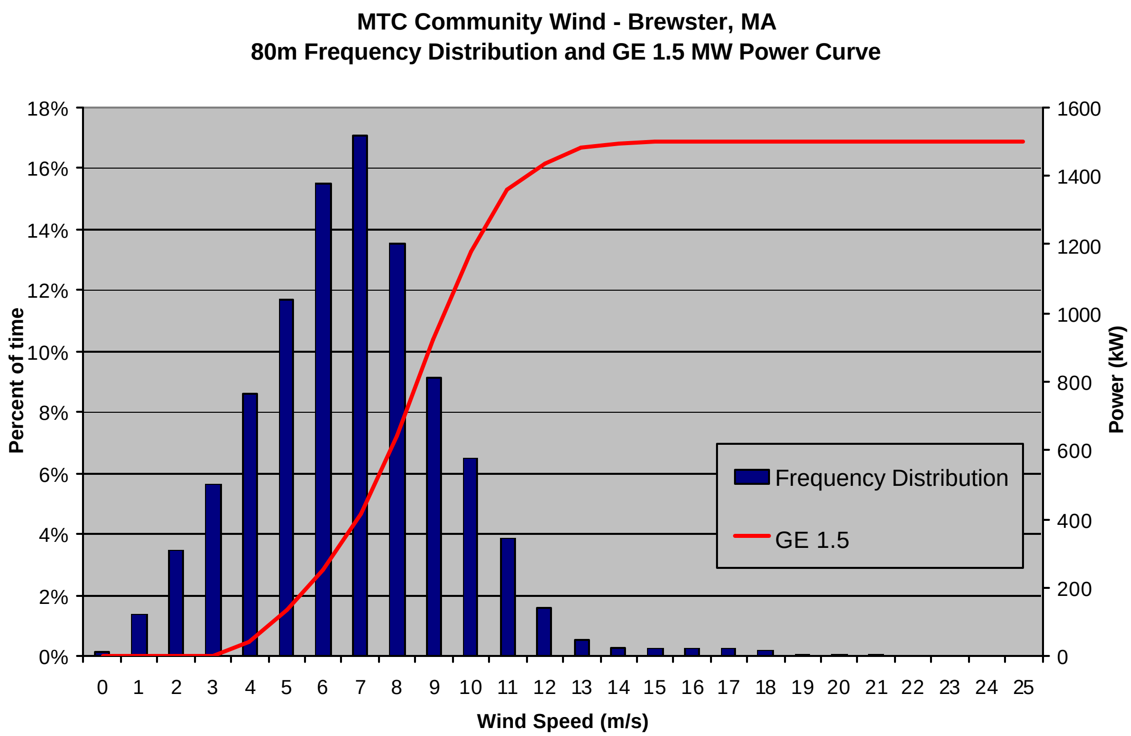

Figure 9-2 80m Wind Distribution and GE 1.5MW Power Curve

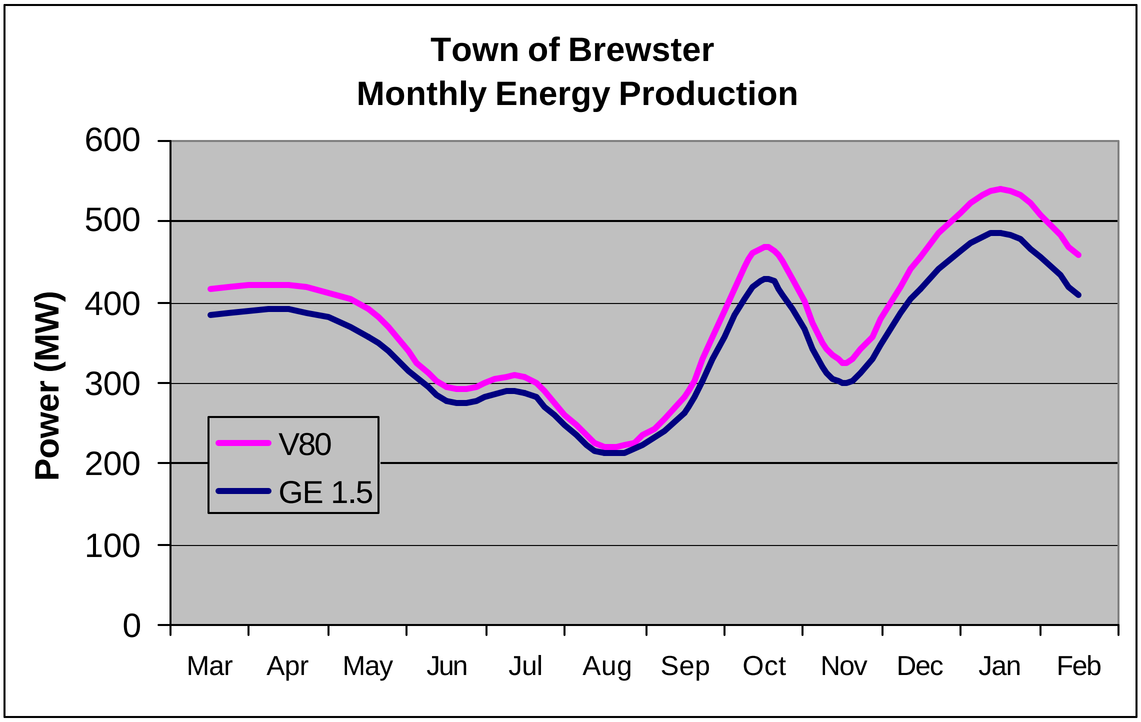

Figure 9-3 Monthly Production Estimates

9.4 Uncertainty Analysis

Based on the analysis detailed above and in Section 4, Black & Veatch has estimated the short-term average wind speed for Brewster to be 5.83 m/s at 49 meters above ground level, and 7.18 m/s at 80 meters above ground level. The corresponding short-term average production for the various turbine types and project options were presented as the Annual Average (P50) in Section 9.3. These values correspond to the 50 percent confidence value estimates, meaning that there is a 50 percent chance that the true long-term average wind speed is higher, and a 50 percent chance it is lower. To determine the sensitivity of the production to variations in wind speed, and to estimate the magnitude of variations possible, the following uncertainty analysis is performed.

- **Long-term wind speed variability:** this is a measure for how well understood the long-term wind resource is, and is determined by the length of the long-term data set analyzed.
- **Correlation standard error:** this value is a measure of how well the on-site data correlated to the long-term data source.

- **Anemometer calibration:** this is the stated calibration of the primary anemometer used to measure the on-site wind resource (or in our case, the RERL Brewster met tower). For uncalibrated instruments, the standard accuracy of the anemometer published by its manufacturer is used. For instruments left installed past their calibration period, or for longer than one year for uncalibrated sensors, an increase in the calibration uncertainty may be applied for expected sensor degradation.
- **Topographic and wake modeling:** the models used to estimate the effects of topography and turbine wakes have uncertainty associated to them.
- **Wind variability:** this is an single year estimate of the long-term variability, signifying the uncertainty of estimating the "next year's" power production.

Due to the unavailability of a long-term reference station, this site screening report does not include probability of exceedence values for P90 or P99. Once a reference data set has been identified that has a strong correlation to the golf course parking lot met tower, Black & Veatch will be able to provide these estimates in a follow-up report.

10.0 General Project Cost Estimate

Black & Veatch prepared a general estimate for the installation of a single commercial-scale wind turbine at a site in Brewster. The estimate involves the installation of a turbine rated about 2 MW (specific turbine types have not been considered for this report). A breakdown of this general estimate is provided in Table 10-1. A more detailed estimate will be provided in the feasibility study.

Readers may note the costs per kW are significantly higher than the often quoted industry model of $1,000 per kW for wind farms. The reason for the higher cost is that all the study, engineering, construction mobilization, and permitting work must be amortized over only one turbine, while these costs are spread across many turbines for a larger wind farm. These prices also reflect the current exchange rate between the U.S. Dollar and the Euro (which is the basis of most wind turbine pricing). General increases in steel and concrete prices, and a large current demand for wind turbines in the U.S., have also increased the costs of wind energy projects. Also, it should be noted that high demand has made it difficult to obtain wind turbines before 2009.

Table 10-1
General Cost Estimate Breakdown

Cost Parameter	**Amount**
Planning and Study Costs	$200,000
Engineering	$200,000
Environmental Permitting	$100,000
Wind Turbine Procurement	$2,400,000
Wind Turbine Shipping	$200,000
Wind Turbine Installation/Site Construction	$500,000
Electrical Connection	$100,000
Utility Upgrades	$250,000
5-Year Warranty and Service	$100,000
TOTAL PROJECT COST	**$4,050,000** **$2,025/kW**

11.0 Preliminary Financial Analysis

Black & Veatch completed an economic analysis to help characterize the economic performance for a community wind project in Brewster using economic criteria established by MTC.

The value for the energy generated at a community wind energy project in Brewster will fall into two general categories: the electricity used to offset the consumption at Brewster facilities, and the electricity sold into the grid. The value for the energy offset is the same at which the Town of Brewster purchases energy, likely between $100 and $120 per MWh. Any energy not consumed at the location where the wind turbine is installed will be purchased by a utility or large power consumer at a value negotiated in a power purchase agreement. As the load information was not available for the Pumping Station or Golf Course Parking Lot sites, Black & Veatch assumed all energy generated by the turbine was sold through a power purchase agreement. This assumption will be re-evaluated in the feasibility study.

Because the electricity from a wind turbine is generated without the emission of air or water pollutants, the energy has additional value. This value is usually realized through the creation and sale of Renewable Energy Certificates (RECs), which are tradable certificates signifying a set amount of pollution avoided through wind energy. Black & Veatch reviewed the general economic payback for a community wind project in Brewster using economic criteria established by MTC. These values are discussed in this section.

11.1 Economic Model Overview

The financial model consists of a spreadsheet-based, 20-year annual cash flow (pro forma) model. The model takes into account the project's capital and operating costs, performance characteristics (e.g., capacity factor), REC sales, and energy sales. The model calculates the cash flows given these assumptions and can then produce the payback. The model assumes Brewster will use current revenue (equity) and debt to finance the project(s).

The primary output is the payback of each project. The payback is the amount of time in years it takes for the revenues to pay for the initial investment. Discounted payback takes into account the time value of money, and discounts the future savings. In general, projects that result in a lower payback are preferred to those with a higher payback.

The results are driven by many assumptions made regarding project capital costs, operating costs, retail cost of energy, REC values, and escalation of costs and revenues.

Although this is a relative simple economic model, in general, the results of the analysis should be sufficient to indicate general project viability, to differentiate between the various possible scenarios. If the project proceeds, it is recommended that a more detailed financial model be constructed to more accurately reflect the details of the project.

11.2 Base Case Scenario Assumptions

The cost and performance assumptions for this study come from the cost estimates in the previous section (Table 10-1). Financial assumptions came from Black & Veatch estimates. These plants include a provision for Renewable Energy Certificate (REC) sales, assuming the MTC "standard offer" of $40/MWh in the first ten years, and $15/MWh from years 11-20. These renewable energy certificates represent the environmental value of the clean energy the turbines will produce. MTC has committed to purchasing the RECs at $40/MWh for the first ten years, $15/MWh is their estimate of the REC value in future years.

Table 11-1. Economic Analysis Assumptions.

Assumption	Value	Basis
Project Assumptions		
Capacity Factor	28.5%	Black & Veatch production estimate
Capital Costs	$4.05 million	Black & Veatch cost estimate
Operations & Maintenance Costs, years 1-5 $ per Wind Turbine	$0	O&M costs for first five years are zero due to turbine warranty (included in Capital costs).
Operations & Maintenance Costs, years 6-20 $ per Wind Turbine	$35,000	B&V estimate, based on project experience
Wholesale Power Rate	$50/MWh	From MTC
Wholesale Power Escalation	2.5%	The price of wholesale power is modeled to escalate by 2.5% annually.
Brewster Financial Assumptions		
Annual Inflation Rate	2.50%	B&V estimate
Nominal Discount Rate	5.0%	B&V Assumption – this is the discount rate for the town.
Debt Rate	5.50%	B&V estimate of debt financing rate available to Brewster
Debt Equity assumption	80/20	Assumed split between equity and debt for Brewster
Developer Financial Assumptions		
Annual Inflation Rate	2.50%	B&V estimate
Equity IRR Hurdle	12%	B&V Assumption – this is the required return on

Table 11-1. Economic Analysis Assumptions.

Assumption	Value	Basis
		equity for the developer.
Debt Rate	8.0%	B&V estimate of debt financing rate available to Developer
Debt Equity assumption	50/50	Assumed split between equity and debt for developer
Production Tax Credit	$19/MWh	For years 1-10, escalates at inflation
REC Price Assumptions		
REC Price years 1-10	$40/MWh	This is the standard offer from MTC for RECs
REC Price years 11-20	$15/MWh	This is what MTC is predicting REC prices will be in MA after 2017.

11.3 Results

The results for each option are shown in Table 11-2. The results show the expected payback for both ownership options. The payback periods are very long, due to the high costs of the wind plants compared to the wholesale rates. The discounted payback for the Brewster-owned option is under 20 years, indicating the project makes economic sense at a 5 percent discount rate. As this is already a low discount rate, the economics appear marginal at this time.

Table 11-2. Payback Results

Owning Entity	Return on Equity	Simple Payback (years)	Discounted Payback (years)
Town of Brewster	16%	10.3	16.20
Developer	12%	10.18	22.99

12.0 Project Management Considerations

None of the project options identified would require an on-site operations or maintenance building. It is expected that any spare parts for the wind turbine can be stored within existing facilities at the Pumping Station or elsewhere in Brewster. During the turbine's warranty period, turbine performance will be monitored remotely by the manufacturer who will be responsible for dispatching repair personnel as needed. It is likely the manufacturer will request Town of Brewster personnel to perform periodic visual inspections of the wind turbine, but maintenance and repair work will be performed by qualified technicians from the nearest large project. Operations and maintenance arrangements will be determined with manufacturers during the turbine purchase negotiation.

When the warranty and service contract period expires, the Town of Brewster will have the option to continue to work with the turbine manufacturer, contract with a third party provider, or train Town personnel to perform these services. The best solution will depend somewhat on how many wind energy projects are installed in the region over the next few years. If an independent service provider or vendor service center is sited in or near Massachusetts, obtaining a contract with that entity will likely be the most cost effective solution.

Appendix A. Wind Resource Maps

Wind resource map of Massachusetts was downloaded from the New England Wind Map web site (http://truewind.teamcamelot.com/ne/).

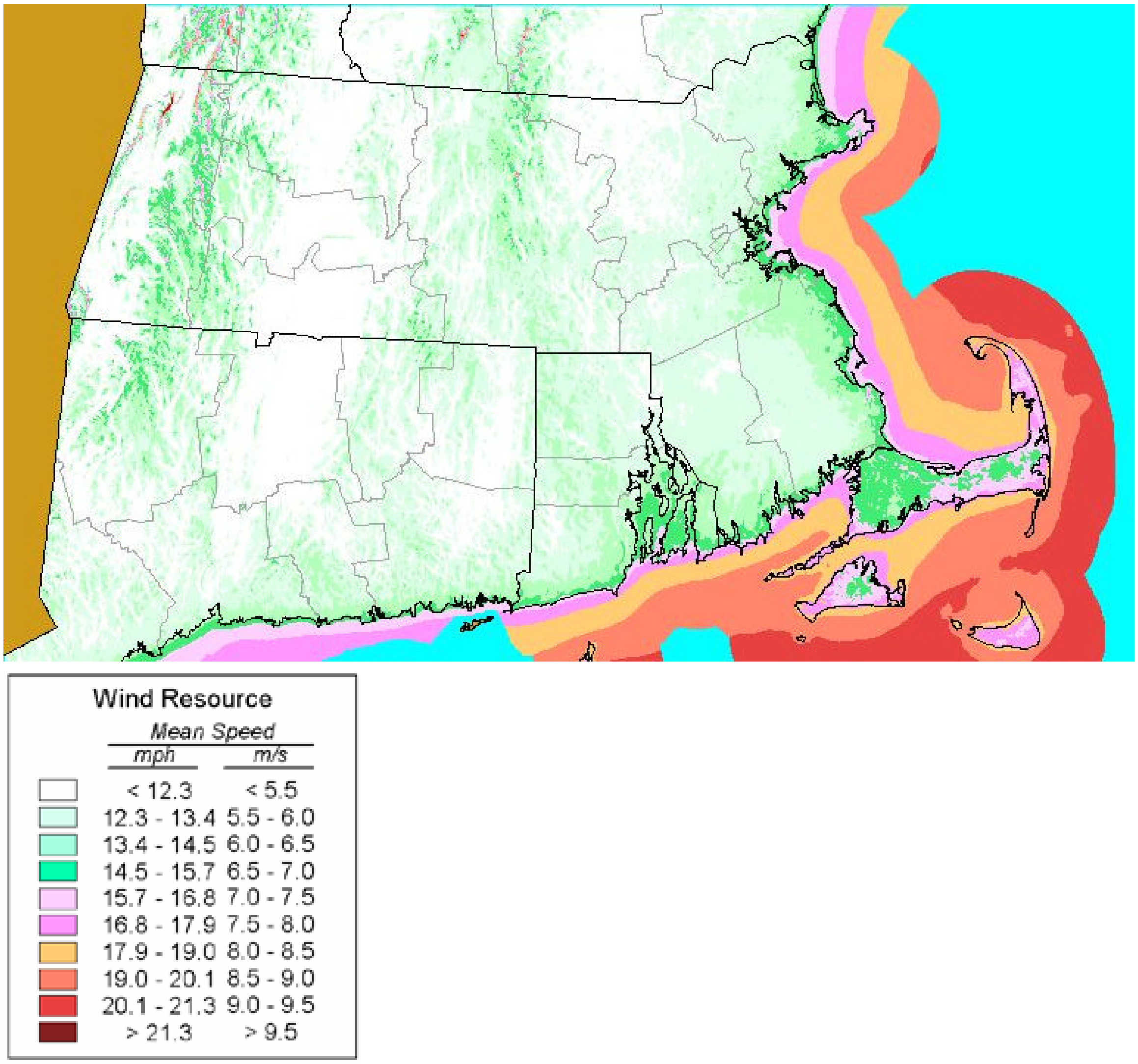

Figure A-1 Massachusetts Wind Resource Map

Appendix B. 3-D Wind Turbine Renderings

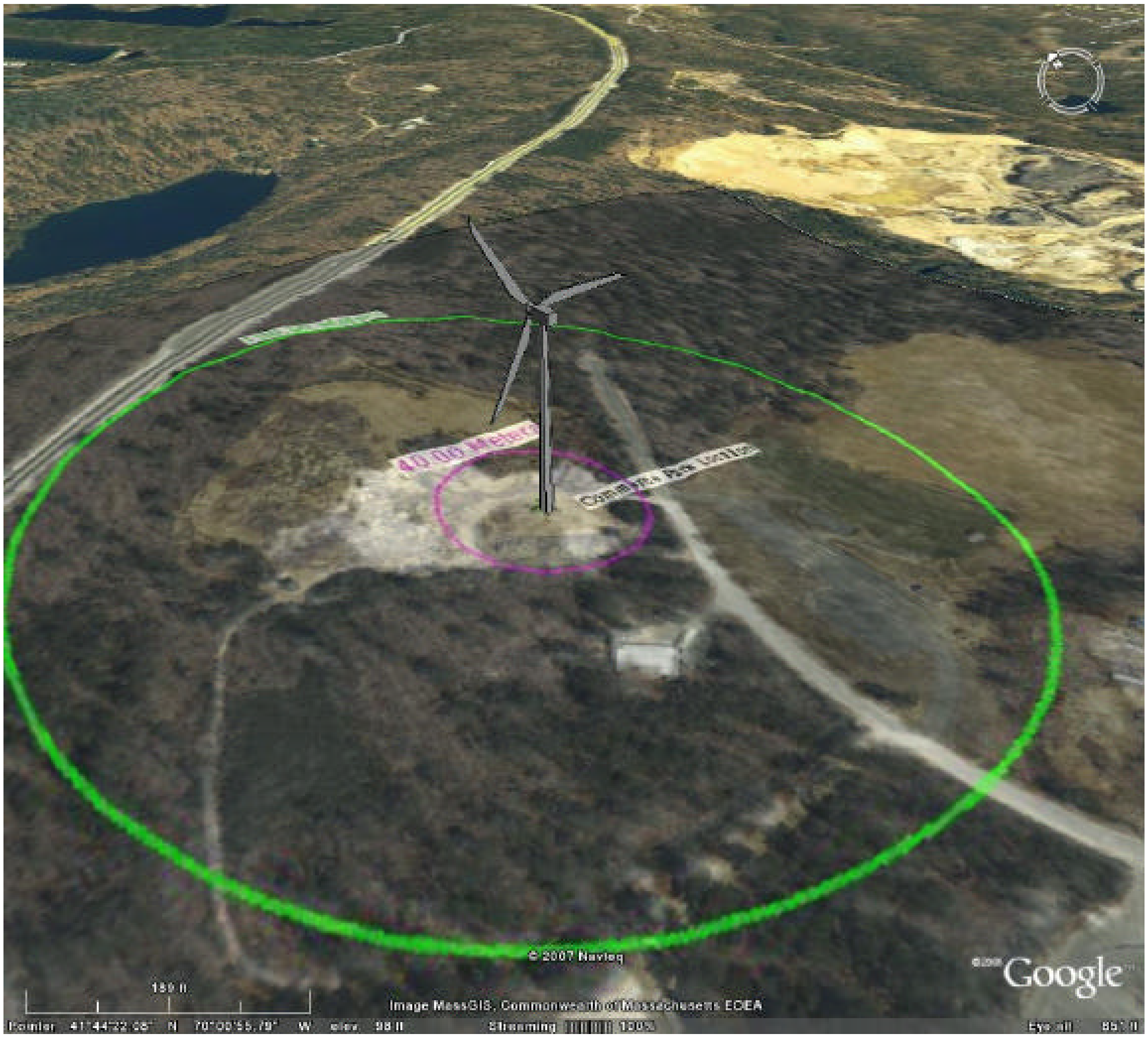

Figure B-1. Commerce Park Location.

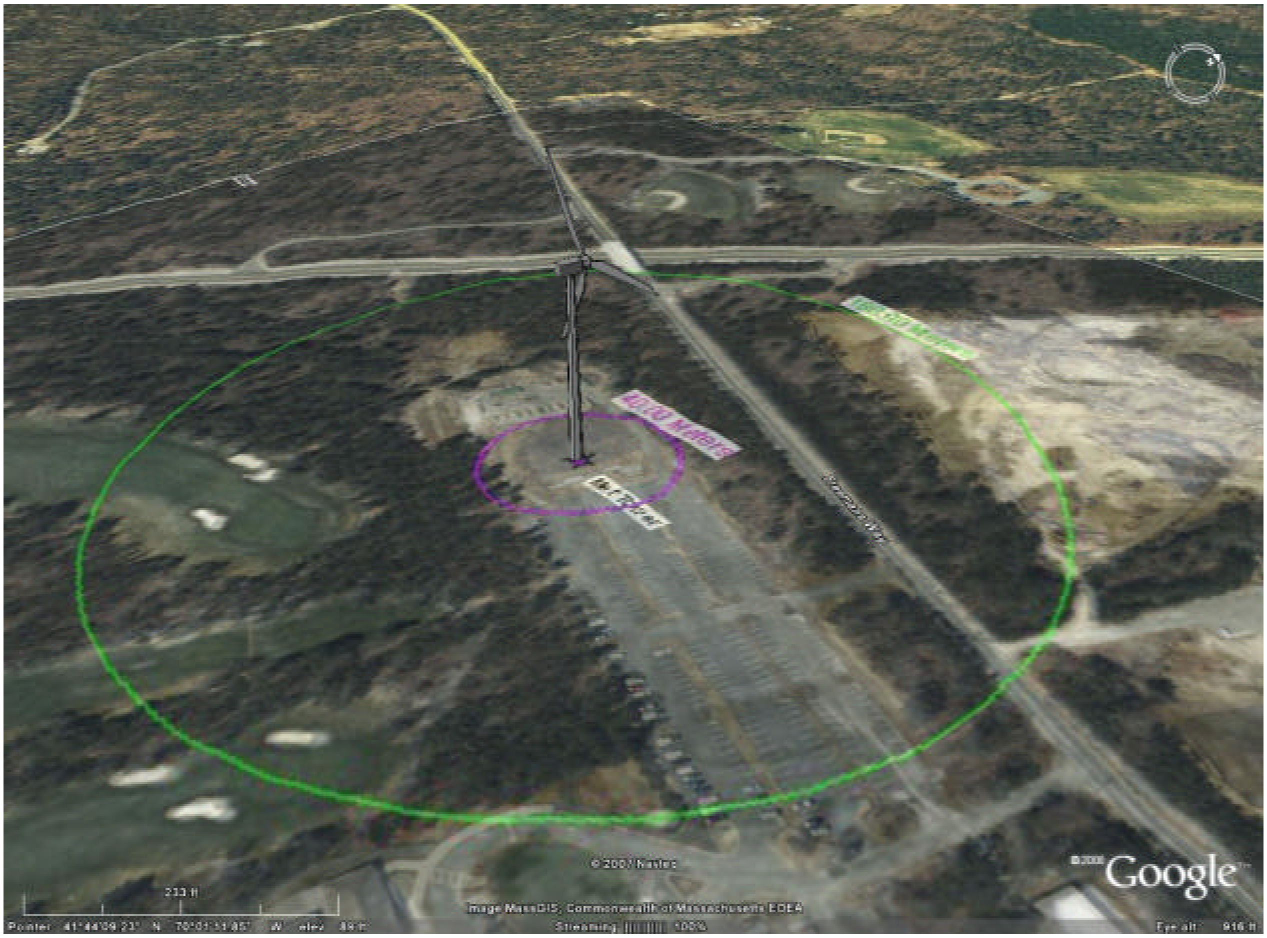

Figure B-2. Golf Course Parking Lot Location.

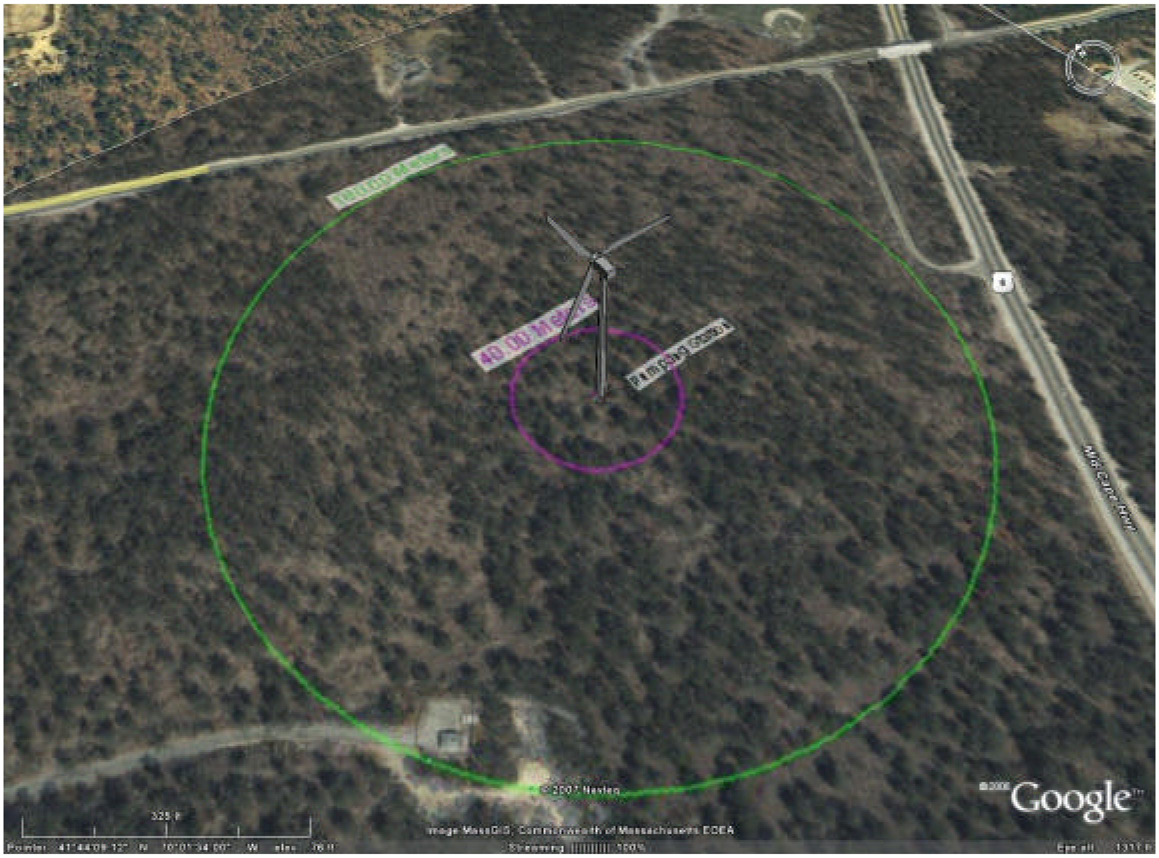

Figure B-3. Pumping Station Location.