

TOWN OF ORLEANS WIND ENERGY FEASIBILITY STUDY

April 8, 2005

Supplemental Review of Two Turbines

Prepared by:

Global Energy Concepts LLC



R. W. Beck, Incorporated



**Funded by the Community Wind Collaborative
of the Renewable Energy Trust**





Via E-mail

April 8, 2005

Mr. Nils Bolgen
Massachusetts Technology Collaborative
Community Wind Collaborative
75 North Drive
Westborough, MA 01581-3340

Dear Mr. Bolgen:

**Subject: Community Wind Collaborative
Town of Orleans Supplemental Feasibility Study**

Enclosed is our supplemental feasibility report for wind energy generation at Orleans which considers a two-turbine approach.

The report has been prepared as an addendum (Appendix D) to our earlier feasibility study report issued on January 21, 2005 and revised on March 16, 2005 and may be inserted to the back of that report accordingly. An addendum page to that report's *Table of Contents* is also provided.

On behalf of Global Energy Concepts and R. W. Beck, we welcome this opportunity to support the Town of Orleans and the MTC in its Community Wind Initiative. If you have any questions, you are welcome to call me at (508) 935-1846 or email me at pcleri@rwbeck.com.

Very truly yours,

On behalf of the R. W. BECK, INC./GLOBAL ENERGY CONCEPTS Team

A handwritten signature in black ink that reads "Paul D. Cleri".

Paul D. Cleri, PE

PDC\

c: G. Meservey, Orleans
K. Galligan, Cape Light Compact
K. Conover, GEC
D. Patton, RWB

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APPENDIX D
SUPPLEMENTAL STUDY OF TWO TURBINES

SUPPLEMENTAL STUDY OF TWO TURBINES

Executive Summary

On the basis of our level of review and the documentation reviewed, this supplemental study supports the following conclusions:

- The Orleans watershed area appears to be a viable location for installation of two wind turbines. Overall, we did not uncover any major technical hurdles to the installation of two 1.5 MW class wind turbines at Site 1 and Site 3 on the proposed site, including transportation of equipment to the site.
- Two wind turbines can be electrically interconnected at the watershed's iron and manganese treatment plant's electric service connection to export power to the utility grid as well as supply the intermittent needs of the treatment plant.

Introduction

This supplemental feasibility study for wind energy generation at Orleans considers a two-turbine approach.

This supplemental study has been prepared as an addendum (Appendix D) to our earlier feasibility study report issued on January 21, 2005 and revised on March 16, 2005 (the "Report") and may be inserted to the back of the Report accordingly. An addendum page to the Report's Table of Contents is also provided.

This supplemental study has been prepared on the same basis as that used for the Report; the reader should refer to Section 1 of the Report. In general, the scope of discussion of this supplemental study refers only to the additional turbine at Site 3 and any changes to the project concept described in the Report that result from the addition of the second turbine at Site 3.

Conceptual Design

The reader should refer to Section 4 of the Report for a complete understanding of the basis of review and analysis and subsequent results of this section herein.

Wind Turbine Locations

Figure 10 shows the proposed layout of the two turbine project utilizing the GE 1.5sl unit. The turbines are to be located at Site 1 and Site 3.

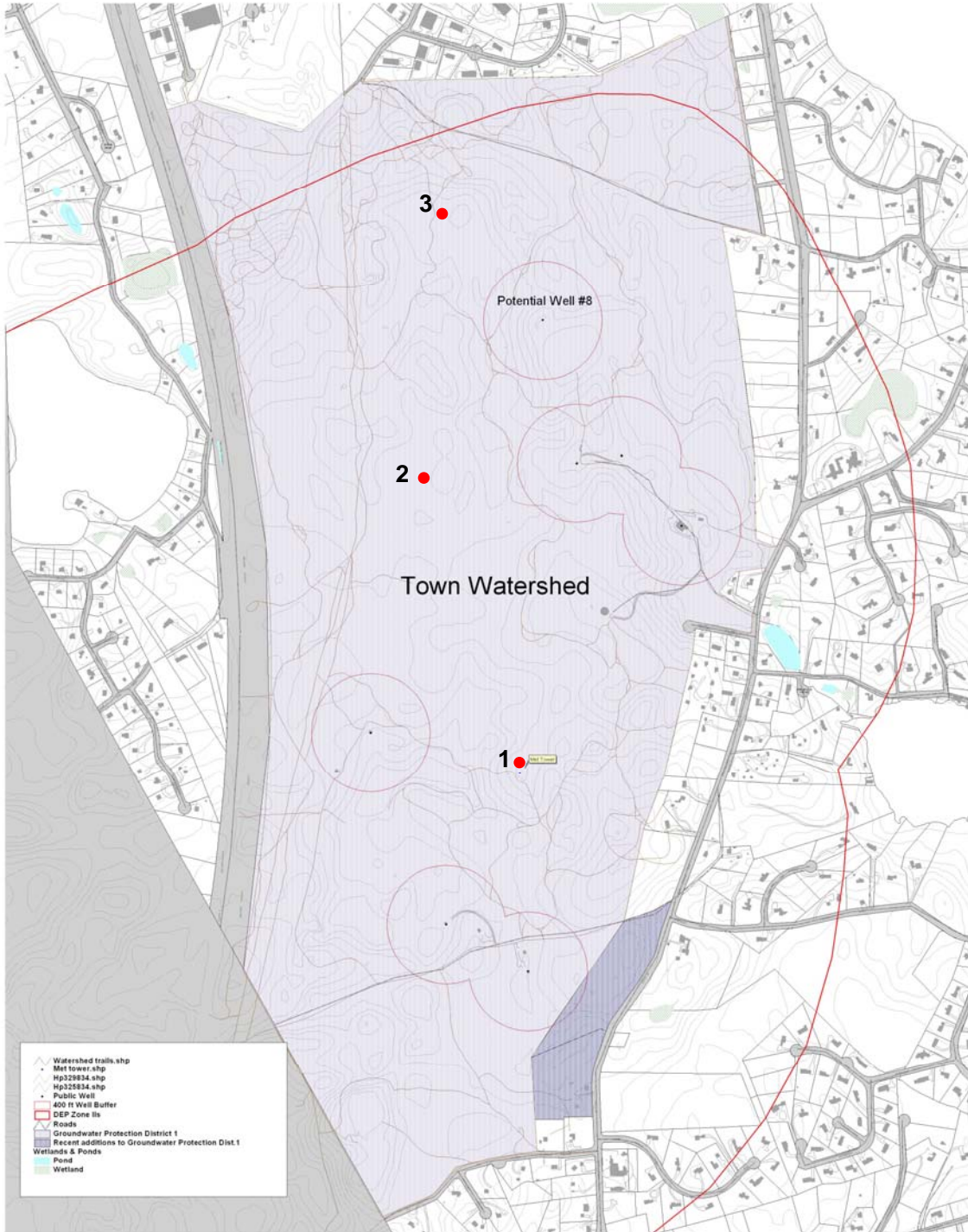


Figure 10 - Two-Turbine Layout at Site 1 and Site 3

Spatial Separation from Key Structures, High-Use Areas, and Off-Site Visual and Noise Receptors

The wind turbines are spaced to meet the setbacks outlined in the Bylaws. The structures of most concern are the watershed's water tower and I&M Plant and nearby industrial buildings north of the watershed. The I&M Plant is 850 feet from the existing met tower/Site 1 and not within proximity of Site 3. The water tower is not within proximity to either Site 1 or Site 3. Site 3 is approximately 925 feet from the nearest property boundary (to the north) and 940 feet from the nearest industrial building (to the north). Hiking trails as well as some watershed maintenance access roads crisscross the watershed but are not considered in determining setbacks from the wind turbines. These distances are more than sufficient and exceed the largest bylaw setback requirement of 600 feet.

Electric Interconnect

The concept for the electric interconnection of two wind turbines would be to run shielded power cable in an underground conduit between the two wind turbines terminating on the power circuit breakers included as part of the wind turbine scope of supply and continuing to the vicinity of the I&M Plant, and interconnecting to the electric system adjacent to the 500 kVA transformer through a padmount switch. There would be eleven new electric manholes at approximately 500-foot to 600-foot intervals along the conduit run to facilitate cable pulling, termination, and replacement (in the event a cable is damaged).

The interconnection voltage would be 23 kV nominal to match the local distribution system voltage. The cable used for the interconnection is proposed to be Size #1 AWG shielded power cable with a rating of 172 Amperes at 100% load factor. This is somewhat oversized for the application given that the current output of a wind turbine in the 900 kW to 2,000 kW range will be on the order of 23 Amperes to 50 Amperes; however, this is the smallest cable size that is generally produced in the 25 kV insulation class and will minimize losses in the long cable run between the two wind turbines.

The three cables (one per phase) would be routed in one duct of two 4-inch, Schedule-80 PVC conduits extending from a manhole installed adjacent to the wind turbine at Site 3 extending past the wind turbine at Site 1 to a manhole located in the vicinity of the I&M Plant transformer. The turbine at Site 1 will be connected by terminating the conductors from Site 3 and those extending from the vicinity of the I&M Plant on the line-side of the circuit breaker at Site 1. The route of the conduits is assumed to be approximately 5250 feet between Site 3 and Site 1 following an irregular path between the sites. The remaining route will be relatively straight down the hill from the wind turbine at Site 1 extending approximately 1200 feet to the I&M Plant and off to the side of any road constructed to access wind turbine Site 1. The use of direct buried conduit is proposed because the route does not involve crossing roadways. Two ducts are included to provide separate ducts for the power cable and a communications duct for any wired remote indication/control provided with the wind turbine package or required for utility control.

The tie-in to the electric system would need to be made adjacent to the existing 500 kVA transformer at the I&M Plant. To make the interconnection, a three-way, pad-mounted switch would need to be installed at that location to permit the wind turbine to be interconnected to the existing electric distribution system between the high voltage terminals of the transformer and the existing NSTAR feeder from the road. The switch is used to permit any of the three circuits

intersecting at the switch to be isolated for maintenance. The switch leg connecting the wind turbine to the existing system would need to be fused to protect the existing system in the event of a fault on the cable run to the wind turbine. It should be noted that Orleans may have to purchase the existing 500 kVA transformer from NSTAR if the I&M Plant electric supply is obtained at the low voltage terminals of the transformer.

Civil and Site Modifications

Site Development

There are no proposed changes to development at Site 1; refer to the Report of a discussion of Site 1 development.

The Site 3 wind turbine would be located in the northern portion of the Orleans watershed. It would be approximately 1125 feet southeast of the end of Giddiah Hill Road and approximately 750 feet east of the existing power line right-of-way. The proposed wind tower location is undeveloped; therefore, substantial clearing of vegetation would be required. Similar to Site 1, the wind turbine site will require a cleared and leveled circular area approximately 260 feet in diameter. Additionally, a 16-foot-wide access road, approximately 1200 feet long will be required from Giddiah Hill Road to the proposed wind turbine Site 3.

Preferred Construction Routing

There are no proposed changes to the recommendations made in the Report for construction routing for Site 1. As noted in the Report, for Site 1 we recommend the Cliff Pond Road haul route (by the I&M Plant). The costs to widen, grade, and fill this route are less than the costs associated with roadway improvement along the length of the maintenance area haul route.

For Site 3, we identified two potential construction haul routes during our site visits to the watershed. Both routes would access the watershed at the west end of Giddiah Hill Road. The first route would use the existing access road that runs in an easterly direction (towards the sand pit) from Giddiah Hill Road. The second route would create a completely new roadway that would parallel the existing power distribution right-of-way before turning eastward to the proposed wind turbine site.

The total length of the haul route using the existing access road is approximately 1360 feet. Of this length, approximately 475 feet would traverse through uncut portions of the watershed. We note that this access road is approximately 10-foot wide and consists of unevenly compacted sand base; therefore, to accommodate construction vehicles, removal of trees to create a corridor approximately 24 feet wide would be required. Also, the existing road would need widening to a minimum width of 16 feet. To meet the maximum grade requirements for the equipment hauls, cuts of up to 7 feet and fills of 26 feet would be required to properly grade this haul route.

We also note that the intersection between the existing access road and Giddiah Hill Road would require significant changes to improve the turning radii for the haul vehicles. To allow the haul vehicles to access Site 3 in a forward direction, a portion of an adjacent parcel would be required to be acquired for the construction of the haul road. Alternatively, the extension of Giddiah Hill Road (towards the electric right-of-way) could be used as a turning area; however, this solution would require that the haul vehicles backup the entire 1360-foot distance to Site 3, a condition that is less than optimal.

As previously noted, the second haul route option would require the construction of a completely new roadway from Giddiah Hill Road to Site 3. The total length of this proposed route is approximately 1240 feet all of which would traverse uncut portions of the watershed. This haul route would be more level than the proposed haul road using existing access road; thus, cuts and fills on the order of 6 feet and 9 feet, respectively, would be required for the roadway's construction.

Compared with the existing access road, the proposed new roadway would be constructed entirely within the watershed area; thus the need for adjacent land acquisitions would be eliminated. Also, the proposed grades would be significantly lower than those on the existing access road.

On the basis of our observations for Site 3, we recommend constructing an entirely new haul road. The costs to clear the land and grade and fill this route are less than the costs associated with grading and roadway improvement along the haul route using the existing access road.

With regard to access along existing roadways outside the watershed area, we have noted during our site visits several potential locations where roadway improvements may be required to improve access for haul vehicles along Giddiah Hill Road. Further studies are required, however, to determine the actual scope and extent of any roadway improvements or utility modifications or relocations or both that may be required to allow transport of the wind turbine components to Site 3.

As noted previously, the minimum width of the construction/access road between the water treatment facility and the wind turbine site is 16 feet. If the erector elects to use a crawler crane and assemble the crane at the I&M Plant site, a minimum roadway width of 24 feet will be required. We recommend that the access roadway be constructed using compacted gravel. The minimum recommended roadway thickness is 12 inches. The gravel should be compacted to a minimum of 95% of its maximum dry density as determined by ASTM D1557.

Construction of the wind turbine site and the access road would be accomplished by conventional means and methods. Clearing of the site would likely be performed by bulldozers. As the observed surface soils appeared to consist predominantly of sandy materials, blasting is not expected to be required. Once the site and access roadway is cleared, bulldozers, graders, vibrating rollers, and other conventional earthmoving equipment would be used to grade and compact the access road.

Additional Watershed Considerations

There are no additional watershed concerns related to the addition of a second turbine to the project.

Wind Resource Assessment and Energy Estimates

The reader should refer to Section 2 of the Report for a complete understanding of the basis of review and analysis and subsequent results of this section herein.

Energy Estimates and Expected Losses

The proposed turbine locations are the existing met tower location and another location in the northern portion of the town watershed. These sites are denoted Site 1 and Site 3 respectively as is discussed in Section 4 of the Report. In order to estimate the energy from this proposed two-

turbine project, the influence of topography on wind resource at Site 3 as well as the wake-induced losses (array losses) when one turbine is downwind of the other, needs to be addressed. We employed a numerical flow model of the proposed project to account for these effects in the development of new annual energy output estimates.

We performed the wind flow and wake loss modeling using WindFarm, a commercially available software program. The MS-Micro/3 wind flow model (component of WindFarm) was used to estimate wind speed at the proposed turbine locations based on the estimated long-term hub-height wind data from the site meteorological tower. USGS SDTS topographic data for the site provided by GeoCommunity were used to model wind flow across the terrain. The site was assumed to have a surface roughness length of 0.3 m, equivalent to wooded areas with generally uniform canopy heights. This value is consistent with the value used in the Report for vertical wind speed extrapolation.

The wind flow model was run using data from the meteorological tower as the input for the model. Wind speeds were predicted to be generally uniform over the project site, so energy production at individual turbine locations is affected less by topography and more by array losses from adjacent turbines. The wind flow modeled predicted a mean wind speed of 6.31 m/s at Site 1, and 6.35 m/s at Site 3, both at 80-m AGL. This is consistent with the 6.3 m/s estimated in the Report, which is to be expected since these data were used as the basis for the flow model.

Gross energy production was estimated using the modeled wind speeds and the reference power curve for the GE 1.5sl turbine. Average sea level air density of 1.225 kg/m³ was estimated for the site. The same reference power curve that was used in the Report was used for the new energy estimates.

Array losses were calculated using the WindFarm energy yield module, using an axisymmetric wake velocity deficit model, wake added turbulence, and using a sum of squares of velocity deficits model for wake combinations. This combination of parameters has been shown to generally yield accurate and unbiased results. Array losses were calculated to be approximately 0.33% using this model.

The estimated gross energy production (inclusive of array losses) for a two turbine project as described above are presented in Table 19.

Table 19
Sea-Level Air Density Estimated Gross Annual Energy Output
(Inclusive of Array Losses) for a Two Turbine Project

Turbine	GE 1.5sl
Rotor Diameter (m)	77
Hub Height (m)	80
Rated Power (MW)	1.5
Gross Annual Output (MWh)	7479
Gross Annual Capacity Factor	28.5%

The gross annual energy presented above represents the sum of the energy delivered at the base of each tower under ideal conditions. Net annual energy production takes into account typical losses and represents the energy delivered to the grid interconnection point for a typical

(average) year. For the Orleans site, we estimated energy losses from a variety of sources. Exact losses can vary significantly from project to project and from time to time; for example, some projects with poor transmission access may experience significant line outages or curtailment. For the purpose of this assessment, we assumed typical values for parameters where site-specific information was not available at this time. An overview of the sources of losses is presented in Section 2 of the Report.

Previous energy loss discussions related to mechanical availability, electrical lines, turbulence/control system, blade contamination, icing/weather, and utility outages have remained unchanged in the analysis of a second turbine.

Uncertainties

A discussion of uncertainties is presented in Section 2 of the Report. The addition of a second turbine to the project and concentration on a 1.5 MW sized turbine has resulted in the following modifications to the previous uncertainty discussion.

- **Uncertainty on Wind Shear Estimates:** The uncertainty on wind shear is primarily dependent on the measurement height of the meteorological tower (50 m) relative to the expected hub height of the turbine (currently expected to be 80 m for a GE 1.5sl). Shear can also vary based on the relative exposure at a meteorological tower relative to turbine locations, vegetation (or seasonal changes in vegetation), and other effects. We estimated the overall shear uncertainty based on a combination of these issues. Shear uncertainty was assumed to be partially dependent on the measurement uncertainty; if the measurements at the tower were biased low due to vegetation effects, the effective shear would most likely be higher. The effective uncertainty associated with shear is approximately 3.4% on wind speed for the GE 1.5sl turbine with an 80-m hub height.
- **Topographical Effects and Wake Uncertainties:** There is uncertainty associated with the estimate of wind speeds produced by the wind flow model for the location of turbine to the north of the meteorological tower, as well as the array losses predicted by the wake loss model. We estimated a 0.25% uncertainty on wind speed, or 0.6% on energy, with a normal distribution, to account for these issues.

Table 20 summarizes the uncertainty on wind speed and energy for each component, and the root-sum-square of each component.

Table 20
Uncertainty Element Summary (Nominal Values)

Uncertainty Type	Uncertainty on Wind Speed, GE 1.5sl	Uncertainty on Energy, GE 1.5sl
Anemometer Accuracy	1.5%	3.6%
Tower Effects on Measurements	1.5%	3.6%
Data Reduction Procedure Accuracy	1.0%	2.4%
Data Quantity Uncertainty	1.6%	3.7%
Long-Term Correlation	2.0%	4.7%

Table 20
Uncertainty Element Summary (Nominal Values)

Uncertainty Type	Uncertainty on Wind Speed, GE 1.5sl	Uncertainty on Energy, GE 1.5sl
Wind Shear Uncertainty	3.4%	8.0%
Topographic effects and wake uncertainties	0.25%	0.59%
Uncertainty on Whether the Long-Term Average Occurs Over the Life of the Project	0.9%	2.1%
Changes in Long-Term Average Over Time	1.0%	2.4%
Root-Sum-Square	5.0%	11.9%

Table 21 and Table 22 present the resulting net energy estimates and capacity factors for one 80-m hub height, GE 1.5sl wind turbine located on the proposed Orleans site at a range of probability-of-exceedance levels. (For example, there is a 75% probability that the energy will exceed the P75 level, and a 25% probability it will be less.)

Table 21
Long-Term Net Annual Energy Estimates – GE 1.5sl

Probability	MWh/yr	Capacity Factor	% of P50
P99	4,961	18.9%	73.9%
P95	5,464	20.8%	81.4%
P90	5,730	21.8%	85.4%
P75	6,190	23.6%	92.2%
P50	6,711	25.5%	100.0%

While Table 21 represents long-term net annual energy estimates, Table 22 represents one-year net annual energy estimates¹.

Table 22
One-Year Net Annual Energy Estimates – GE 1.5sl

Probability	MWh/yr	Capacity Factor	% of P50
P99	4,586	17.5%	68.4%
P95	5,162	19.6%	77.0%
P90	5,463	20.8%	81.5%
P75	6,032	23.0%	90.0%
P50	6,700	25.5%	100.0%

Planning Level Opinion of Probable Capital and O&M Costs

The reader should refer to Section 5 herein for a complete understanding of the basis of review and analysis and subsequent results of this subsection.

Capital Costs

Table 23 below summarizes our opinion of the proposed wind turbine plant’s probable planning level capital costs.

Transportation costs have been assumed to increase 75% with the addition of a second turbine to the project. The cost increase is principally related to the delivery of additional turbine and tower components. Planning and logistics costs incorporated into the original cost estimate are not likely to be repeated for the second turbine.

Table 23
Summary Opinion of Probable Planning Level Project Capital Costs ⁽¹⁾
for Two Wind Turbines

Item	Cost for Two GE 1.5sl Units
Subtotal for wind turbine generator	\$2,700,000
Subtotal for civil/sitework and turbine erection	\$775,000
Subtotal for electrical systems and erection	\$300,000
Subtotal for wind turbine transportation ⁽²⁾	\$490,000
Subtotal - Construction Costs	\$4,265,000
Owner’s Costs, including engineering & permitting	\$400,000
Subtotal – Project Costs	\$4,665,000

¹ One-year energy estimates represent the energy output of any one given year in the 20-year expected project lifetime.

Table 23
Summary Opinion of Probable Planning Level Project Capital Costs ⁽¹⁾
for Two Wind Turbines

Subtotal for optional electrical systems ⁽³⁾	\$170,000
Project Contingency	\$725,000
Total Estimated Project Costs	\$5,560,000
Installed Cost per Kilowatt (\$/kW) ⁽⁴⁾	\$1,555 - \$1,853
Notes:	
(1) In 2005 dollars.	
(2) Includes a nominal value for road modifications, if necessary.	
(3) Optional electrical equipment to interface with the utility grid as required depending upon the particular final interconnect design and equipment supplied with the turbine package.	
(4) With and without contingencies and optional items.	

Operations and Maintenance Costs

Incorporation of a second turbine into the O&M costs required the following modifications that have resulted in a small decrease in estimated per turbine O&M costs.

- Operations costs were estimated to increase 75% principally due to the need to respond to twice as many turbine faults and events. However, it was assumed that basic project monitoring would not increase due to the presence of a second turbine.
- Scheduled and unscheduled turbine maintenance was assumed to double with the addition of a second turbine. There are no significant economies that would be achieved due to the presences of a second turbine.
- Project Administration was assumed to have only a modest increase (assumed to be 25%) due to the second turbine.

These adjustments were applied and project O&M costs were recalculated.

Table 24 indicates how O&M costs are expected to change over the project life. These estimates assume the purchase of a two year all-inclusive O&M warranty.

Table 24
Estimated O&M Costs of Two Typical Wind Turbines

O&M Item	Year 1-2	Year 3-5	Year 6-10	Year 11-15	Year 16-20
Typical 1.5 MW wind turbine					
Operations, scheduled and unscheduled maintenance, warranty (first two years)	\$32,300	\$34,400	\$36,500	\$40,600	\$43,600
Administration	\$1,600	\$1,700	\$1,700	\$1,750	\$1,800
Total \$/wind turbine	\$33,900	\$36,100	\$38,200	\$42,350	\$45,400
Notes:					
Constant 2005 Dollars					

Photo Simulations

On the next several pages are photo simulations or visualizations for the project depicting two 1.5-MW scale wind turbines located at Site 1 and Site 3 on the town watershed area as seen from various locations in the community. Previous visualizations included only a single turbine. The wind turbine proposed for the project will have a hub height of 80 meters (260 feet) and a rotor diameter of 77 meters (183 feet). The rendered turbines seen in the visualizations are representative of the proposed turbine and are identical to the turbine used in the original visualizations.

When possible, the same photos used in the original visualizations were reused to show two turbines. In several cases it was necessary to take additional photos to cover the area of the project. In situations where only a single turbine would be visible in the camera frame, two photos were joined and a wide-angle visualization was created. In cases where the turbine would not be visible due to obstructions (trees, buildings, etc.) a wire frame of the turbine was imposed on the photo rather than the rendered turbine, which would not be visible.

There are several factors that can affect the appearance of visualizations including:

- Time of day the photo was taken
- Cloud cover and atmospheric haze
- Camera exposure time
- Image resolution
- Focal length and projection area (film size)
- Blade and yaw positions
- Viewing medium (computer screen, projection, print, etc.)
- Distance of viewer from visualization
- Light conditions when viewing visualization

Every effort was taken to make the photo visualizations as accurate as possible, however, there is considerable uncertainty associated with photo visualizations and actual views may differ than those presented here.



Figure 11 - Photo visualization vantage points and the proposed wind turbine sites



**Figure 12 - Location 1: Rt. 28, 0.4 km Northeast of Site 1
(Site 1 rendered, Site 3 wire frame)**



**Figure 13 - Location 2: Pilgrim Lake
(top: both turbines rendered, bottom: Site 1 rendered with Site 2 as wire frame)**



Figure 14 - Location 4: Soccer Field in Eldredge Park



**Figure 15 - Location 5: Nauset Marine Dock on Meeting House Pond
(both turbines as wire frame)**

